OIL/SOURCE-ROCK STUOY

NORTHERN DENVER BASIN - PALEOZOIC

REPORT NO. 8

Nilco Lucerne Peterson #1

12-22N-46W, GARDEN CO., NEBRASKA

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I. SUMMARY

The Paleozoic sedimentary section from 4682 to 5670 feet in the Nilco Lucerne Peterson #1 well, 12-22N-46W, Garden County, Nebraska, was analyzed for source-rock potential. Thirty-three (33) cuttings samples composed primarily of shales, carbonates and evaporites were analyzed. Petroleum Information cards listed lithologic tops for the Permian Stone Corral (4682 feet), Pennsylvanian (5010 feet) and Precambrian granite (5666 feet). This limited information prevented the subdivision of Permian and Pennsylvanian sections into time stratigraphic units.

The Permian section (4682-5010 feet) contains dark-gray shales from 4680 to 4740 feet which have fair quantities of organic matter. These rocks are in the early stage of liquid hydrocarbon generation and are not considered significant sources of petroleum. The Pennsylvanian section (5010-5666 feet) contains a zone from 5520 to 5670 feet that has fair organic richness. These rocks are dominated by marginally-mature amorphous organic matter, but are not considered a major source of oil. Deeper burial is required for this interval to reach optimum thermal maturity and the main phase of hydrocarbon generation.

There is no geochemical evidence for the presence of migrated petroleum in this well. The narrow distribution of saturated hydrocarbons, however, may represent some type of low level contamination not indigenous to the potential source rocks.

II. INTRODUCTION

Core Laboratories', Inc. geochemical study will determine the regional hydrocarbon source potential of the Permian and Pennsylvanian sections in the northern Denver basin. In addition, nine Permian and Pennsylvanian oils will be characterized to determine oil to oil and oil to source correlations. Fourteen (14) individual preliminary well reports and a crude oil correlation study will form the basis for our regional interpretation. These geochemical data from individual reports will be integrated into a geologic framework for the final report.

The Nilco Lucerne Peterson #1 is located in Garden County, Nebraska (12-22N-46W). Permian through Precambrian rocks were penetrated from 4682 to 5666 feet. A total of thirty-three (33) samples from 4680 to 5670 feet were analyzed for organic richness, kerogen type and thermal maturity. Sample quality was poor in some sections and prevented further analysis. Analytical techniques include measurement of total organic carbon, soxhlet extraction, liquid chromatographic separation of the extract on a silica gel column and high resolution gas chromatography of the C_{10+} saturated hydrocarbon fraction performed on a glass capillary column. In addition, the insoluble organic matter (kerogen) was studied by transmitted and fluorescent light microscopy, vitrinite reflectance and elemental analysis.

Our report is organized in three parts: 1) Interpretation, 2) Graphical Displays and 3) Analytical Data. The Interpretation contains the written text of the report. This includes our conclusions stated in a Summary which precedes this Introduction. Following this Introduction is a more detailed Discussion of Results which provides an evaluation of the hydrocarbon source potential of the sedimentary section penetrated by the Peterson #1 well. This is followed by the description of our standard Analytical Procedures. The second part of the report contains Graphical Displays of the geochemical data. Figure 1 shows a graphical summary of the geochemical data. Figure 2 shows lithology and total organic carbon content. The soluble organic matter is characterized in Figure 3. Figure 4 shows kerogen type and thermal maturity levels. The third section of the report contains the Analytical Data. Table I gives lithologic descriptions and total organic carbon content. Table II lists

concentrations and compositions of the extractable organic matter. Significant geochemical ratios are listed in Table III. Tables IV and V contain data on kerogen observations and vitrinite reflectance measurements, respectively. Table VI shows elemental hydrogen to carbon ratios for the kerogen. Table VII lists normalized n-paraffin distributions for the C_{15+} saturated hydrocarbons and Table VIII lists the normalized isoprenoid distributions. Figures 5 through 7 are gas chromatograms of the C_{10+} saturated hydrocarbon distributions.

III. DISCUSSION OF RESULTS

Permian 4682*-5010 feet

In general, the eleven (11) Permian cuttings samples analyzed consist of organic-lean shales and carbonates that do not have favorable hydrocarbon source potential. Dark-gray shales from 4680 to 4740 feet and a limestone at 4920 to 4950 feet contain an average of 0.70% total organic carbon and have fair organic richness. The shale interval contains mostly hydrogen-deficient gas-prone woody and coaly kerogen with secondary amounts of amorphous organic matter also present. The elemental hydrogen to carbon ratio for this organic matter is 0.87 indicating only a limited potential to generate liquid hydrocarbons. These Permian sediments are probably in the early stage of liquid hydrocarbon generation based on a thermal alteration index of 2+ and a 0.89% mean vitrinite reflectance measurement.

The extractable organic matter concentration at 4680 to 4740 feet is 417 ppm; a level below those required for good liquid petroleum source rocks. The gas chromatogram of the saturated hydrocarbon distribution for this sample contains a relatively narrow distribution and low quantities of the heavier molecular weight ($>C_{24}$) normal paraffins. This distribution may represent some type of low level contamination.

Pennsylvanian 5010-5666 feet

In general, the twenty-two (22) Pennsylvanian cuttings samples analyzed consist of anhydrite, limestones and shales that do not contain sufficient organic matter for favorable hydrocarbon source-rock potential. A predominantly shale interval from 5520 to 5670 feet contains an average of 0.70% total organic carbon and has fair organic richness. This interval is dominated by amorphous organic matter. Pennsylvanian sediments are marginally mature based on a thermal alteration index of 2+ and a 0.88% mean vitrinite reflectance measurement. The elemental hydrogen to carbon ratio for the kerogen at 5520 to 5610 feet is 0.82 indicating only limited potential to generate liquid hydrocarbons.

* Top of Stone Corral is within Permian

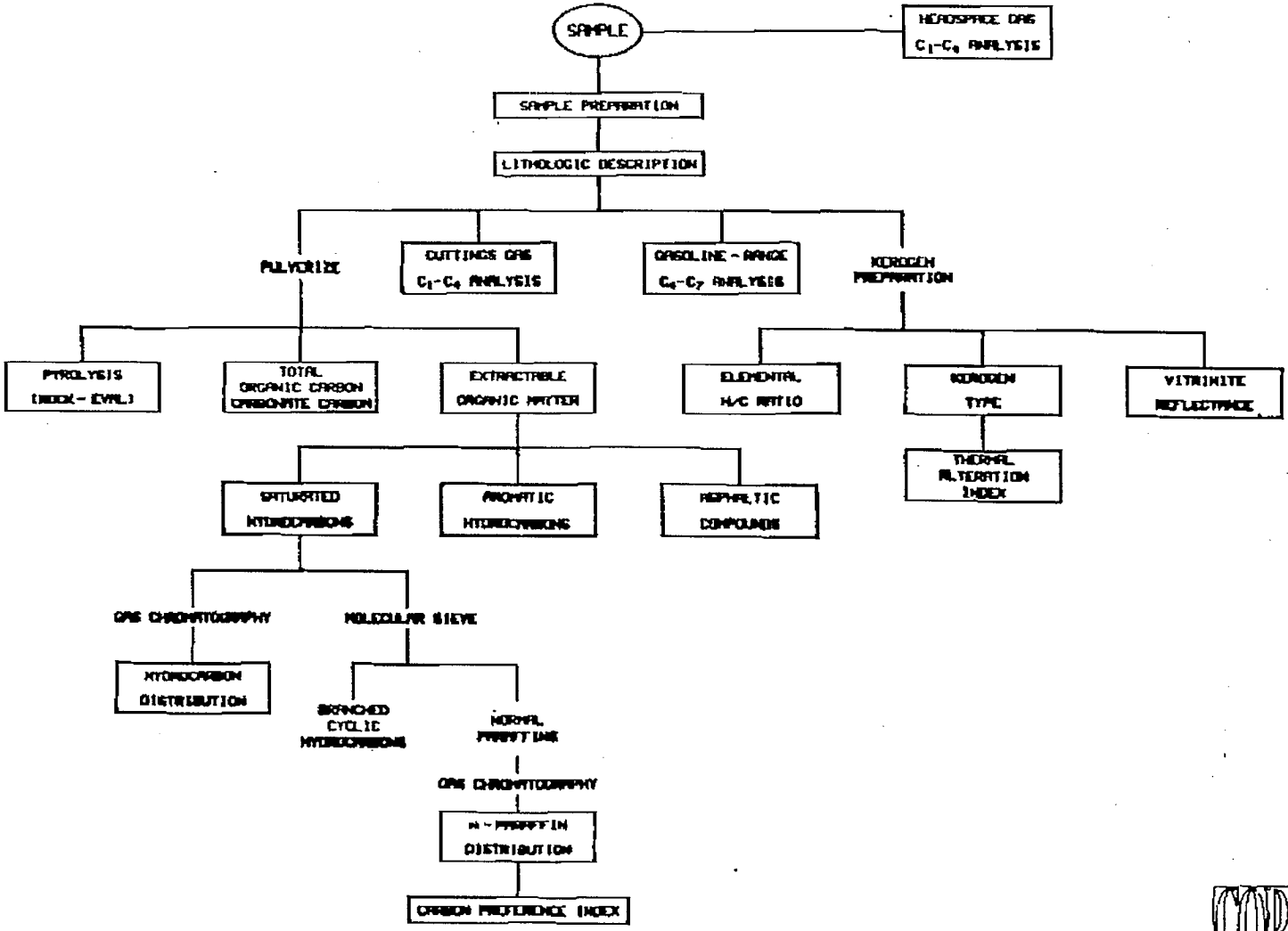
Concentrations of the extractable organic matter are below those associated with good petroleum source rocks. The saturated hydrocarbon distributions for Pennsylvanian cuttings samples have relatively low quantities of the heavier molecular weight ($>C_{24}$) normal paraffins. These distributions are not characteristic of most crude oils and may represent some type of contamination. Higher temperatures, associated with deeper burial, may be required for the Pennsylvanian section to reach optimum maturity.

IV. ANALYTICAL PROGRAM

The following analytical program was used in determining the hydrocarbon source potential of Paleozoic intervals in the Denver basin.

The quantity of total organic carbon is determined by combustion of pre-treated, carbonate-free, pulverized samples in a Leco WR-12 Analyzer. Generally, no further analyses are performed on samples having total organic carbon content values of less than 0.3% for carbonates and 0.5% for fine-grained clastic sediments. Samples with sufficient total organic carbon content are then analyzed for kerogen type, vitrinite reflectance and C_{15+} extractable organic matter content. If the concentration of the extract is less than 200 ppm, no further analyses are performed on the samples. Samples with extractable organic matter concentrations greater than 200 ppm are then characterized by liquid and gas chromatography analyses.

A description of the analytical procedures used by Core Lab's Geochemical Services Department follows this analytical program.



ANALYTICAL SCHEME FOR SOURCE-BED EVALUATION

DESCRIPTION OF ANALYTICAL PROCEDURES

SAMPLE PREPARATION

Cutting samples are thoroughly washed to remove drilling mud, and if necessary are placed in a solvent to float off contaminants, such as coals or drilling additives. The samples are then air-dried and are examined under a binocular microscope to remove any remaining contaminants. A magnet is used to remove any metal which may be present. The outside surface of sidewall and conventional core samples is removed and then the samples are thoroughly washed with water and allowed to air dry.

LITHOLOGICAL DESCRIPTION

A complete lithological description of each sample is made under a binocular microscope. All obvious cave material is removed and the sample submitted for total organic carbon analysis. The description includes an examination for migrated hydrocarbons under ultraviolet light.

TOTAL ORGANIC CARBON ANALYSIS (TOC)

Total organic carbon analysis measures the organic richness of a rock in weight percent organic carbon. Organic richness is the first requirement for an oil or gas source rock. The analysis is also used as a screening technique to determine which samples merit more detailed analysis. The dried rock samples are pulverized and treated with hot and cold hydrochloric acid to remove carbonates (inorganic carbon). After acid treatment, the organic carbon content is determined by combustion of the sample in a Leco WR-12 Carbon Analyzer. Blanks, standards, and duplicates are routinely run to insure highly reliable results.

