UGR File #233
Battelle Columbus Labs.
Sept. 24, 1979

INDIVIDUAL WELL REPORT
FROM THE PROGRAM ON

UGR FILE #233

CHARACTERIZATION AND ANALYSIS OF DEVONIAN SHALES AS RELATED TO RELEASE OF GASEOUS HYDROCARBONS

WELL N-4 HARDIN COUNTY, ILLINOIS

by

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BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

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TABLE OF CONTENTS

	Page
LIST OF CONTRIBUTORS	i
INTRODUCTION AND SUMMARY	1
OBJECTIVE AND SCOPE	1
Task 1. Core Sampling	2
Task 2. Gas Contents and Release Rates	2
Task 3. Chemical Characterization	2
Task 4. Physical Characterization Data	3
Task 5. Lithology of N-4 Shales	3

LIST OF TABLES

Table 1.	Well Data for N-4	4
Table 2.	Field Sampling Data for Well N-4	7
Table 3.	Initial Gas Release Data for Well N-4	8
Table 4.	Chemical Characterization Data for Well N-4	9
Table 5.	Summary of Physical Characterization Data	10
Table 6.	Statistical Analyses of Physical Characterization Data	11
Table 7.	Mercury Intrusion Porosities of N-4 Shales	12
Table 8.	Energy-Dispersive Analysis of N-4 Shales	13

LIST OF FIGURES

Figure 1.	On Surface Times for Well N-4	14
Figure 2.	Carbon Versus Depth for Well N-4	15
Figure 3.	Hydrogen Versus Depth for Well N-4	16
Figure 4.	H/C Atomic Ratio Versus Depth for Well N-4	17

LIST OF FIGURES (Continued)

		Page
Figure 5.	Sulfur Versus Depth for Well N-4.	18
Figure 6.	Carbon Versus Bulk Density for Well N-4	19
Figure 7.	Hydrogen Versus Bulk Density for Well N-4	20
Figure 8.	Sulfur Versus Bulk Density for Well N-4	21
Figure 9.	Porosity Versus H/C Atomic Ratio for Well N-4 . . .	22
Figure 10.	Porosity Versus Bulk Density for Well N-4	23
Figure 11.	Porosity Versus Carbon for Well N-4	24
Figure 12.	SEM Microphotograph of Sample N-4-257	25
Figure 13.	SEM Microphotograph of Sample N-1-147	26
Figure 14.	SEM Microphotograph of Sample N-4-73.	27

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INTRODUCTION AND SUMMARY

Comprehensive characterization work was performed on shales from Hardin County, Illinois (N-4). A total of 39 samples (19 for Battelle and 20 for other DOE contractors) were collected from this site. N-4 shales are basically characterized by complete absence of hydrocarbon gases and rather low organics (C-H) contents. In the absence of hydrocarbon gases no meaningful correlations could be observed between the characterization data and potential productive capacity of the well.

OBJECTIVE AND SCOPE

The objective of this program is to determine the relationships between shale characteristic, hydrocarbon gas content, and well location to provide a sound basis for defining the productive capacity of the Eastern Devonian shale deposits and for guiding research, development, and demonstration projects to enhance the recovery of natural gas from the shale deposits. The program includes a number of elemental tasks as a part of the Resource Inventory and Shale Characterization subprojects of DOE's Eastern Gas Shales Project and is designed to provide a wide variety of support data for that project.

A large number of core samples of gas bearing Eastern Devonian shale will have been examined by the end of the program. After the characterization data for individual wells have been compiled, attempts will be made to establish the interrelationships between the shale

characteristics, the hydrocarbon gas content, and well locations from which the samples were obtained, employing the Automatic Interaction Detection (AID) Analysis.

The following tasks comprise the total efforts in this research program:

Task	Descriptive Title
1	Core Sampling
2	Gas Content and Gas Release Kinetics
3	Chemical Characterization of Shale
4	Physical Characterization of Shale
5	Lithology of Shale

Task 1. Core Sampling

Well N-4 (Hardin County, Illinois) samples were cored December 1978. A total of 39 samples were collected; 19 for Battelle and 20 for other DOE contractors. Twenty-two barrels of shale core was obtained. The coring was made between depths of 32 and 269 feet. Additional well and field sampling data are summarized in Tables 1 and 2. Figure 1 depicts on-surface times for the N-4 shales.

Task 2. Gas Contents and Release Rates

Gas contents determined for N-4 shales are depicted in Table 3. These shales, like most wells in Illinois, do not exhibit any hydrocarbon gas contents.

Task 3. Chemical Characterization

Table 4 summarizes the total carbon, hydrogen, nitrogen contents of the N-4 shales. Sulfur contents are also presented in the table. Total carbon contents vary between 1.5 and 6.4 percent, hydrogen contents, being more uniform, 0.2 and 0.3 percent, and the sulfur contents from 0.6 to 3.0 percent.

Figures 2 through 5 summarize the chemical characterization data as a function of depth.

Task 4. Physical Characterization Data

Partial physical characterization data on N-4 shales are presented in Table 5. These are bulk and true densities, porosities (calculated from the density data) and surface areas. Statistical analysis with key parameters on these data are given in Table 6. Figures 6 through 11 illustrate one-to-one relationships between various physical and chemical characterization data.

Porosities were also determined with the mercury intrusion method. Some of these values, shown in Table 7, agree well with the values in Table 5 calculated from the density data.

Permeability measurements were made on three N-4 samples, namely N-4-73, -147, and -257. The values found were 6.66×10^{-6}. 4.99×10^{-6}, and 4.17×10^{-6} darcy for the three samples mentioned.

Task 5. Lithology of N-4 Shales

Mineral analysis of N-4 shale samples through powder examination by petrographic microscope was not possible. Two types of grains could be observed, one being a carbonate mineral, the others being highly opaque aggregates. The energy dispersive analyses of these samples are shown in Table 8. The K, Al, and Si counts indicate the presence of quartz, illite, and probably other clay minerals. Also a small amount of pyrite is indicated in Samples N-4-147 and -257, by the Fe and S contents. A significant amount of Na was noted, but the mineral in which it occurred could not be determined by the techniques used.

SEM views of these shale samples are shown in Figures 12 through 14.

TABLE I. WELL DATA FOR N- 4

LOCATION: HARDIN COUNTY, IL

ALTITUDE: 578 FEET

COORDINATES: 37.53 (DEGREES.MINUTES) LATITUDE
88.38 (DEGREES.MINUTES) LONGITUDE

CORING BEGAN AT 32 FEET AND STOPPED AT 269 FEET. IT TOOK 22 BARRELS TO COMPLETE.

SAMPLES WERE RETURNED TO BATTELLE ON 12/11/78.

THERE WERE 19 SAMPLES COLLECTED FOR BATTELLE AND 20 SAMPLES COLLECTED FOR OTHERS.

RUN INFORMATION FROM WELL N- 4

RUN NO. 1 CORING BEGAN AT 32 FEET AND CORING STOPPED AT 36 FEET. THE AVERAGE CORING RATE IS 1.17 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .17 HOURS

RUN NO. 2 CORING BEGAN AT 36 FEET AND CORING STOPPED AT 39 FEET. THE AVERAGE CORING RATE IS 2.42 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .17 HOURS

RUN NO. 3 CORING BEGAN AT 39 FEET AND CORING STOPPED AT 43 FEET. THE AVERAGE CORING RATE IS .83 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .25 HOURS

RUN NO. 4 CORING BEGAN AT 43 FEET AND CORING STOPPED AT 48 FEET. THE AVERAGE CORING RATE IS 1.42 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .17 HOURS

RUN NO. 5 CORING BEGAN AT 48 FEET AND CORING STOPPED AT 52 FEET. THE AVERAGE CORING RATE IS 1.33 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .17 HOURS

RUN NO. 6 CORING BEGAN AT 68 FEET AND CORING STOPPED AT 74 FEET. THE AVERAGE CORING RATE IS 2.66 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .17 HOURS

TABLE 1. (Continued)

RUN INFORMATION FROM WELL CONTINUED H- 4

RUN NO. 7 CORING BEGAN AT 74 FEET AND CORING STOPPED AT 78 FEET. THE AVERAGE CORING RATE IS 3.66 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .17 HOURS

RUN NO. 8 CORING BEGAN AT 78 FEET AND CORING STOPPED AT 80 FEET. THE AVERAGE CORING RATE IS 1.17 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .25 HOURS

RUN NO. 9 CORING BEGAN AT 80 FEET AND CORING STOPPED AT 84 FEET. THE AVERAGE CORING RATE IS 6.50 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .17 HOURS

RUN NO. 10 CORING BEGAN AT 84 FEET AND CORING STOPPED AT 86 FEET. THE AVERAGE CORING RATE IS 2.25 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .25 HOURS

RUN NO. 11 CORING BEGAN AT 86 FEET AND CORING STOPPED AT 89 FEET. THE AVERAGE CORING RATE IS 3.59 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .25 HOURS

RUN NO. 12 CORING BEGAN AT 89 FEET AND CORING STOPPED AT 92 FEET. THE AVERAGE CORING RATE IS 1.83 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .58 HOURS

RUN NO. 13 CORING BEGAN AT 92 FEET AND CORING STOPPED AT 96 FEET. THE AVERAGE CORING RATE IS 3.00 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .33 HOURS

RUN NO. 14 CORING BEGAN AT 96 FEET AND CORING STOPPED AT 100 FEET. THE AVERAGE CORING RATE IS 2.92 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .13 HOURS

RUN NO. 15 CORING BEGAN AT 100 FEET AND CORING STOPPED AT 104 FEET. THE AVERAGE CORING RATE IS 3.42 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .33 HOURS

RUN NO. 16 CORING BEGAN AT 104 FEET AND CORING STOPPED AT 119 FEET. THE AVERAGE CORING RATE IS 9.17 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .33 HOURS

RUN NO. 17 CORING BEGAN AT 119 FEET AND CORING STOPPED AT 136 FEET. THE AVERAGE CORING RATE IS 15.25 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .42 HOURS

RUN NO. 18 CORING BEGAN AT 136 FEET AND CORING STOPPED AT 166 FEET. THE AVERAGE CORING RATE IS 28.66 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .42 HOURS

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Battelle Columbus Labs.
Sept. 24, 1979

TABLE 1. (Continued)
RUN INFORMATION FROM WELL CONTINUED H- 4

RUN NO. 19	CORING BEGAN AT 166 FEET AND CORING STOPPED AT 191 FEET. THE AVERAGE CORING RATE IS 13.66 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .50 HOURS
RUN NO. 20	CORING BEGAN AT 191 FEET AND CORING STOPPED AT 226 FEET. THE AVERAGE CORING RATE IS 19.92 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .50 HOURS
RUN NO. 21	CORING BEGAN AT 226 FEET AND CORING STOPPED AT 245 FEET. THE AVERAGE CORING RATE IS 10.75 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .52 HOURS
RUN NO. 22	CORING BEGAN AT 245 FEET AND CORING STOPPED AT 269 FEET. THE AVERAGE CORING RATE IS 4.42 MINUTES PER FOOT. THE SAMPLES WERE ON THE SURFACE IN .42 HOURS

UGR File #233
Battelle Columbus Labs.
Sept. 24, 1979

TABLE 2. FIELD SAMPLING DATA FOR WELL N 4

SAMPLE ID.	COLOR	ON SURFACE TIME	BARREL NO	SEQ NO.
N 4- 73.	5Y2/1	2.67	6	0
N 4- 90.	5Y4/1	.92	12	0
N 4- 100.	5Y4/1	.66	15	0
N 4- 104.	5Y2/1	.42	15	0
N 4- 116.	5Y2/1	1.17	16	0
N 4- 123.	5Y2/1	.93	17	0
N 4- 131.	5Y2/1	1.13	17	0
N 4- 138.	5YR2/1	1.25	18	0
N 4- 147.	5Y2/1	1.33	18	0
N 4- 159.	5Y2/1	1.86	18	0
N 4- 168.	5Y2/1	1.75	19	0
N 4- 180.	5Y2/1	2.03	19	0
N 4- 199.	5YR2/1	2.47	20	0
N 4- 210.	5Y2/1	2.53	20	0
N 4- 220.	5YR2/1	2.63	20	0
N 4- 227.	5Y2/1	1.73	21	0
N 4- 237.	5Y2/1	1.87	21	0
N 4- 247.	5YR2/1	2.50	22	0
N 4- 257.	5YR2/1	2.67	22	0

UGR File #233
Battelle Columbus Labs.
Sept. 24, 1979

TABLE 3. INITIAL GAS RELEASE DATA: WELL N 4

05/18/79

SAMPLE ID	PRESSURE TORR	FREE VOLUME CC	CORE VOLUME CC	POROSITY PCT.	GAS COMPOSITION, VOLUME PERCENT: METHANE	ETHANE	PROPANE	BUTANE	PENTANE	TOTAL HYDROC.	NITROGEN	OXYGEN	CARBON DIOXIDE	GAS RELEASED/ UNIT VOLUME OF SHALE	SEQ NO.
N 4- 73.	700.	522.	928.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	88.49	1.37	10.15	0.00	1
N 4- 90.	750.	463.	937.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82.35	12.54	5.08	0.00	2
N 4- 100.	750.	331.	619.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	79.06	17.82	3.08	0.00	3
N 4- 104.	750.	298.	1152.	5.84	0.00	0.00	0.00	0.00	0.00	0.00	84.70	6.10	8.19	0.00	4
N 4- 116.	750.	569.	831.	2.25	0.00	0.00	0.00	0.00	0.00	0.00	76.85	14.80	3.37	0.00	5
N 4- 123.	700.	397.	1053.	5.60	0.00	0.00	0.00	0.00	0.00	0.00	83.44	4.14	12.44	0.00	6
N 4- 131.	700.	455.	395.	2.16	0.00	0.00	0.00	0.00	0.00	0.00	84.80	7.46	7.71	0.00	7
N 4- 138.	750.	588.	862.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	79.20	19.98	.81	0.00	8
N 4- 147.	750.	572.	878.	3.79	0.00	0.00	0.00	0.00	0.00	0.00	79.75	19.17	1.08	0.00	9
N 4- 159.	700.	433.	1017.	3.46	0.00	0.00	0.00	0.00	0.00	0.00	84.24	12.39	3.36	0.00	10
N 4- 168.	700.	400.	1050.	4.13	0.00	0.00	0.00	0.00	0.00	0.00	86.08	2.13	11.09	0.00	11
N 4- 173.	750.	692.	758.	2.87	0.00	0.00	0.00	0.00	0.00	0.00	79.95	14.96	5.07	0.00	12
N 4- 189.	700.	506.	944.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	86.45	7.92	5.66	0.00	13
N 4- 210.	700.	453.	997.	2.06	0.00	0.00	0.00	0.00	0.00	0.00	89.81	3.46	6.71	0.00	14
N 4- 220.	750.	853.	597.	.08	0.00	0.00	0.00	0.00	0.00	0.00	78.40	20.63	.95	0.00	15
N 4- 227.	750.	464.	986.	5.64	0.00	0.00	0.00	0.00	0.00	0.00	82.68	15.70	1.62	0.00	16
N 4- 237.	750.	785.	665.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	81.72	15.55	2.69	0.00	17
N 4- 247.	750.	671.	779.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	80.79	18.41	.83	0.00	18
N 4- 257.	750.	868.	582.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	80.59	18.41	.98	0.00	19

UGR File #233
Battelle Columbus Labs.
Sept. 24, 1979

TABLE 4. CHEMICAL CHARACTERIZATION DATA, 05/21/79

SAMPLE ID	TOTAL CARBON PERCENT	TOTAL HYDROGEN PERCENT	TOTAL NITROGEN PERCENT	TOTAL SULFUR PERCENT	CARD CODE	SEQ NO.
N 4- 73.	5.1	.3	.2	3.0	5	1
N 4- 90.	2.0	.2	.1	2.2	5	2
N 4- 100.	2.7	.2	.1	1.8	5	3
N 4- 104.	4.6	.2	.1	2.7	5	4
N 4- 116.	3.1	.2	.1	.6	5	5
N 4- 123.	1.5	.2	.1	.8	5	6
N 4- 131.	3.1	.2	.1	1.6	5	7
N 4- 139.	4.5	.2	.1	.7	5	8
N 4- 147.	2.6	.2	.1	.9	5	9
N 4- 159.	4.8	.2	.1	.8	5	10
N 4- 168.	6.4	.2	.1	1.2	5	11
N 4- 178.	3.1	.2	.1	1.0	5	12
N 4- 199.	5.2	.3	.1	2.0	5	13
N 4- 210.	5.5	.3	.1	1.4	5	14
N 4- 220.	2.4	.3	.1	.7	5	15
N 4- 227.	2.9	.2	.1	.7	5	16
N 4- 237.	5.9	.3	.1	2.8	5	17
N 4- 247.	5.0	.3	.1	1.3	5	18
N 4- 257.	4.1	.2	.1	1.6	5	19