EXTRACTION OF SOLUBLE ORGANIC MATTER (BITUMEN)

Soluble organic matter in a rock can result from the organic matter deposited with the rock or from the introduction of non-indigenous migrated hydrocarbons. It is important to know how much soluble organic matter is present for evaluating potential oil source rocks. The amount of indigenous soluble organic matter reflects the rock's total organic matter, type of organic matter, and thermal history. To determine

The CPI is used to evaluate thermal maturity. Saturated hydrocarbon distributions are also useful for oil-to-source rock correlations. In addition to a gas chromatogram, the percent composition of *n*-paraffins, percent composition of isoprenoids, pristane/phytane ratio and Carbon Preference Index are reported from this analysis.

VISUAL KEROGEN ANALYSIS

High-powered microscope examination of kerogen in transmitted light and under ultraviolet light determines thermal maturation state and whether the type of organic matter is favorable for petroleum generation. The kerogen composition is reported as % alginite (algal and amorphous debris), % exinite (herbaceous plant debris and palynomorphs), % woody plant debris, and % coaly fragments. The ability of the various kerogen types to yield oil decreases in the following order: alginite - exinite - woody - coaly. The color (Thermal Alteration Index) of the spore and pollen grains present is also used as an indicator of thermal maturation level.

For visual kerogen analysis, standard palynological techniques are used to separate the kerogen from the rock matrix. The isolated organic matter (kerogen) is mounted on a glass slide and examined under a high-powered Leitz microscope.

VITRINITE REFLECTANCE

Vitrinite reflectance provides a method for determining the thermal alteration history of a sediment. Vitrinite particles, originating from wood, are found dispersed throughout most sedimentary rock samples which are younger than Silurian. Since vitrinite reflectance increases regularly with increased thermal alteration, a reflectance measurement can be used to determine the degree of thermal maturation of that sediment.

Kerogen is prepared for vitrinite reflectance by imbedding the isolated kerogen in a bioplastic plug. The hardened plug is polished and the reflectance of the individual vitrinite particles are measured under a microscope. A histogram of reflectance values for each sample is reported.

ELEMENTAL ANALYSIS OF KERODGEN (H/C)

Chemical analysis of kerogen is used to characterize the type of organic matter present in a sediment in terms of its oil or gas generating potential. Kerogens with a high hydrogen content or high H/C ratio tend to generate oil. To measure the elemental composition, isolated kerogen is combusted in a Perkin-Elmer Elemental Analyzer. This method provides a direct, calibrated measurement for characterizing the kerogen type present in a sediment. The results are reported as % hydrogen, % carbon, % nitrogen and H/C ratio.