UGR File #233
Battelle Columbus Labs.
Sept. 24, 1979

TABLE 5. SUMMARY OF PHYSICAL CHARACTERIZATION DATA
05/18/79

SAMPLE ID.	BULK DENSITY, G/CC	TRUE DENSITY, G/CC	POROSITY, PCT	SURFACE AREA, M2/G	SEQ NO.
N 4- 71.	2.591	2.572	0.000	1.017	1
N 4- 90.	2.639	2.564	0.000	1.475	2
N 4- 100.	2.669	2.504	0.000	.822	3
N 4- 104.	2.587	2.747	5.838	2.046	4
N 4- 116.	2.637	2.698	2.246	1.195	5
N 4- 123.	2.611	2.768	5.681	.979	6
N 4- 131.	2.612	2.670	2.159	1.052	7
N 4- 138.	2.608	2.567	0.000	.945	8
N 4- 147.	2.566	2.667	3.793	1.266	9
N 4- 159.	2.645	2.740	3.456	.697	10
N 4- 168.	2.666	2.781	4.132	.772	11
N 4- 178.	2.606	2.683	2.871	1.018	12
N 4- 199.	2.605	2.467	0.000	.943	13
N 4- 210.	2.603	2.658	2.063	2.494	14
N 4- 220.	2.658	2.660	.075	2.230	15
N 4- 227.	2.626	2.783	5.637	2.616	16
N 4- 237.	2.605	2.526	0.000	3.160	17
N 4- 247.	2.614	2.472	0.000	3.669	18
N 4- 257.	2.583	2.488	0.000	2.593	19

UGR File #233
Battelle Columbus Labs.
Sept. 24, 1979

TABLE 6. STATISTISTICAL ANALYSES OF PHYSICAL CHARACTERIZATION DATA
05/18/79

WELL N 4

	MEAN	STANDARD DEVIATION	VARIANCE	COEFFICIENT OF DEVIATION	95 PCT. CONFIDENCE INTERVAL LOWER LIMIT	UPPER LIMIT	NO OF SAMPLES
BULK DENSITY, G/CC	2.618	.03	.00	.01	2.604	2.631	19
TRUE DENSITY, G/CC	2.632	.11	.01	.04	2.580	2.685	19
POROSITY, PCT	1.997	2.21	4.89	1.11	.932	3.061	19
SURFACE AREA, M2/G	1.631	.90	.82	.55	1.195	2.067	19

*I IS INSIGNIFICANT

UGR File #233
Battelle Columbus Labs.
Sept. 24, 1979

TABLE 7. MERCURY INTRUSION POROSITIES OF N-4 SHALES

Sequence Number	Sample ID	Porosity
1	N-4-73	1.86
3	N-4-100	2.12
5	N-4-116	8.75
7	N-4-131	10.33
9	N-4-147	2.92
11	N-4-168	3.45
13	N-4-199	3.45
15	N-4-220	4.77
17	N-4-237	5.30
19	N-4-257	3.98

TABLE 8. ENERGY-DISPERSIVE ANALYSIS OF N-4 SHALES

Sample Number	Na	K	Ca	Mg	Al	Si	Fe	S	Ti	P	Fe/S	K/Al	K/Si	Al/Si
N-4-73	1.8	8.2	-	-	16.5	67.0	5.8	-	0.7	-	∞	0.50	0.12	0.25
N-4-147	2.4	11.1	1.7	-	19.2	61.0	2.7	1.2	0.7	-	2.2	0.58	0.18	0.32
N-4-257	2.3	9.0	3.7	-	17.3	64.6	1.4	1.1	0.6	-	1.2	0.52	0.14	0.27

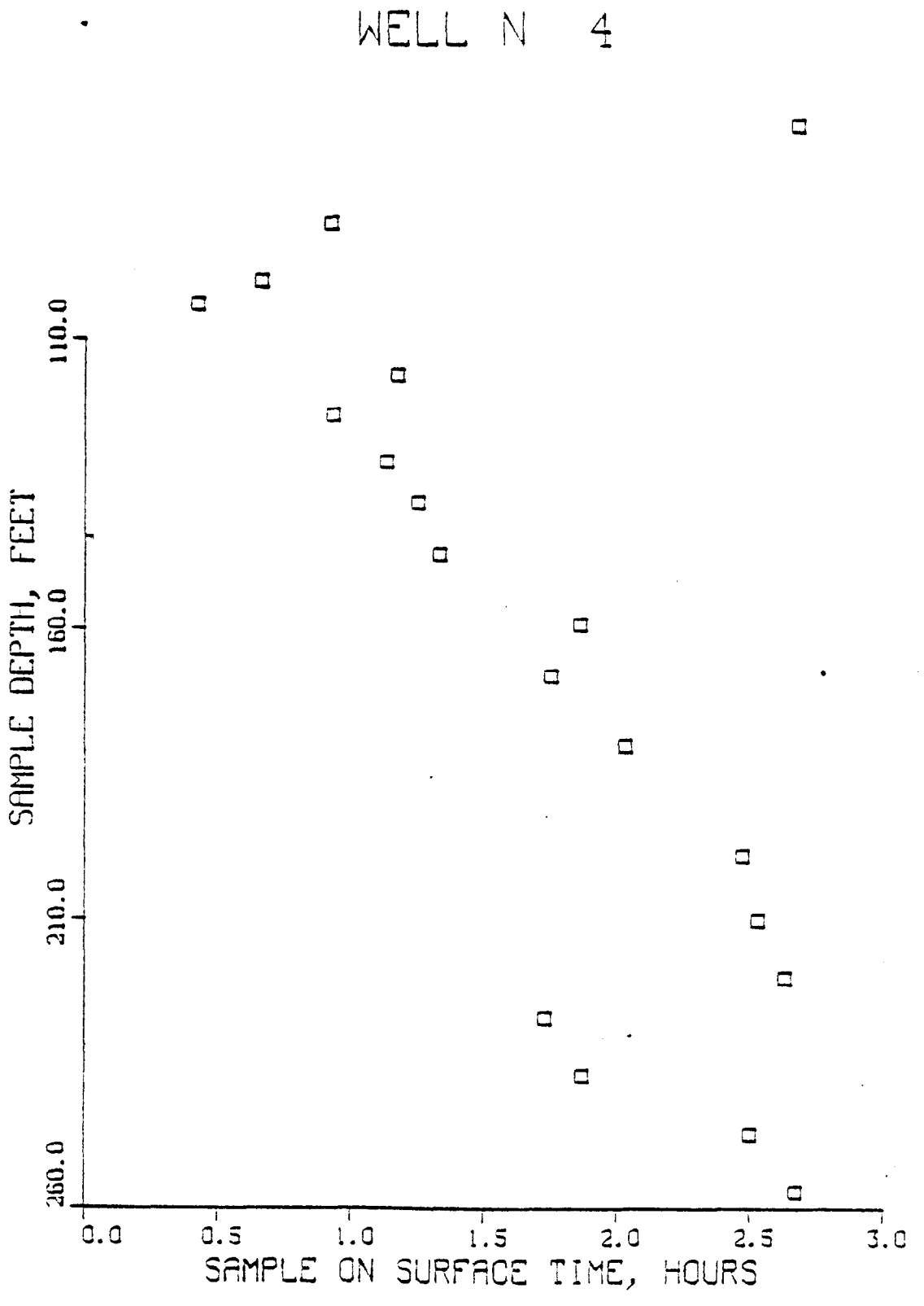

FIGURE 1. ON SURFACE TIMES FOR WELL N-4

UGR File #233
Battelle Columbus Labs.
Sept. 24, 1979

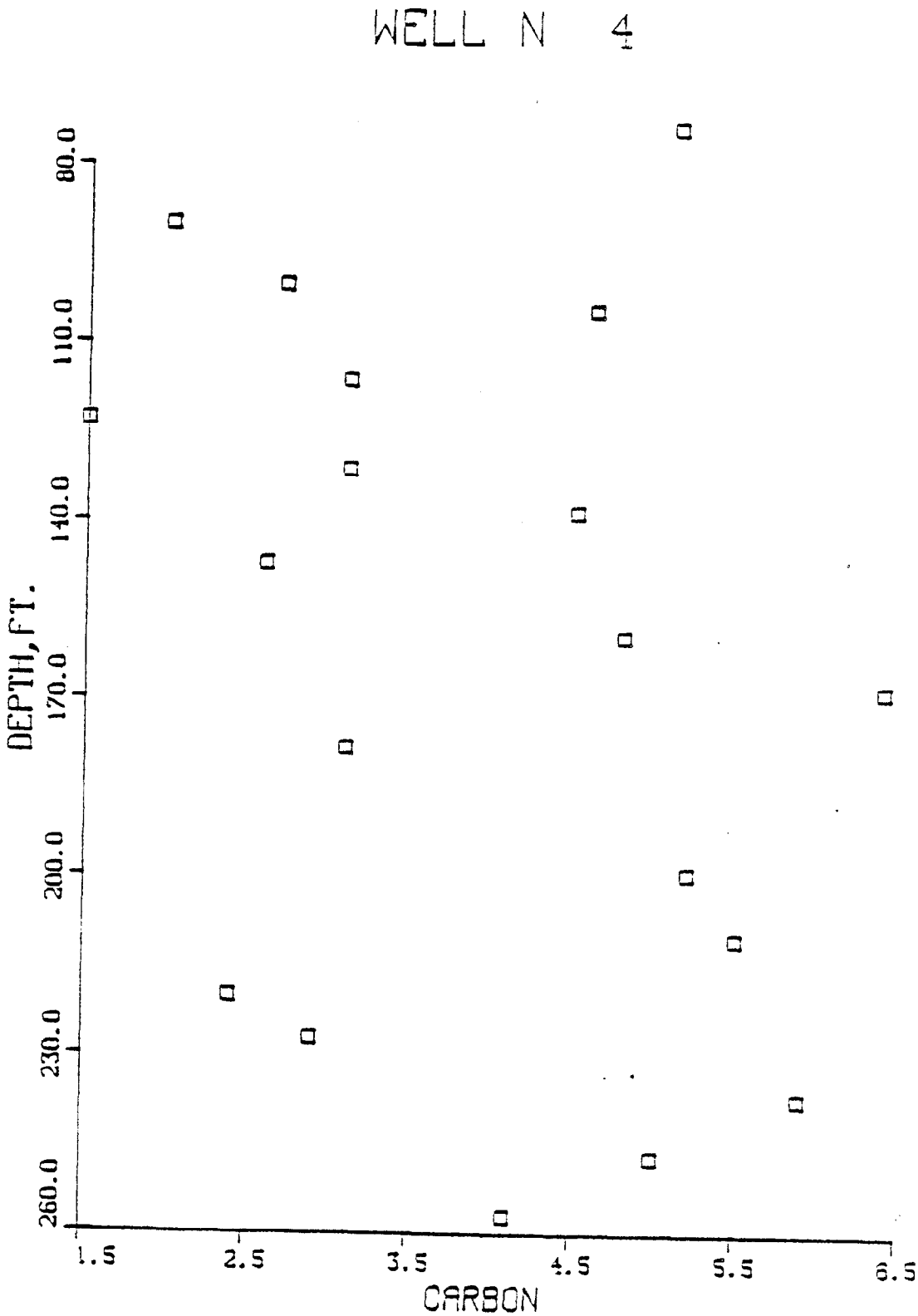

FIGURE 2. CARBON VERSUS DEPTH FOR WELL N-4