FIGURE 1
GEOCHEMICAL SUMMARY PROFILE

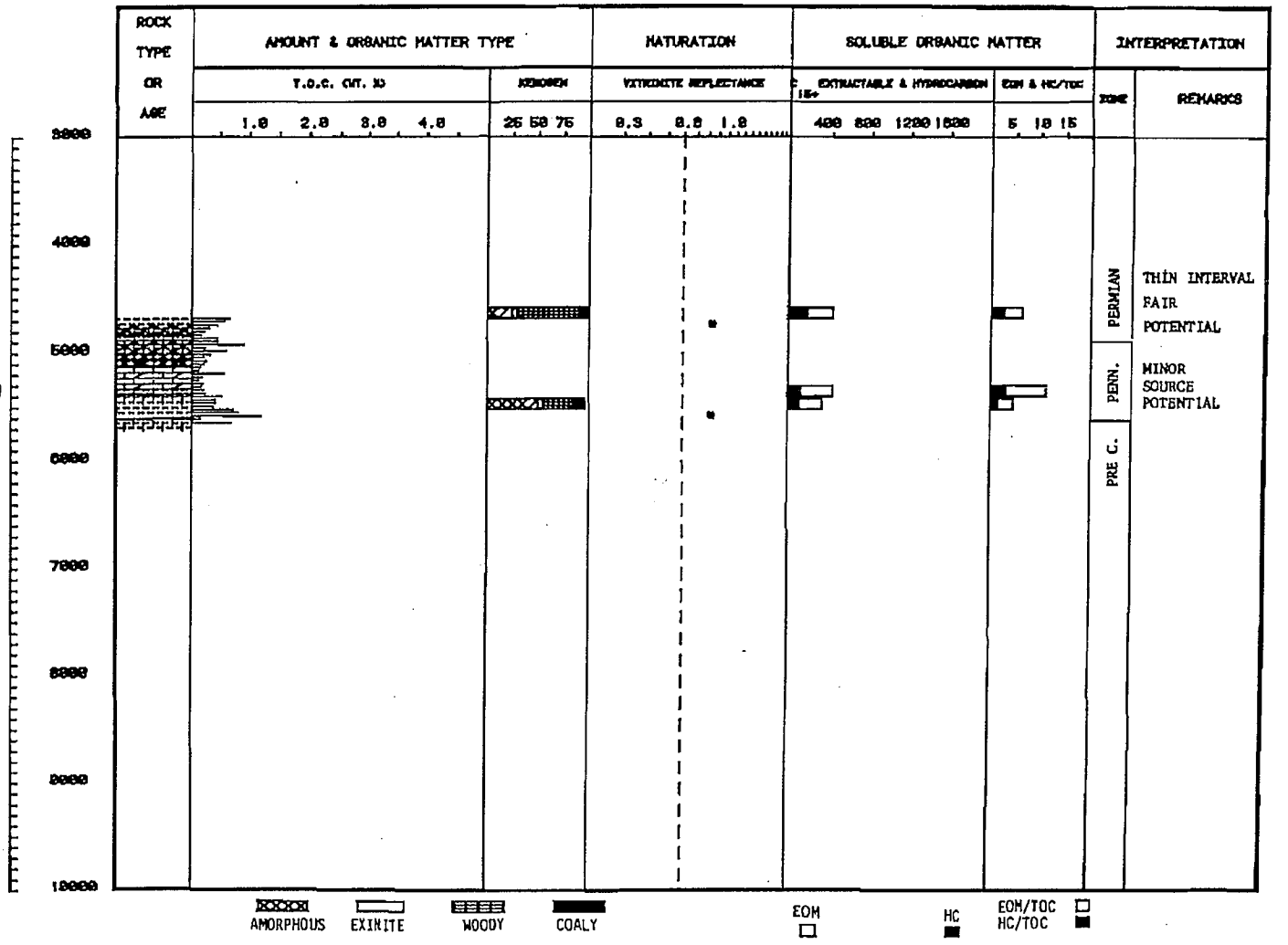


FIGURE 2

TOTAL ORGANIC CARBON CHARACTERIZATION

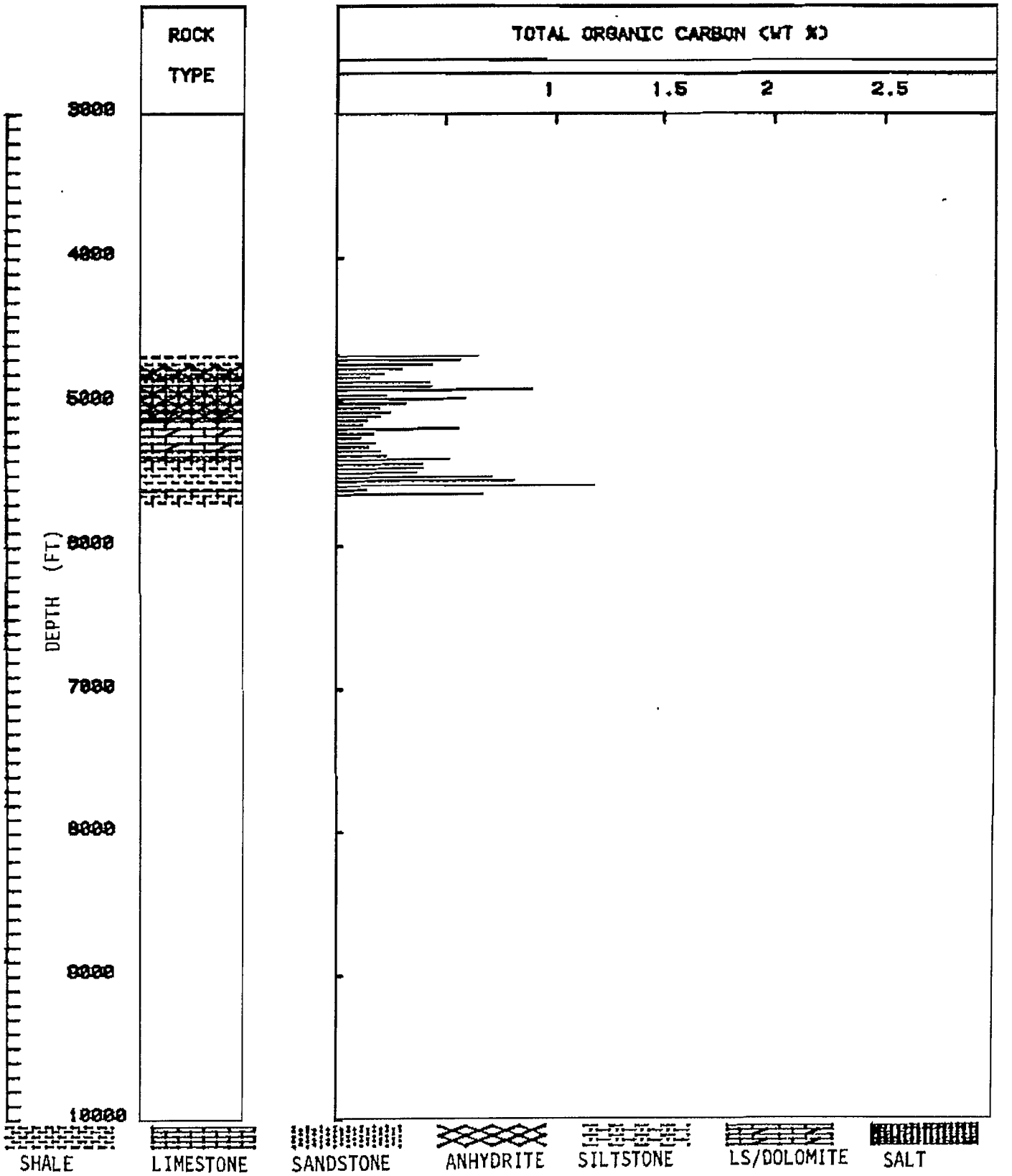


FIGURE 4

KEROGEN TYPE

THERMAL MATURITY

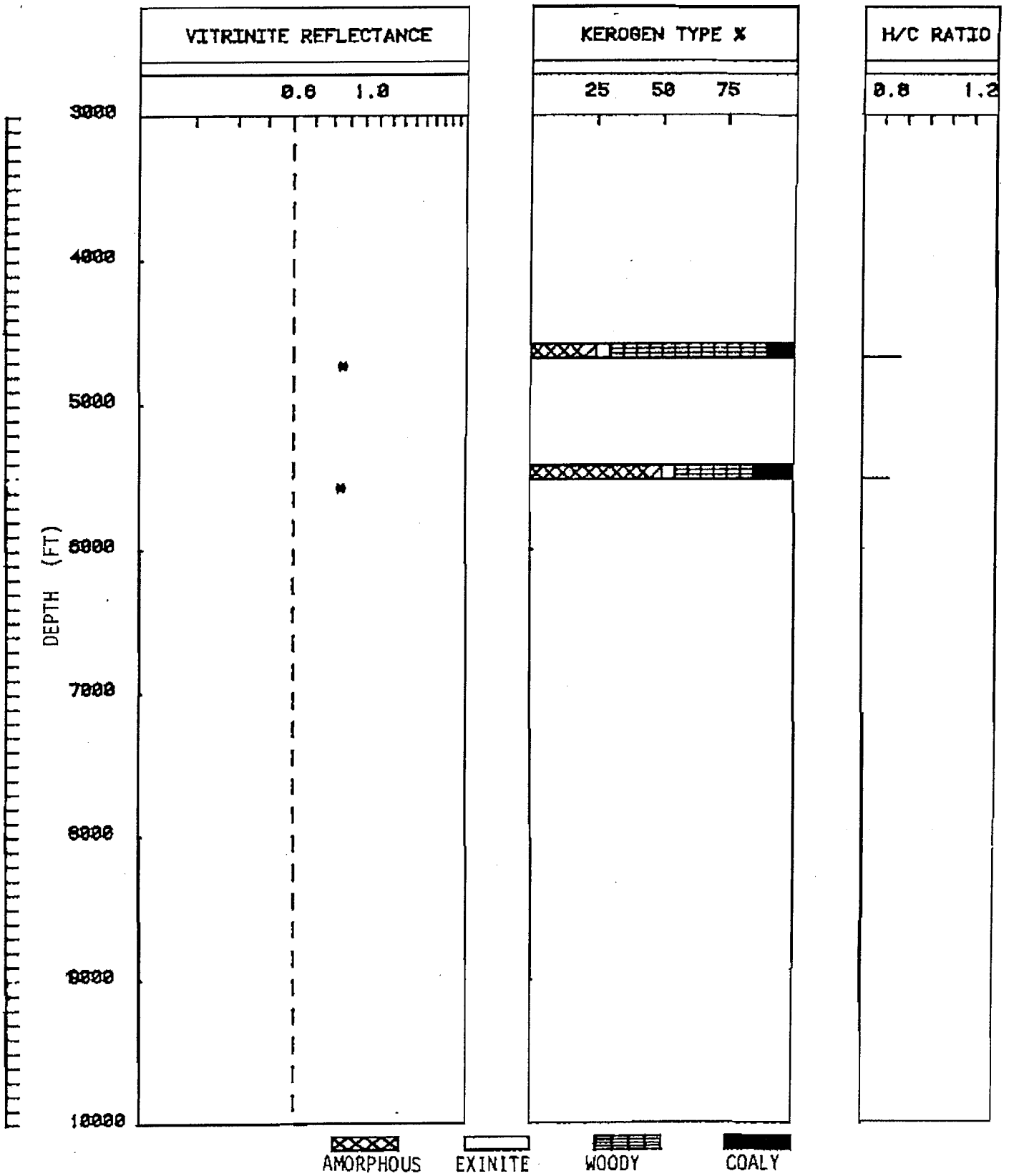


Table 1

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
4680-4710	ctgs	50% sh; m-dk gy, abnt mic xln pyr, occ v sl carb, frm, mod fss 50% sltst; m-lt orng, m orng-red, mica, frm Pres-ls; lt gy, mic xln, arg, frm	0.65/0.65
4710-4740	ctgs	60% sh; m-dk gy, lt gy, mica, occ mic xln pyr, occ sl slty, occ v sl carb, frm, mod fss 20% anhy; wh, lt gy, mass, frm 20% sltst; m-lt orng, m orng-red, mica, frm	0.57
4740-4770	ctgs	40% anhy; wh, lt gy, mass, frm 40% mdst-sh; m-dk gy, lt gy, mica, occ sl calc, frm, blky-mod fss 20% sltst; m orng-red, lt tn, frm	0.44
4770-4800	ctgs	40% sh; dk gy, m gy-brn, mica, frm, mod fss-fss 30% anhy; wh, lt gy, mass, frm 30% sltst; lt orng-red, mica, frm	0.30
4800-4830	ctgs	50% sltst; lt gy, lt orng-red, mica, occ calc, frm 40% anhy; wh, lt gy, mass, frm 10% sh; dk gy, m gy, lt gy, mica, occ mic xln pyr, occ v sl carb, frm, mod fss-fss Tr-ss; m gy, lt orng, f gr, mod srtd, sub ang-sub rdd, frm	0.22
4830-4860	ctgs	70% ls; lt gy, m gy, mic xln, occ sl arg, hd-frm 30% anhy; lt gy, wh, lt orng, mass, occ xln, frm Pres-mdst; lt orng-red, frm	0.15

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
4860-4890	ctgs	60% ls; m-lt gy, lt gy-tn, m gy, mic-vf xln, sl arg, hd-frm 20% sltst; m orng-red, lt tn, occ calc, frm 20% anhy; wh, lt gy, m orng, mass, occ elg xls, frm Tr-sh; dk gy-blk, m-dk gy, mica, occ sl carb?, frm, fss	0.43
4890-4920	ctgs	60% anhy; lt gy, wh, m gy, mass, occ c xls, frm 40% sh; dk gy, m gy, blk, mica, occ mic xln pyr, occ calc, frm, fss Tr-ls; m-lt gy, lt gy-tn, m gy, mic-vf xln, sl arg, hd-frm; sltst; m orng-red, lt tn, occ calc, frm	0.44
4920-4950	ctgs	40% ls; m gy, lt gy, m-dk gy, mic xln, sl arg, occ chky, frm 20% anhy; lt gy, wh, mass, frm 20% sltst; m orng-red, lt tn, mica, frm 20% sh; dk gy, mica, occ v sl carb, frm, fss 10% dol; lt gy, vf xln, occ v sl carb?, frm	0.89/0.89
4950-4980	ctgs	40% sh; m-dk gy, dk gy, m-dk gy-brn, mica, frm, fss 30% sltst; m orng-red, lt tn, mica, frm 10% anhy; lt gy, wh, mass, frm 10% ls; m gy, lt gy, m-dk gy, mic xln, sl arg, occ chky, frm 10% dol; lt gy, lt tn, vf xln, sl arg, frm	0.23
4980-5010	ctgs	50% anhy; lt tn, lt gy, wh, mass, frm 30% sh; dk gy-blk, mica, occ mic xln pyr, occ slty, frm, fss 10% ls; lt gy-tn, lt gy, mic xln, arg, frm 10% mdst; m orng-red, lt orng-red, frm Pres-dol; lt tn, vf xln, frm	0.59

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
5010-5040	ctgs	30% ls/dol; m gy-brn, mic xln, sl arg, hd-frm 30% anhy; lt tn, lt gy, wh, mass, frm 20% ls; m gy-brn, dk gy, lt gy, mic xln, occ arg, hd-frm 20% sh; dk gy, dk gy-blk, mica, occ v sl carb?, occ sl calc, frm, fss Tr-mdst; m orng-red, lt orng-red, frm	0.32
5040-5070	ctgs	40% anhy; lt tn, lt gy, wh, mass, frm 30% dol; lt tn, m gy-brn, mic xln, arg, hd-frm 30% ls; m gy-brn, mic-vf xln, arg, hd Pres-sh; dk gy, mica, frm, mod fss Tr-mdst; m orng-red, lt orng-red, occ slty, frm	0.20
5070-5100	ctgs	50% anhy; lt tn, lt gy, wh, mass, frm 30% ls; lt gy-tn, m gy-brn, mic xln, arg, hd-frm 20% dol; lt tn, m gy-brn, mic xln, arg, hd-frm Pres-sh; dk gy, mica, occ v sl carb?, occ sl calc, frm, mod fss; mdst; m orng-red, lt orng-red, occ slty, frm	0.25
5100-5130	ctgs	50% anhy; lt tn, lt gy, wh, mass, frm 20% dol; lt tn, lt pk, mic-vf xln, suc, frm 20% ls; lt gy-tn, m gy-brn, mic xln, arg, hd-frm 10% sh; dk gy, mica, occ v sl carb?, occ sl calc, frm, mod fss Tr-mdst; m orng-red, lt orng-red, occ slty, frm	0.20

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
5130-5160	ctgs	50% dol; lt tn, m gy-brn, m pk, mic-vf xln, occ suc, hd-frm 30% ls; lt tn, lt gy, m gy-brn, mic xln, occ chky, hd-frm 10% anhy; lt tn, wh, mass, hd-frm 10% sh; dk gy-brn, dk gy, mica, occ mic xln pyr, frm, mod fss Tr-mdst; lt orng, mica, frm	0.14
5160-5190	ctgs	70% ls; lt tn, lt gy, m gy-brn, mic xln, occ chky, hd-frm 20% dol; lt tn, m gy-brn, m pk, mic-vf xln, occ suc, hd-frm 10% sh; dk gy-brn, dk gy, mica, occ mic xln pyr, frm, mod fss Pres-mdst; lt orng, mica, frm; anhy; lt tn, wh, mass, hd-frm	0.12/0.14
5190-5220	ctgs	60% ls; lt gy, lt tn, m gy-brn, mic xln, occ chky, hd-frm 30% dol; lt tn, lt pk, m gy-purp, mic-vf xln, occ suc, frm 10% sh; dk gy, blk, mica, occ mic xln pyr, occ carb, frm, fss Pres-anhy; lt gy, lt tn, wh, lt pk, mass, occ c xls, frm Tr-mdst; lt orng, m orng, mica, occ slty, frm	0.56
5220-5250	ctgs	60% ls; lt tn, lt gy, m-lt gy, wh, mic-f xln, hd-frm 30% dol; m gy, m gy-purp, vf xln, suc, frm 10% mdst; lt orng, m orng, dk red-brn, mica, occ slty, frm Tr-sh; dk gy, mica, frm, fss	0.17

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
5250-5280	ctgs	50% ls; lt tn, lt gy, m-lt gy, wh, mic-f xln, hd-frm 30% dol; lt tn, m gy-brn, m gy-purp, mic-vf xln, occ suc, hd-frm 20% sh; dk gy, m-dk gy, dk gy-brn, mica, occ mic xln pyr, occ sl carb?, frm, fss Pres-mdst; dk orng, lt orng, occ slty, frm; anhy; lt gy, wh, mass, frm	0.11
5280-5310	ctgs	70% ls; lt tn, m-lt gy, lt orng, wh, mic xln, occ chky, occ arg, hd-frm 20% sltst; dk red-brn, m orng-brn, mica, frm 10% dol; lt tn, m gy-brn, m gy-purp, mic-vf xln, occ suc, hd-frm Tr-sh; dk gy, mica, frm, fss	0.18
5310-5340	ctgs	60% ls; lt tn, m-lt gy, lt orng, wh, mic xln, occ chky, occ arg, hd-frm 20% sh; dk gy, mica, frm, fss 10% dol; m brn, m tn, vf xln, suc, frm 10% sltst; m orng, mica, hd-frm Tr-anhy; wh, mass, frm	0.15
5340-5370	ctgs	50% sh; dk gy, dk gy-brn, mica, sl carb, frm, fss 30% ls; lt tn, m-lt gy, lt orng, wh, mic xln, occ chky, occ arg, hd-frm 20% sltst; m orng, mica, hd-frm Pres-dol; dk brn, dk gy-purp, m gy-purp, mic-vf xln, occ suc, hd-frm; anhy; lt tn, mass, frm	0.20

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
5370-5400	ctgs	40% ls; lt tn, m gy, mic-vf xln, hd 30% sh; dk gy, mica, occ mic xln pyr, frm, blky-mod fss 30% sltst; m orng, frm Pres-mrl; m orng, frm Tr-anhy; wh, mass, hd-frm	0.23
5400-5430	ctgs	40% sh; dk gy, m-dk gy, mica, occ carb, frm, blky-mod fss 30% mrl; m orng, lt orng-tn, m gy-orng, frm 20% mdst; lt gy-tn, m orng, mica, frm 10% ls; lt tn, lt gy, mic xln, occ chky, hd-frm Tr-anhy; lt tn-wh, mass, frm	0.52/0.50
5430-5460	ctgs	60% sh; m-dk gy, m gy-gn, mica, occ sl carb, frm, blky-mod fss 30% ls; m gy, lt tn, m gy-purp, mic-vf xln, occ arg, hd-frm 10% mrl; m orng, lt orng-tn, m gy-orng, frm Tr-anhy; clr, c xls, frm	0.40
5460-5490	ctgs	50% sh; m-dk gy, mica, hd-frm, blky-sub fss 30% mdst; lt orng, m orng, mica, occ slty, hd-frm 20% ls; lt tn, lt gy, m gy-purp, mic xln, hd Tr-anhy; lt gy, wh, f xls, frm; mrl; m orng, lt orng-tn, m gy-orng, frm	0.40
5490-5520	ctgs	70% sh; m-dk gy, m gy, m gy-purp, dk rd, mica, frm-blky, mod fss 20% mdst; lt orng, m orng, off wh, mica, occ slty, frm 10% ls; lt tn, lt gy, m gy-purp, mic xln, hd Pres-anhy; clr, lt tn-wh, mass, occ f xls, frm	0.37