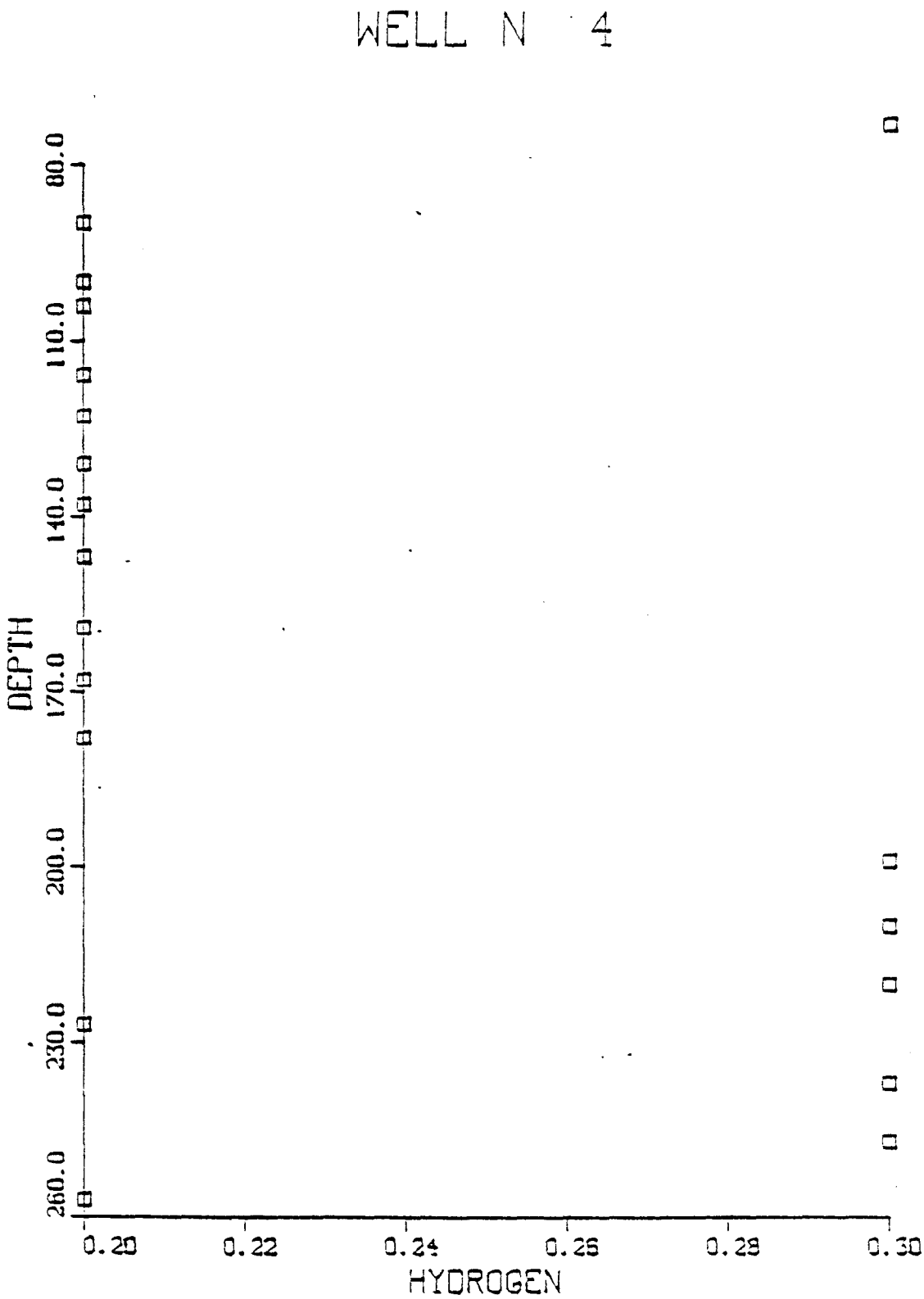

FIGURE 3. HYDROGEN VERSUS DEPTH FOR WELL N-4

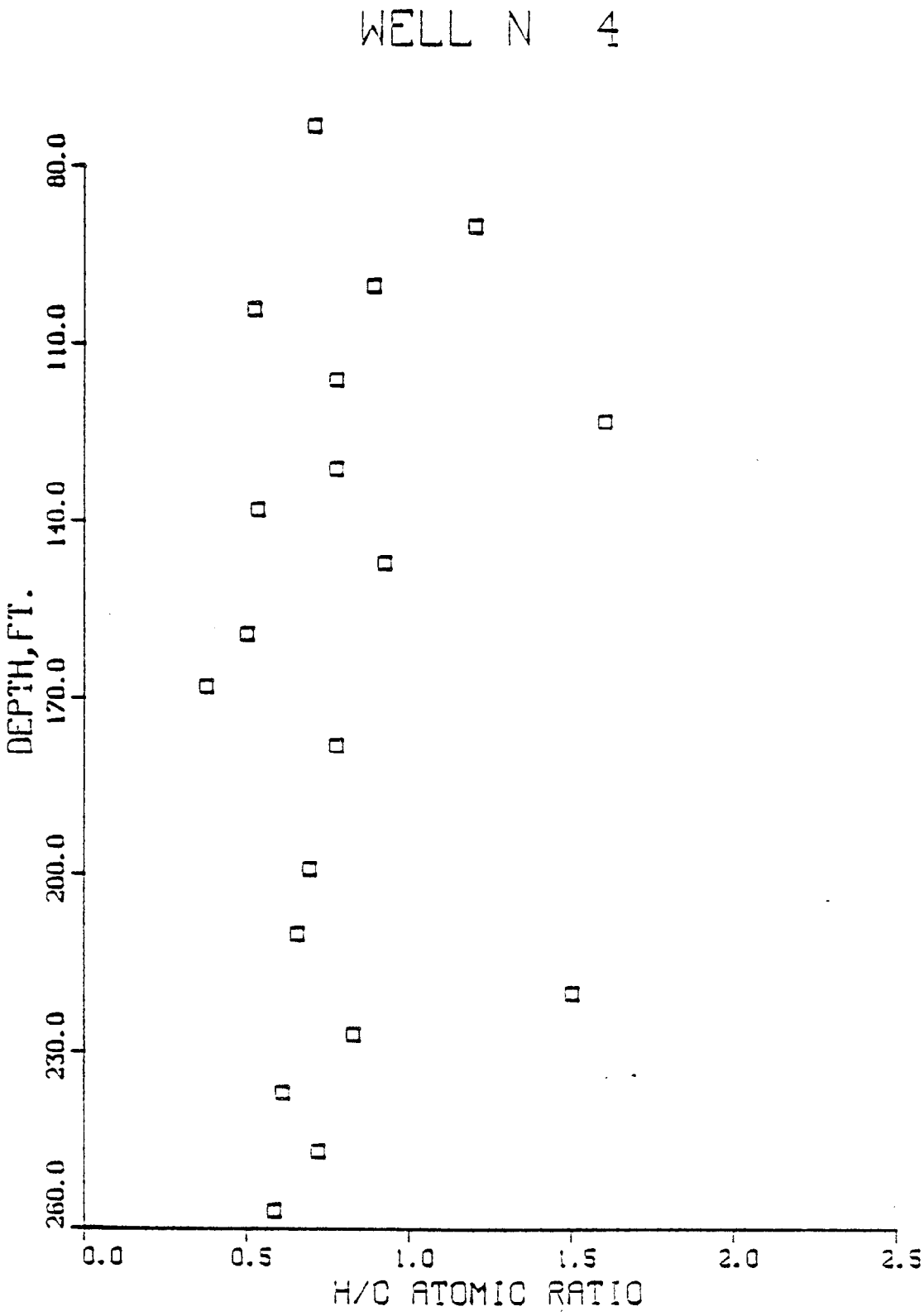

FIGURE 4. H/C ATOMIC RATIO VERSUS DEPTH FOR WELL N-4