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
5520-5550	ctgs	70% sh; m-dk gy, m gy, m gy-purp, dk rd-purp, mica, frm, blky-mod fss 20% mdst; lt orng, frm 10% anhy; lt tn, wh, mass, hd Pres-ls; lt tn, lt gy, mic xln, hd	0.71
5550-5580	ctgs	80% sh; m-dk gy, m orng, lt gy, mica, occ v sl carb, hd-frm, blky-fss 20% mdst; m orng, lt orng, mica, frm 10% anhy; clr, lt tn, wh, c xls, occ mass, frm Tr-ls; lt tn, mic xln, hd	0.81
5580-5610	ctgs	70% sh; dk gy, m-dk gy, lt gy-gn, m gy-purp, mica, occ sl carb, hd-frm, sub-mod fss 30% mdst; m orng, lt orng, mica, frm Pres-anhy; lt tn, wh, mass, hd-frm; sd; lt tn tnrsl, c gr, sub ang Tr-ls; m gy, mic xln, hd	1.18
5610-5640	ctgs	30% ls; lt gy, lt tn, mic xln, hd 30% mdst; m orng, dk rd-purp, mica, frm 30% sh; m-dk gy, m gy, mica, frm, blky-sub fss 10% sd; lt tn trnsl, c gr-pbl, sub ang-rdd	0.14
5640-5670	ctgs	50% sh; m-dk gy, m gy, mica, frm, blky-sub fss 20% mdst; dk gy, m gy-purp, occ v slty, occ sdy, frm-sft 20% sd; lt tn trnsl, m orng trnsl, c gr-gran 10% ls; lt gy, lt tn, mic xln, hd Tr-anhy; wh, mass, hd	0.67/0.66

* TOC = Total Organic Carbon

Table II

Results of C_{15+} Extractable Organic Matter (EOM) Analysis

Depth (ft)	Sample Type	TOC (wt %)	EOM (ppm)	HC (ppm)	Composition of C_{15+} Extractable Organic Matter (Normalized Percent) F-1	F-2	F-3	CPI
4680-4740	ctgs	0.65	417	173	37.0	13.0	50.0	1.30
5400-5490	ctgs	0.38	421	116	32.2	10.2	57.6	- -
5520-5610	ctgs	0.68	318	104	18.9	20.7	60.4	- -

TOC = Total Organic Carbon; EOM = Extractable Organic Matter (C_{15+}); HC = C_{15+} Hydrocarbons (saturates + aromatics); CPI = Carbon Preference Index (C_{24}-C_{34} carbon number range); F-1 = saturates; F-2 = aromatics; F-3 = asphaltics

Table III

Geochemical Ratios

Depth (ft)	$\frac{EOM}{TOC} \times 100$	$\frac{HC}{TOC} \times 100$	$\frac{HC}{EOM} \times 100$
4680-4740	6.4	2.7	41.5
5400-5490	11.1	3.1	27.6
5520-5610	4.7	1.5	32.7

TOC = Total Organic Carbon (ppm); EOM = C_{15+} Extractable Organic Matter (ppm); HC = C_{15+} Hydrocarbons (ppm)

Table IV

VISUAL KEROGEN OBSERVATIONS

DATE APRIL 28, 1981
WELL PETERSON #1
S.B.E.
JOB NO. 80209

DENVER BASIN
STUDY
PETERSON #1

X = >20%
/ = SECONDARY
* = 5-20%
T = TRACE

DEPTH	THERMAL ALTERATION INDEX							COLOR						KEROGEN TYPE						SPORINITE FLUORESCENCE COLOR						PRES				REMARKS
	1 UNALTERED	1+	2 SLIGHT ALTERATION	2+	3 MODERATE ALTERATION	3+	4 STRONG ALTERATION	4+	5 SEVERE ALTERATION	GREENISH LIGHT YELLOW	YELLOW	YELLOW - ORANGE	ORANGE - BROWN	LIGHT - BROWN	BROWN	DARK - BROWN	BLACK	ALGAL DEBRIS	AMORPHOUS DEBRIS	FINELY DISSEM. O.M.	HERB PLANT DEBRIS	WOODY PLANT DEBRIS	COALY PLANT DEBRIS	PALYNOMORPHS	GREEN	GREENISH YELLOW	YELLOW	SALLOW YELLOW	ORANGE	BROWN	BLACK	GOOD	FAIR	POOR	VERY POOR RECOVERY	BARREN OF O.M.	
4680 - 4740				X	T						X	T						/			X	*	T				T				X				
5520 - 5610				X	T						X	T						X	*		*	*	T				T				X				

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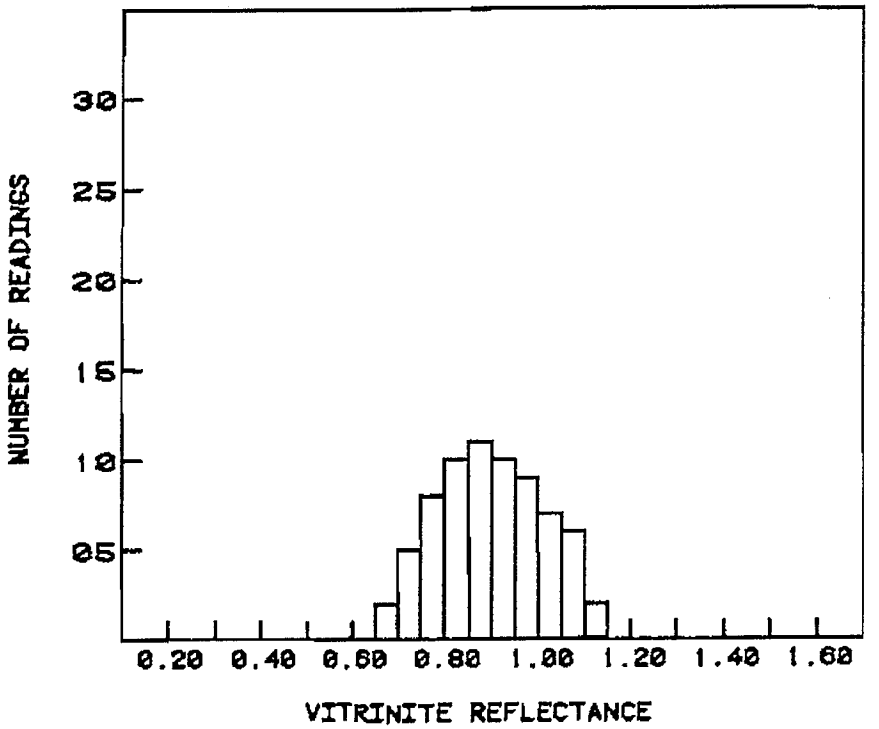
Table V

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

PETERSON #1

DEPTH: 4660-4740 FEET

MEAN REF.: 0.89%

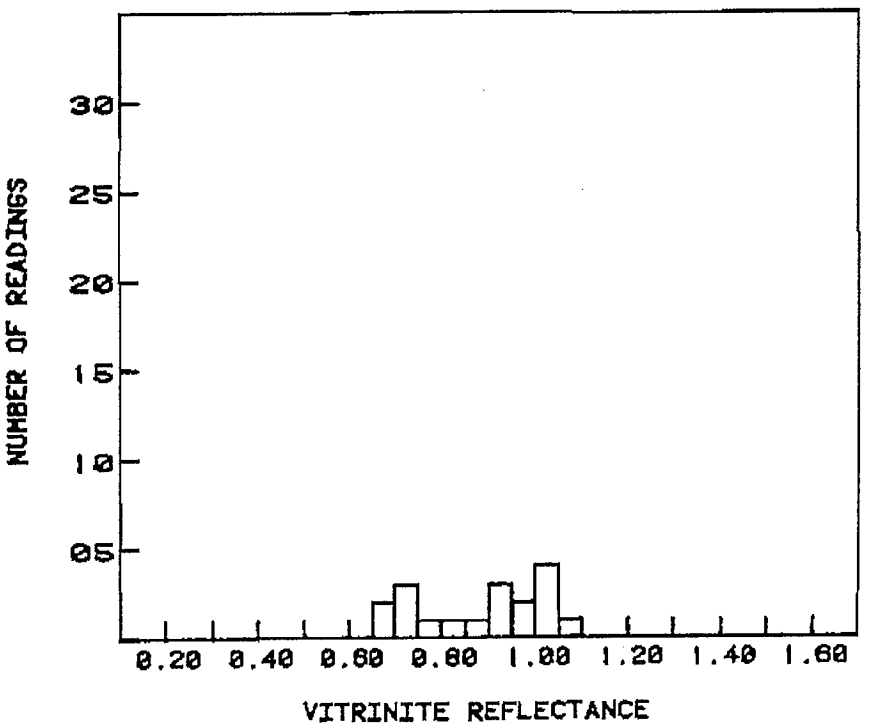
MAX. REF.: 1.10%

MIN. REF.: 0.67%

READINGS: 70

SAMPLE: CUTTINGS

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

PETERSON #1

DEPTH: 5520-5610 FEET

MEAN REF.: 0.88%

MAX. REF.: 1.07%

MIN. REF.: 0.65%

READINGS: 18

SAMPLE: CUTTINGS

Table VI

Elemental Analysis

Depth (ft)	Hydrogen:Carbon Ratio (H/C)
4680-4740	0.87
5520-5610	0.82

Table VII

Normalized n-Paraffin Distribution

	4680-4740	5400-5490	5520-5610
C_{15}	8.5	5.4	16.6
C_{16}	12.2	10.6	17.4
C_{17}	13.8	15.3	15.1
Pristane	8.0	7.9	7.2
C_{18}	12.5	14.3	10.1
Phytane	6.1	5.9	3.9
C_{19}	10.2	11.2	7.0
C_{20}	7.2	8.2	5.1
C_{21}	5.4	6.5	4.6
C_{22}	4.7	5.7	4.5
C_{23}	3.8	4.2	3.5
C_{24}	1.9	2.2	1.9
C_{25}	1.4	1.1	1.1
C_{26}	0.9	0.5	0.6
C_{27}	0.9	0.4	0.4
C_{28}	0.5	0.2	0.2
C_{29}	0.7	0.2	0.4
C_{30}	0.4	0.1	0.1
C_{31}	0.5	0.1	0.2
C_{32}	0.3	<0.1	0.1
C_{33}	0.1	- -	- -
C_{34}	<0.1	- -	- -
Pristane/Phytane	1.31	1.34	1.85
CPI	1.30	- -	- -

Table VIII

Normalized Isoprenoid Distribution

	5520-5610
Ip13	2.7
Ip14	3.9
Ip15	7.1
Ip16	17.4
Ip18	19.9
Pristane	31.7
Phytane	17.3