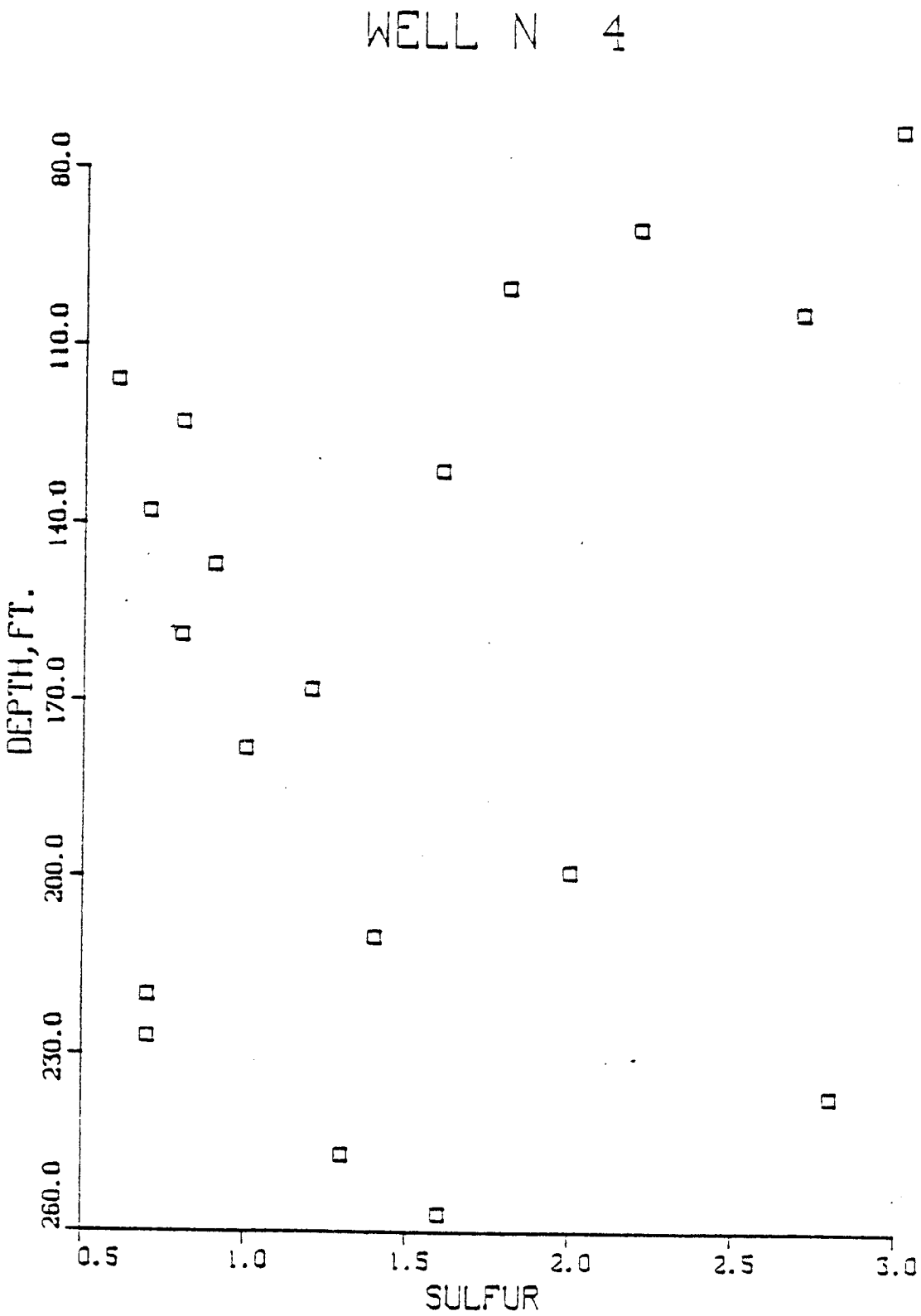

FIGURE 5. SULFUR VERSUS DEPTH FOR WELL N-4

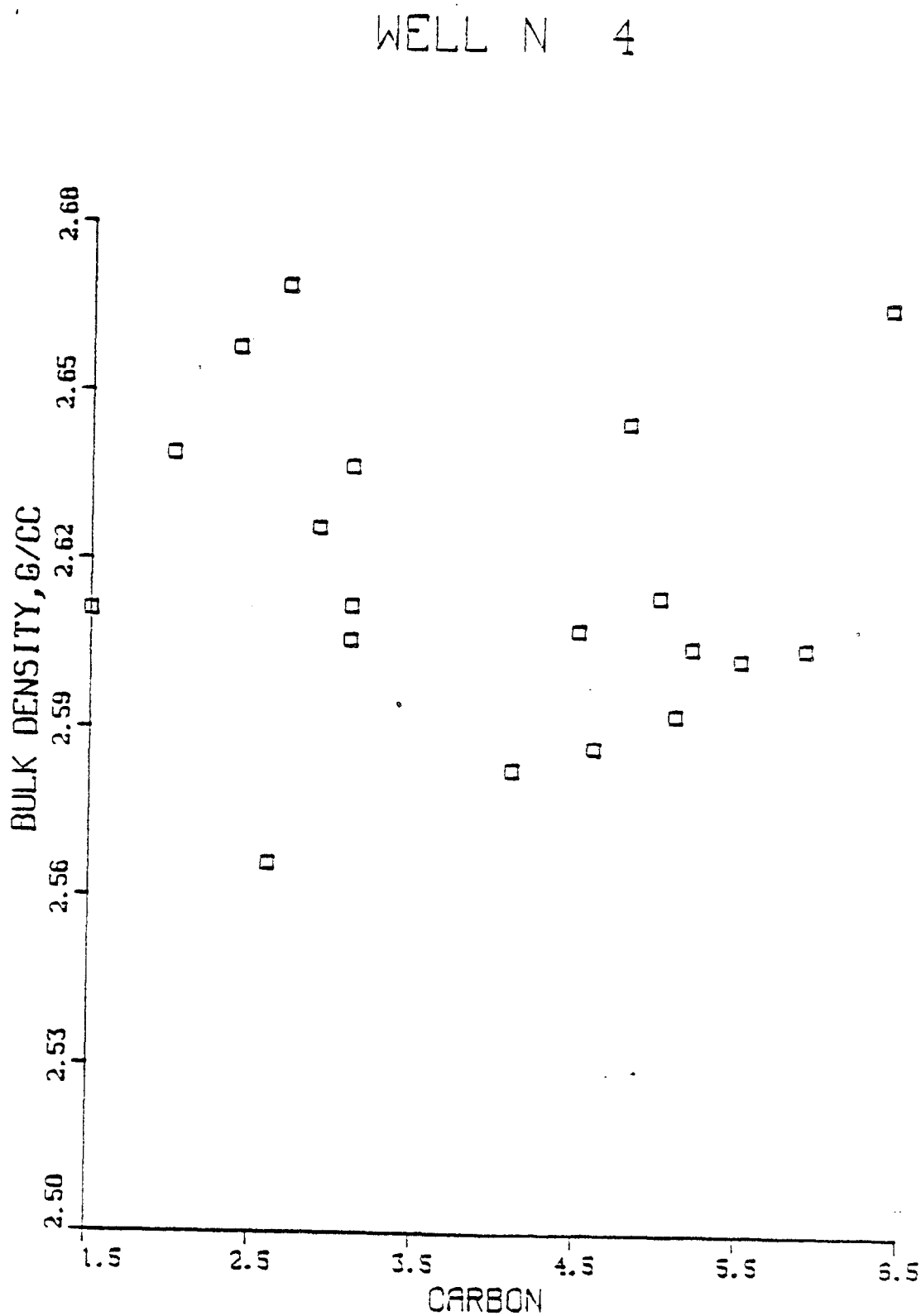

FIGURE 6. CARBON VERSUS BULK DENSITY FOR WELL N-4

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Sept. 24, 1979