FIGURE 5

Peterson #1

C_{10+} Saturated Hydrocarbon Fraction

4680-4740 feet

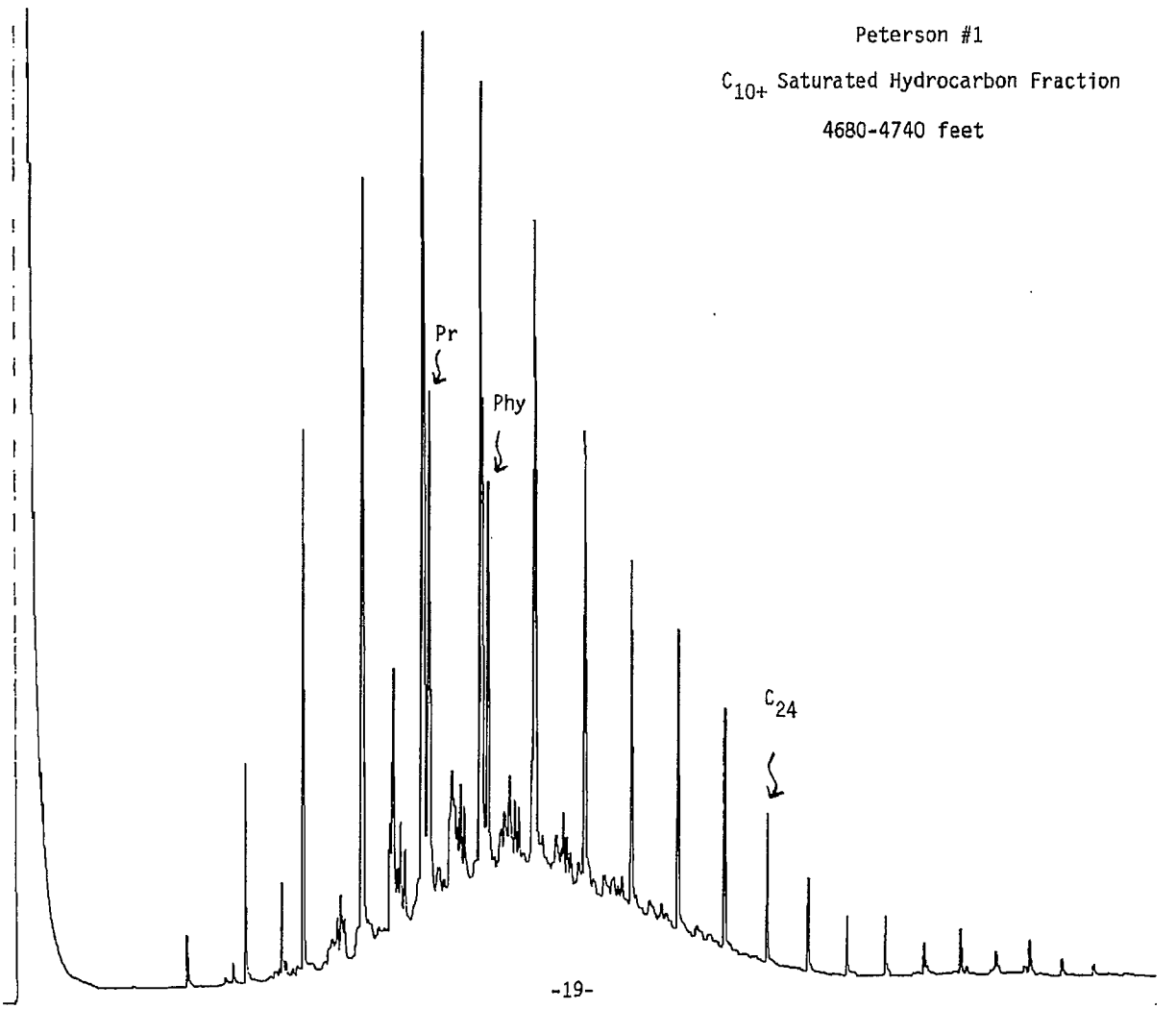


FIGURE 6

Peterson #1

C_{10+} Saturated Hydrocarbon Fraction

5400-5490 feet

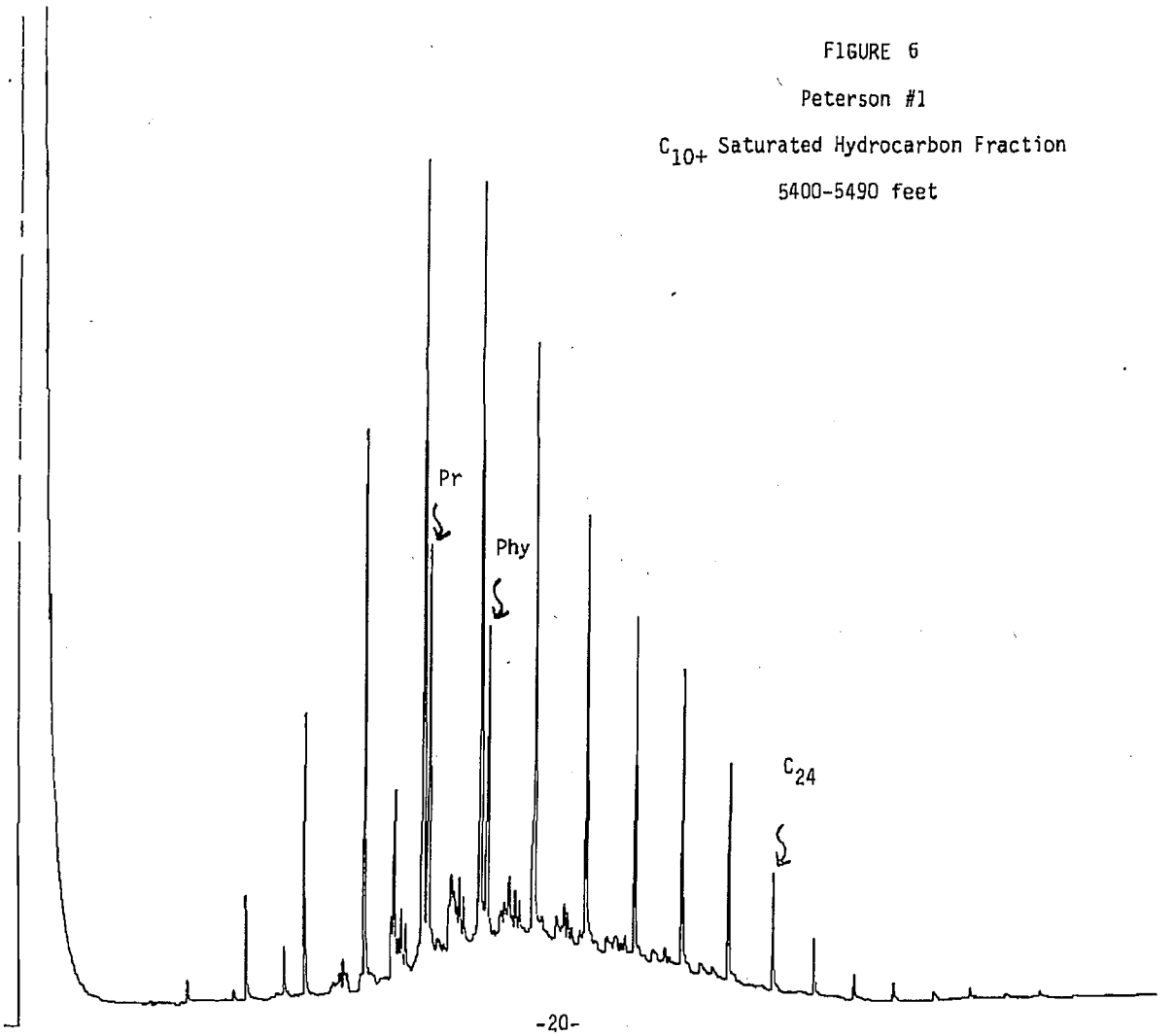
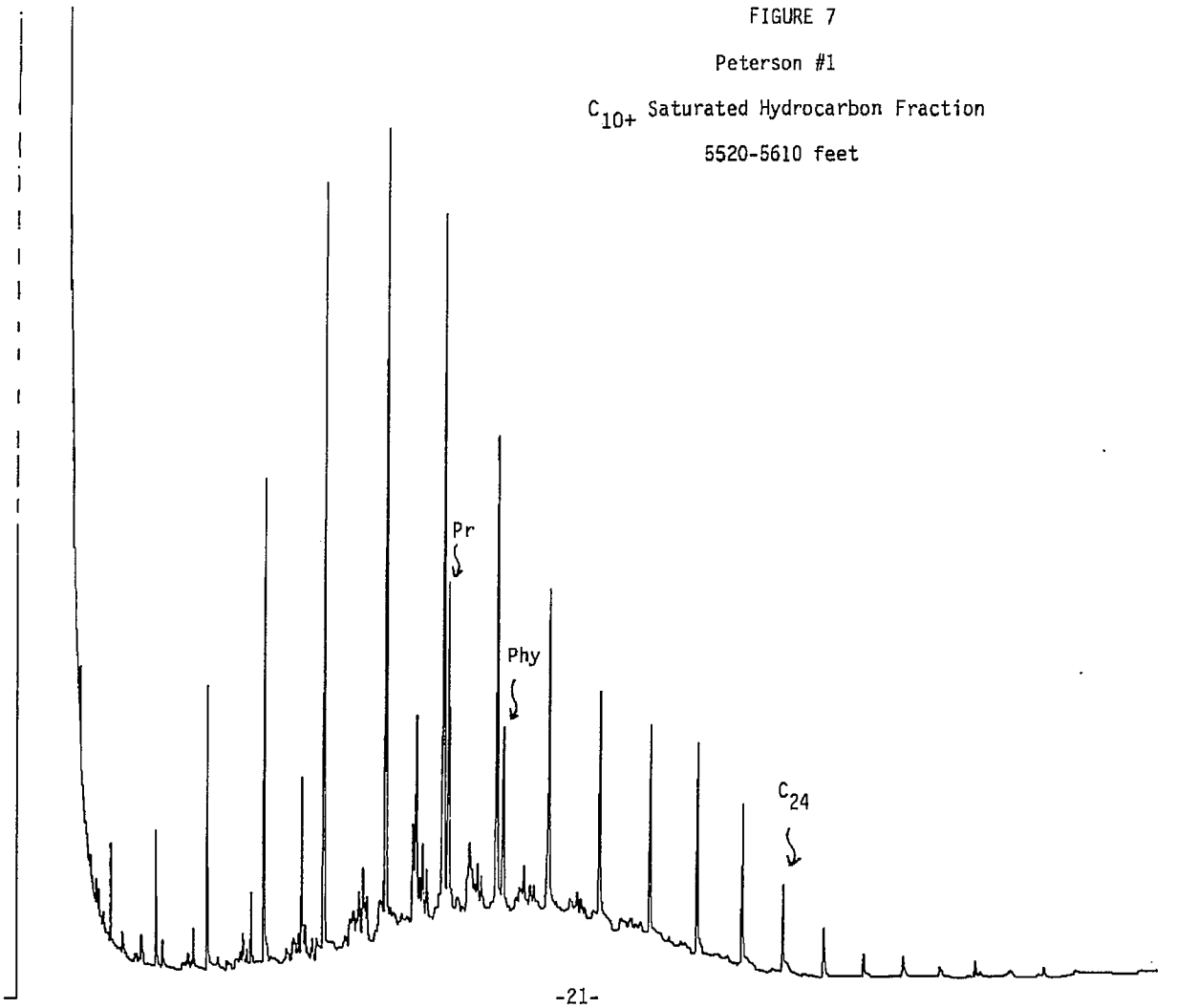


FIGURE 7

Peterson #1

C_{10+} Saturated Hydrocarbon Fraction

5520-5610 feet



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OIL/SOURCE-ROCK STUDY
NORTHERN DENVER BASIN - PALEOZOIC
REPORT NO. 10
TUCKER McCONAUGHY #1
22-15N-41W, KEITH CO., NEBRASKA

CORE LAB

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I. SUMMARY

The Paleozoic sedimentary section from 4150 to 5500 feet in the Tucker McConaughy #1, 22-15N-41W, Keith County, Nebraska, was analyzed for hydrocarbon source potential. Forty-six (46) cuttings samples, composed of shales, siltstones and sandstones, were analyzed. Lithologic tops from Petroleum Information cards were used to divide the Permian and Pennsylvanian sections.

Permian (4150-4703 feet) rocks are dominated by dark-gray shales that have fair to good organic richness. These intervals are thermally mature and have fair oil source potential. Pennsylvanian (4703-5500 feet total depth) rocks also have fair to good organic richness but generally contain less soluble organic matter and are considered only minor sources of petroleum.

There is no geochemical evidence for the presence of migrated petroleum in this well. The narrow distribution of saturated hydrocarbons, however, may represent some type of low level contamination.

II. INTRODUCTION

Core Laboratories', Inc. geochemical study will determine the regional hydrocarbon source potential of the Permian and Pennsylvanian sections in the northern Denver basin. In addition, nine Permian and Pennsylvanian oils will be characterized to determine oil to oil and oil to source correlations. Fourteen (14) individual preliminary well reports and a crude oil correlation study will form the basis for our regional interpretation. These geochemical data from individual reports will be integrated into a geologic framework for the final report.

The Tucker McConaughy #1 is located in Keith County, Nebraska (22-15N-41W). Permian and Pennsylvanian rocks were penetrated from 4150 to 5500 feet and a total of forty-six (46) samples were analyzed for organic richness, kerogen type and thermal maturity. Analytical techniques include measurement of total organic carbon, soxhlet extraction, liquid chromatographic separation of the extract on a silica gel column, and high resolution gas chromatography of the C_{10+} saturated hydrocarbon fraction performed on a glass capillary column. In addition, the insoluble organic matter (kerogen) was studied by transmitted and fluorescent light microscopy, vitrinite reflectance and elemental analysis.

Our report is organized in three parts: 1) Interpretation, 2) Graphical Displays and 3) Analytical Data. The Interpretation contains the written text of the report. This includes our conclusions stated in a Summary which precedes this Introduction. Following this Introduction is a more detailed Discussion of Results which provides an evaluation of the hydrocarbon source potential of the sedimentary section penetrated by the Tucker McConaughy #1 well. This is followed by the description of our standard Analytical Procedures. The second part of the report contains Graphical Displays of the geochemical data. Figure 1 shows a graphical summary of the geochemical data. Figure 2 shows lithology and total organic carbon content. The soluble organic matter is characterized in Figure 3. Figure 4 shows kerogen type and thermal maturity levels. The third section of the report contains the Analytical Data. Table I gives lithologic descriptions and total organic carbon content. Table II lists

concentrations and compositions of the extractable organic matter. Significant geochemical ratios are listed in Table III. Tables IV and V contain data on kerogen observations and vitrinite reflectance measurements, respectively. Table VI shows elemental hydrogen to carbon ratios for the kerogen. Table VII lists normalized n-paraffin distributions for the C_{15+} saturated hydrocarbons and Table VIII lists the normalized isoprenoid distributions. Figures 5 through 12 are gas chromatograms of the C_{10+} saturated hydrocarbon distributions.

III. DISCUSSION OF RESULTS

Permian 4150-4703 feet

The eighteen (18) Permian cuttings samples analyzed consist of dark-gray shales that contain an average of 0.77% total organic carbon. These intervals have fair organic richness. Cuttings from 4240-4510 feet contain woody and coaly kerogen while the interval at 4600-4690 feet is dominated by amorphous organic matter. Permian sediments are thermally mature and in the main stage of oil generation based on a thermal alteration index of 3 and a 1.01% maximum mean vitrinite reflectance measurement. The elemental hydrogen to carbon ratio averages 0.77 indicating limited potential to generate additional liquid hydrocarbons.

Concentracions of extractable organic matter and associated total hydrocarbons average 539 ppm and 155 ppm, respectively. These levels are usually associated with fair hydrocarbon source rocks. Gas chromatograms of the saturated hydrocarbon fractions contain a relatively narrow normal paraffin distribution. Carbon preference indices average 1.21, although the low quantities of C_{24} to C_{34} normal paraffins reduce the reliability of this maturity measurement.

Pennsylvanian 4703-5500 feet total depth

Pennsylvanian cuttings intervals contain an average of 0.86% total organic carbon and have fair organic richness. These dark-gray shales contain predominantly amorphous organic matter that is in the main stage of hydrocarbon generation. This conclusion is based on a thermal alteration index of 3 and a 1.01% maximum mean vitrinite reflectance measurement. Elemental hydrogen to carbon ratios for the kerogen average 0.85 and indicate only a limited potential to generate liquid hydrocarbons.

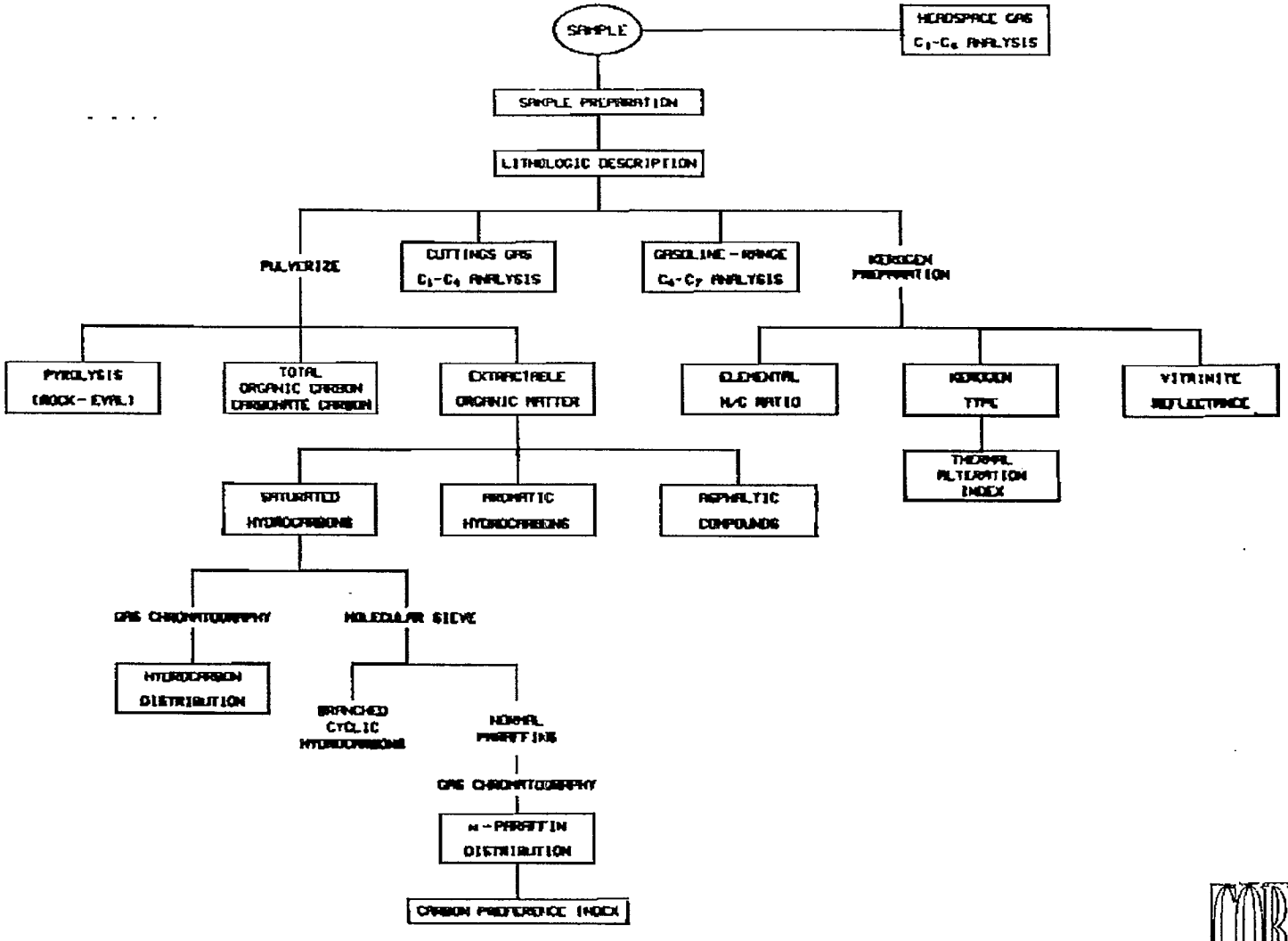
Extractable organic matter concentrations are below those required for good petroleum source rocks. The saturated hydrocarbon distributions have relatively narrow distributions with low quantities of the heavier molecular weight ($>C_{24}$) normal paraffins. These distributions are not characteristic of most crude oils and may represent some form of contamination.

IV. ANALYTICAL PROGRAM

The following analytical program was used in determining the hydrocarbon source potential of Paleozoic intervals in the Denver basin.

The quantity of total organic carbon is determined by combustion of pre-treated, carbonate-free, pulverized samples in a Leco WR-12 Analyzer. Generally, no further analyses are performed on samples having total organic carbon content values of less than 0.3% for carbonates and 0.5% for fine-grained clastic sediments. Samples with sufficient total organic carbon content are then analyzed for kerogen type, vitrinite reflectance and C_{15+} extractable organic matter content. If the concentration of the extract is less than 200 ppm, no further analyses are performed on the samples. Samples with extractable organic matter concentrations greater than 200 ppm are then characterized by liquid and gas chromatography analyses.

A description of the analytical procedures used by Core Lab's Geochemical Services Department follows this analytical program.



ANALYTICAL SCHEME FOR SOURCE-BED EVALUATION

DESCRIPTION OF ANALYTICAL PROCEDURES

SAMPLE PREPARATION

Cutting samples are thoroughly washed to remove drilling mud, and if necessary are placed in a solvent to float off contaminants, such as coals or drilling additives. The samples are then air-dried and are examined under a binocular microscope to remove any remaining contaminants. A magnet is used to remove any metal which may be present. The outside surface of sidewall and conventional core samples is removed and then the samples are thoroughly washed with water and allowed to air dry.

LITHOLOGICAL DESCRIPTION

A complete lithological description of each sample is made under a binocular microscope. All obvious cave material is removed and the sample submitted for total organic carbon analysis. The description includes an examination for migrated hydrocarbons under ultraviolet light.

TOTAL ORGANIC CARBON ANALYSIS (TOC)

Total organic carbon analysis measures the organic richness of a rock in weight percent organic carbon. Organic richness is the first requirement for an oil or gas source rock. The analysis is also used as a screening technique to determine which samples merit more detailed analysis. The dried rock samples are pulverized and treated with hot and cold hydrochloric acid to remove carbonates (inorganic carbon). After acid treatment, the organic carbon content is determined by combustion of the sample in a Leco WR-12 Carbon Analyzer. Blanks, standards, and duplicates are routinely run to insure highly reliable results.

EXTRACTION OF SOLUBLE ORGANIC MATTER (BITUMEN)

Soluble organic matter in a rock can result from the organic matter deposited with the rock① or from the introduction of non-indigenous migrated hydrocarbons② It is important to know how much soluble organic matter is present for evaluating potential oil source rocks. The amount of indigenous soluble organic matter reflects the rock's total organic matter, type of organic matter, and thermal history. To determine

soluble organic matter concentration, powdered rock samples are placed in Soxhlet thimbles and extracted for 24 hours with chloroform. An aliquot of extracted material is then transferred to a pre-weighed container and the chloroform solvent is evaporated under nitrogen at 40°C. The concentration of the stabilized extract (soluble organic matter) residue is reported in parts per million.

LIQUID CHROMATOGRAPHIC SEPARATION

The composition of the soluble organic matter is determined by liquid chromatographic separation into saturated hydrocarbons, aromatic hydrocarbons, and asphaltic compounds. Compositional data is useful in evaluating oil source quality and thermal maturation. An aliquot of the soluble organic matter extract in chloroform is concentrated and iso-octane solvent is added. Concentration and addition of iso-octane is repeated until all chloroform has been removed without complete evaporation to dryness. The extract in iso-octane is then placed on a silica gel column and successively eluted with hexane, benzene, and benzene/methanol to determine % saturates, % aromatics, and % asphaltics.