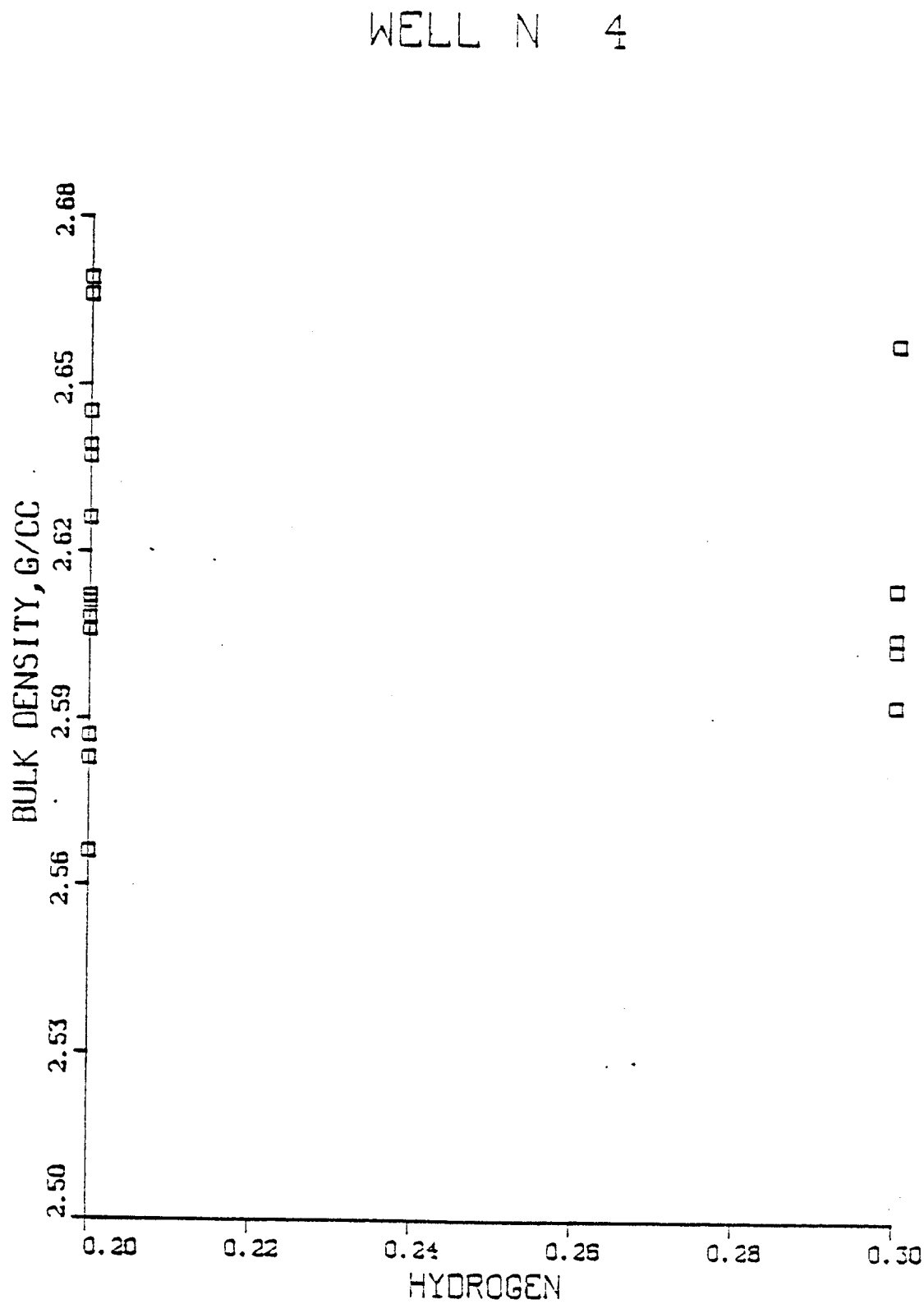

FIGURE 7. HYDROGEN VERSUS BULK DENSITY FOR WELL N-4

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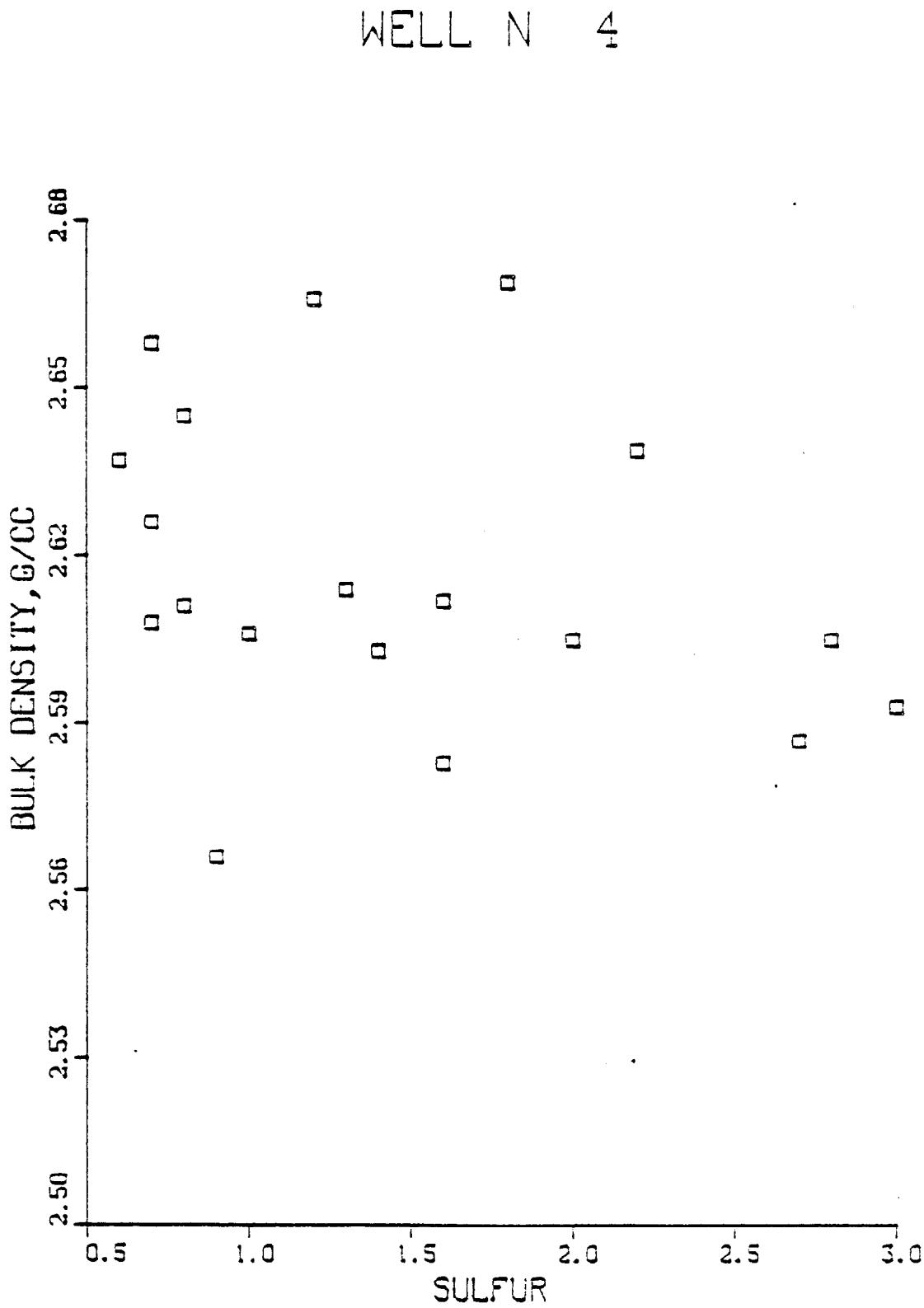