GAS CHROMATOGRAPHY OF C_{10+} SATURATED HYDROCARBONS

The saturated hydrocarbon fraction from liquid chromatography is analyzed by gas chromatography before it is evaporated to dryness. This allows analysis of hydrocarbons below C_{15}. The distribution of C_{10+} saturated hydrocarbons documents whether petroleum-like hydrocarbons are present in a rock sample. A high resolution glass capillary column is used to separate the hydrocarbons. The temperature-programmed analysis is performed on a Hewlett Packard gas chromatograph equipped with a flame ionization detector. From the distribution of n-paraffins the Carbon Preference Index (CPI) is calculated according to the following equation:

$$C.P.I. = \frac{1}{2}\left[\frac{\sum_{25}^{33} \text{Odd-Carbon n-Paraffins}}{\sum_{26}^{34} \text{Even-Carbon n-Paraffins}} + \frac{\sum_{25}^{33} \text{Odd-Carbon n-Paraffins}}{\sum_{24}^{32} \text{Even-Carbon n-Paraffins}}\right]$$

The CPI is used to evaluate thermal maturity. Saturated hydrocarbon distributions are also useful for oil-to-source rock correlations. In addition to a gas chromatogram, the percent composition of n-paraffins, percent composition of isoprenoids, pristane/phytane ratio and Carbon Preference Index are reported from this analysis.

VISUAL KEROGEN ANALYSIS

High-powered microscope examination of kerogen in transmitted light and under ultraviolet light determines thermal maturation state and whether the type of organic matter is favorable for petroleum generation. The kerogen composition is reported as % alginite (algal and amorphous debris), % exinite (herbaceous plant debris and palynomorphs), % woody plant debris, and % coaly fragments. The ability of the various kerogen types to yield oil decreases in the following order: alginite - exinite - woody - coaly. The color (Thermal Alteration Index) of the spore and pollen grains present is also used as an indicator of thermal maturation level.

For visual kerogen analysis, standard palynological techniques are used to separate the kerogen from the rock matrix. The isolated organic matter (kerogen) is mounted on a glass slide and examined under a high-powered Leitz microscope.

VITRINITE REFLECTANCE

Vitrinite reflectance provides a method for determining the thermal alteration history of a sediment. Vitrinite particles, originating from wood, are found dispersed throughout most sedimentary rock samples which are younger than Silurian. Since vitrinite reflectance increases regularly with increased thermal alteration, a reflectance measurement can be used to determine the degree of thermal maturation of that sediment.

Kerogen is prepared for vitrinite reflectance by imbedding the isolated kerogen in a bioplastic plug. The hardened plug is polished and the reflectance of the individual vitrinite particles are measured under a microscope. A histogram of reflectance values for each sample is reported.

ELEMENTAL ANALYSIS OF KEROGEN (H/C)

Chemical analysis of kerogen is used to characterize the type of organic matter present in a sediment in terms of its oil or gas generating potential. Kerogens with a high hydrogen content or high H/C ratio tend to generate oil. To measure the elemental composition, isolated kerogen is combusted in a Perkin-Elmer Elemental Analyzer. This method provides a direct, calibrated measurement for characterizing the kerogen type present in a sediment. The results are reported as % hydrogen, % carbon, % nitrogen and H/C ratio.