FIGURE 8. SULFUR VERSUS BULK DENSITY FOR WELL N-4

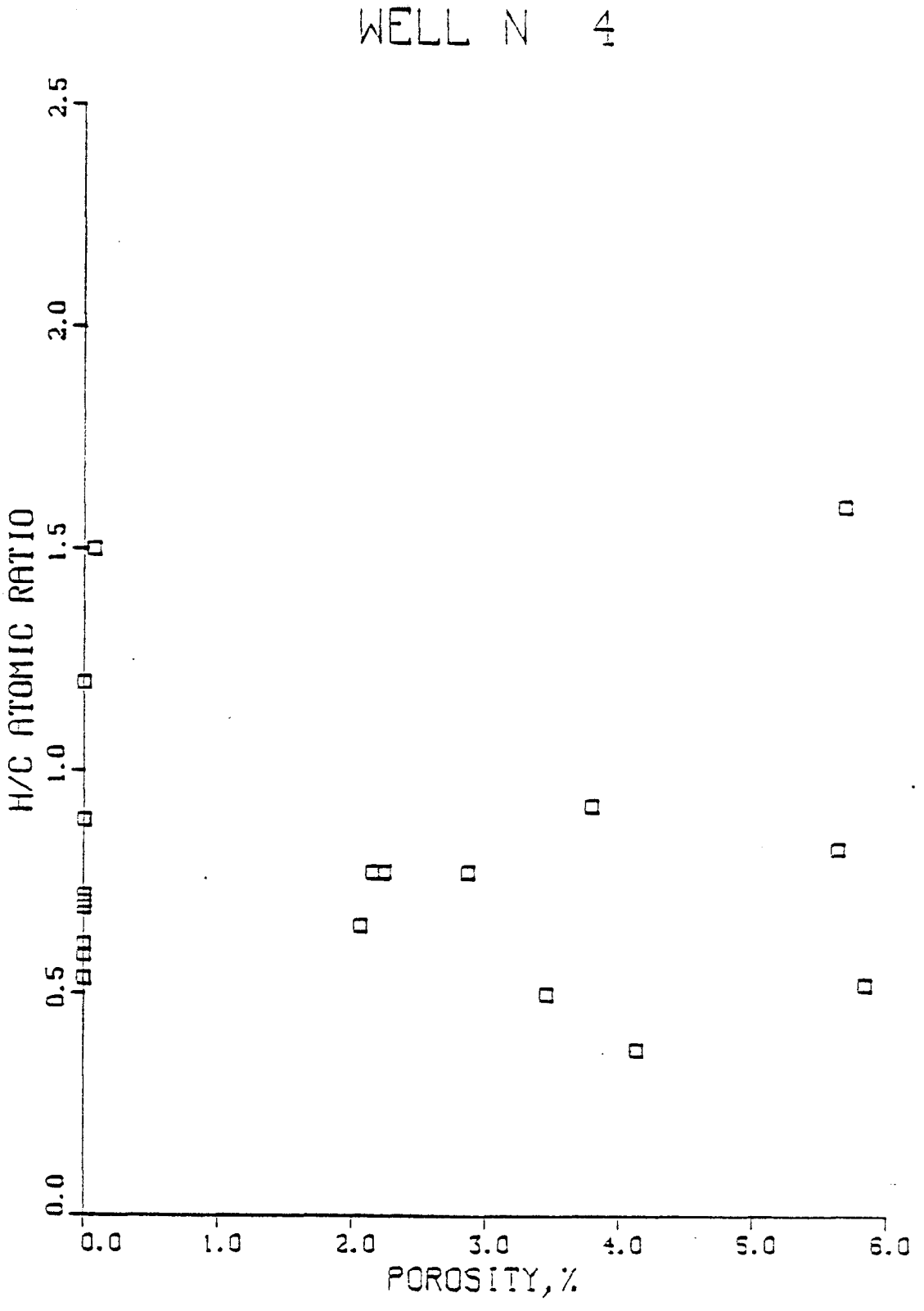

FIGURE 9. POROSITY VERSUS H/C ATOMIC RATIO FOR WELL N-4

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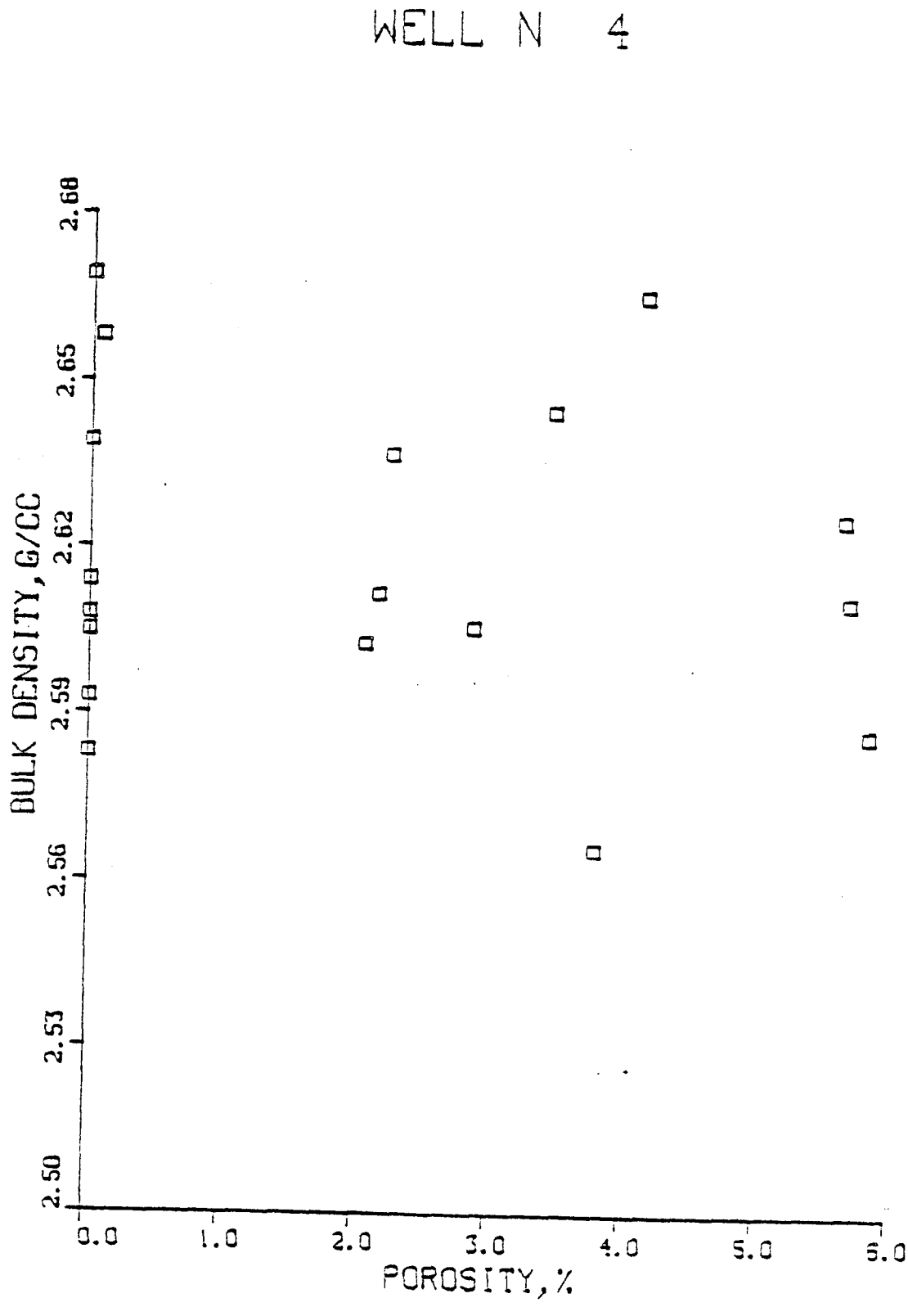


FIGURE 10. POROSITY VERSUS BULK DENSITY FOR WELL N-4

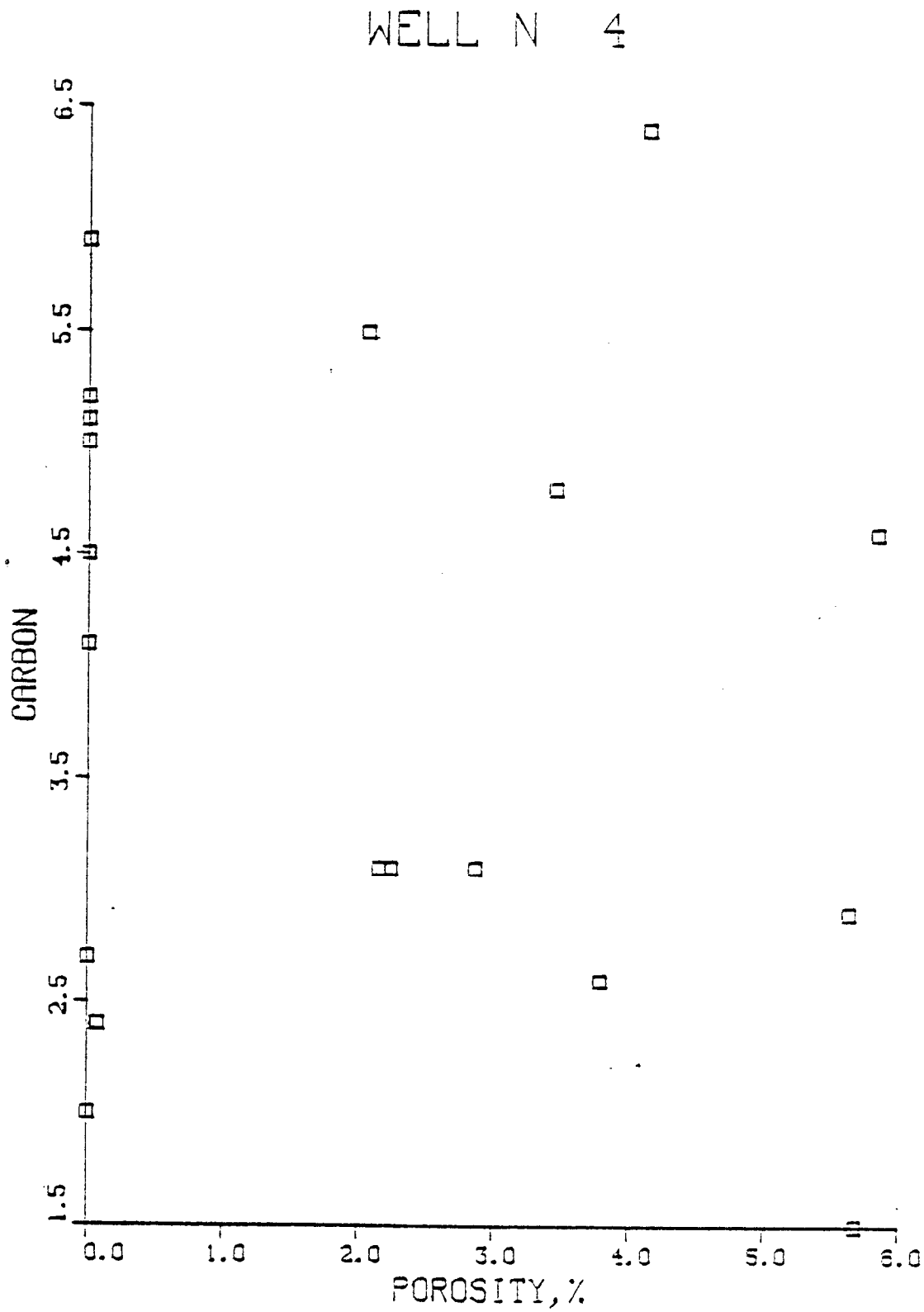
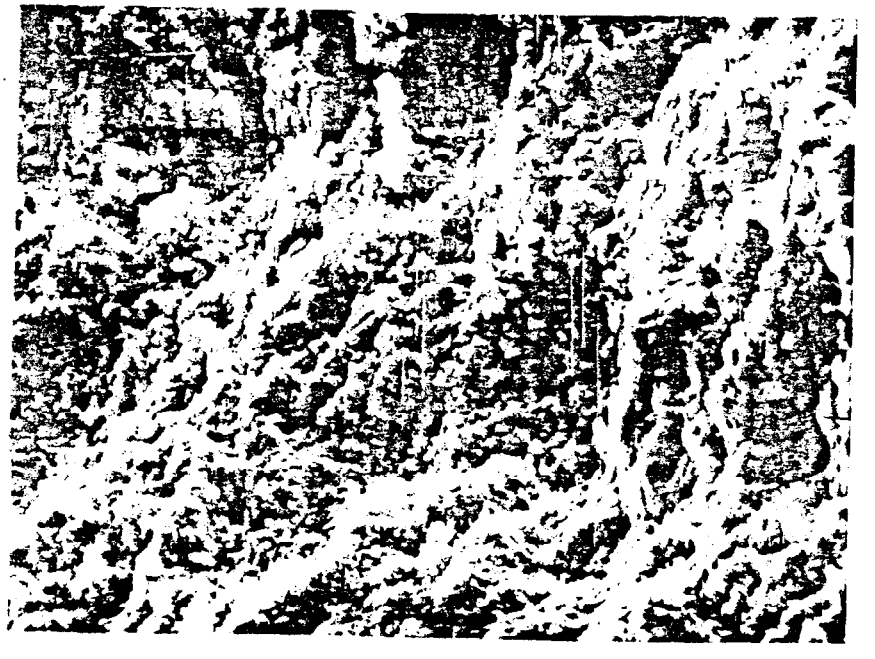


FIGURE 11. POROSITY VERSUS CARBON FOR WELL N-4



700 X

FIGURE 12. SEM MICROPHOTOGRAPH OF SAMPLE N-4-257

700 X

FIGURE 13. SEM MICROPHOTOGRAPH OF SAMPLE N-1-147

700 X

FIGURE 14. SEM MICROPHOTOGRAPH OF SAMPLE N-4-73