FIGURE 1
GEOCHEMICAL SUMMARY PROFILE

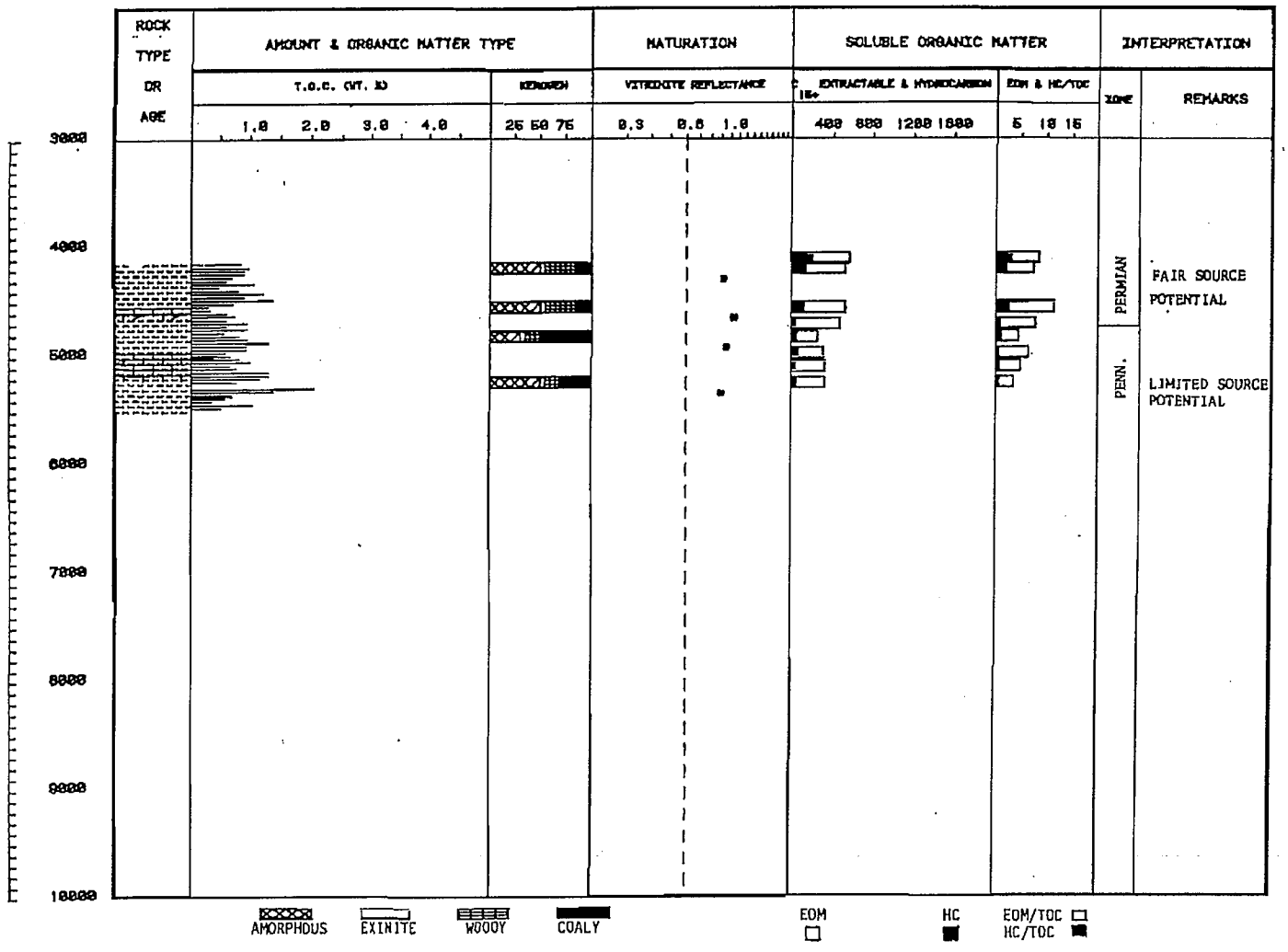


FIGURE 2

TOTAL ORGANIC CARBON CHARACTERIZATION

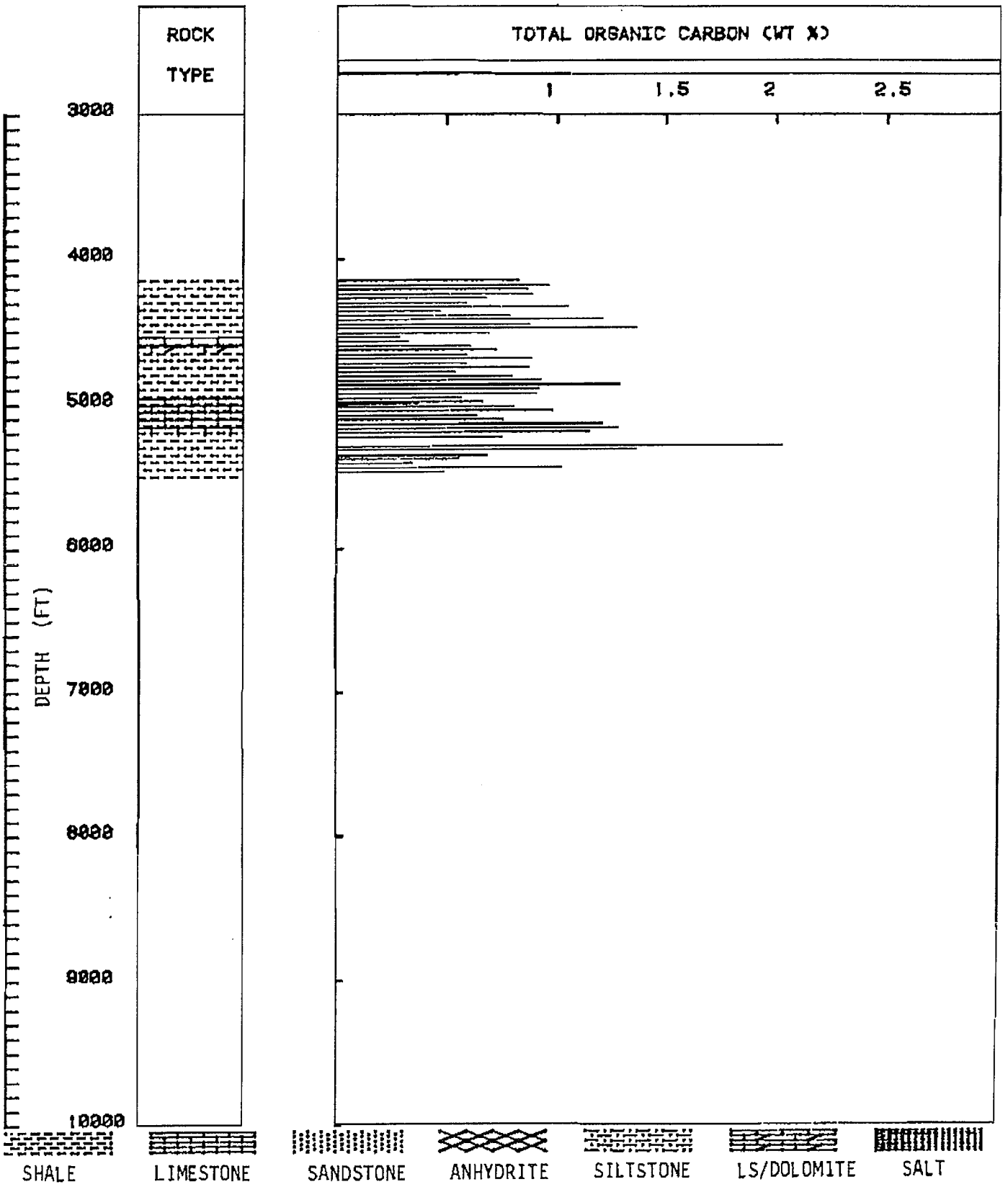


FIGURE 3

SOLUBLE ORGANIC MATTER CHARACTERIZATION

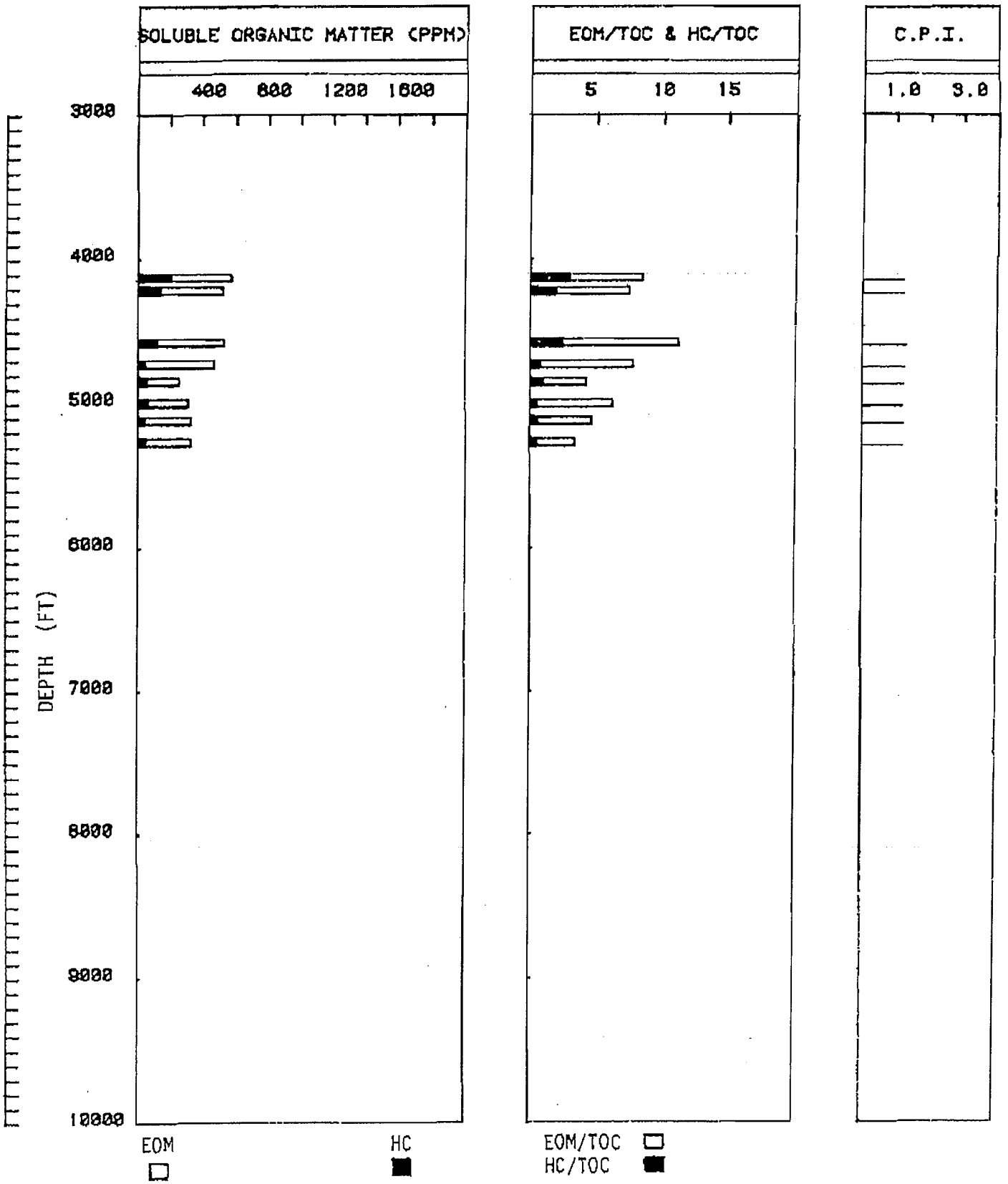


FIGURE 4

KEROGEN TYPE

THERMAL MATURITY

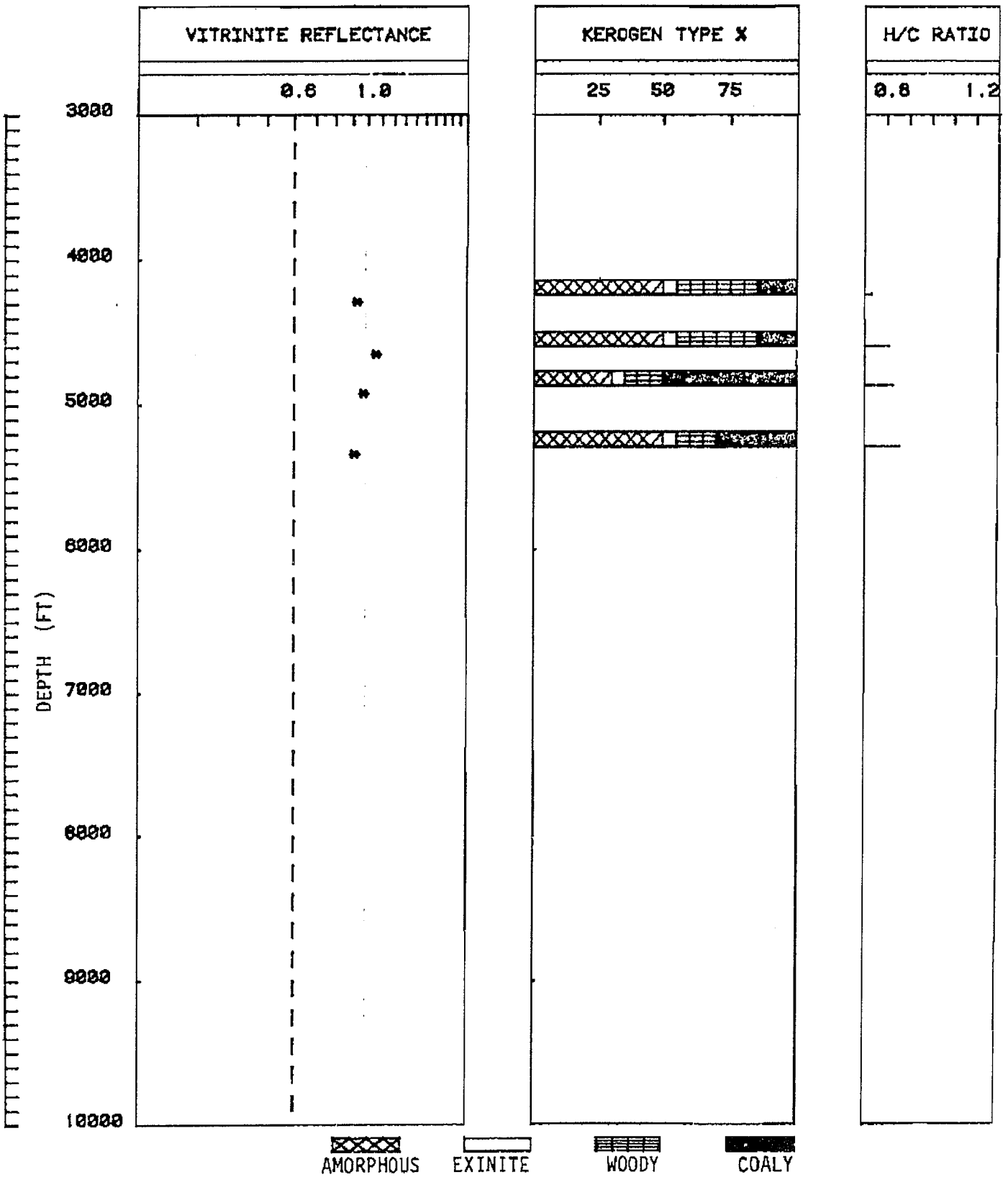


Table I

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
4150-4180	ctgs	Sh; dk gy, m gy, lt gy-gn, m purp, mica, occ sl slty, frm, fss Pres-ls; lt gy, m gy, mic-f xln, hd	0.83
4180-4210	ctgs	Sh; dk gy, m-dk gy, mica, abnt mic xln pyr, occ v sl carb, frm, fss Pres-anhy; m orng, wh, f xls, frm Tr-mdst; m orng, mica, frm	0.96
4210-4240	ctgs	90% sh; dk gy, m-dk gy, mica, abnt mic xln pyr, occ v sl carb, frm, fss 10% mdst; m orng, mica, frm Pres-anhy; lt tn, wh, m orng, mass, occ gran?, frm	0.87
4240-4270	ctgs	90% sh; dk gy, m-dk gy, mica, abnt mic xln pyr, occ v sl carb, frm, fss 10% mdst; m orng, mica, frm Pres-anhy; lt tn, wh, m orng, mass, occ gran?, frm Tr-sltst; m orng, mica, frm	0.89
4270-4300	ctgs	80% sh; dk gy, m-dk gy, m-dk orng-rd, dk rd, mica, occ v sl carb, frm, mod fss-fss 20% ss; m orng, vf-f gr, m-mod srtd, sub ang-rdd, fri, anhy? Tr-anhy; wh, mass, frm	0.68
4300-4330	ctgs	90% sh; dk gy, m-dk gy, m-dk orng-rd, dk rd, mica, occ v sl carb, frm, mod fss-fss 10% ss; m orng, vf-f gr, m-mod srtd, sub ang-rdd, fri, anhy? Tr-anhy; wh, m orng, mass, occ f xls, frm; mdst; v lt gy, frm	0.59

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
4330÷4360	ctgs	Sh; dk gy, m-dk gy, m-dk orng-rd, dk rd, mica, occ v sl carb, frm, mod fss-fss Pres-ss; m orng, vf-f gr, m-mod srtd, sub ang-rdd, fri, anhy? Tr-anhy; wh, m orng, mass, occ f xls, frm; mdst; v lt gy, frm	1.05/1.04
4360-4390	ctgs	60% sh; dk gy, m-dk gy, m-dk orng-rd, mica, occ v sl carb, frm, mod fss-fss 40% dol; v lt tn, lt gy, m gy, vf xln, suc, hd Tr-anhy; wh, m orng, gran?, frm	0.47
4390-4420	ctgs	Sh; dk gy, m-dk orng-rd, lt gy-gn, lt gy-purp, v lt gy, mica, occ v sl carb, frm, mod fss-fss Pres-ss; m orng, lt gy, m gy-gn, vf -f gr, p-mod srtd, sub ang-sub rdd, frm-fri, occ anhy?	0.79
4420÷4450	ctgs	Sh; dk gy, m-dk orng-rd, lt gy-gn, lt gy-purp, v lt gy, mica, occ v sl carb, frm, mod fss-fss Tr-dol; lt tn, mic xln, suc hd; ss; m orng, lt gy, m gy-gn, vf-f gr, p-mod srtd, sub ang-sub rdd, frm-fri, occ anhy?	1.21
4450÷4480	ctgs	Sh; dk gy, m-dk orng-rd, dk gy-purp, mica, occ sl carb, occ slty, occ sdy, frm, sub fss-fss Tr-anhy; wh, mass, frm	0.88
4480÷4510	ctgs	Sh; dk gy, m-dk orng-rd, dk gy-purp, mica, occ sl carb, occ slty, occ sdy, frm, sub fss-fss Pres-dol; m-lt gy, lt tn, vf xln, suc, sl arg, frm Tr-Fos	1.37
4510÷4540	ctgs	50% sh; dk gy, m-dk gy, m-dk orng-rd, mica, occ sl carb, occ slty, frm, fss 50% dol; lt gy, lt tn, vf xln, suc, arg, frm Tr-anhy; wh, mass, frm	0.70

* TOC = Total Organic Carbon

Table 1 (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
4540-4570	ctgs	50% sh; dk gy, m-dk orng-rd, mica, occ sl carb, occ slty, occ anhy? incl, frm, mod fss-fss 50% dol; lt tn, lt gy, m gy-brn, vf xln, suc, arg, frm Tr-anhy; wh, mass, frm	0.28
4570-4600	ctgs	60% dol; lt gy, lt tn, m gy, vf xln, suc, frm 40% sh; dk gy, m-dk gy, dk orng-rd, mica, occ mic xln pyr, occ v sl carb, occ slty, frm, fss Tr-anhy; wh, m orng, occ mass, occ f xls, frm	0.32/0.29
4600-4630	ctgs	70% sh; dk gy, m-dk gy, m-dk orng-rd, mica, occ v sl carb, occ slty, frm, fss 30% dol; lt gy, lt tn, m gy, vf xln, suc, frm Tr-ss; lt gy, f gr, mod srtd, sub ang, frm; anhy; wh, m orng, occ mass, occ f xls, frm	0.61
4630-4660	ctgs	90% sh; dk gy, m-dk gy, m-dk orng-rd, mica, occ v sl carb, occ slty, occ anhy? incl, frm, mod fss-fss 10% dol; lt gy, lt tn, m gy, vf xln, suc, frm Pres-anhy; wh, mass, frm	0.73
4660-4690	ctgs	90% sh; dk gy, m-dk gy, m-dk orng-rd, mica, occ v sl carb, occ slty, occ anhy? incl, frm, mod fss-fss 10% dol; lt gy, lt tn, m gy, vf xln, suc, frm Pres-anhy; wh, m orng, occ mass, occ m xls, frm	0.59

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
4690-4720	ctgs	90% sh; dk gy, m-dk orng-rd, dk rd-brn, mica, occ v sl carb, frm, mod fss-fss 10% dol; v lt tn, mic-vf xln, suc, hd-frm Tr-sd; wh trnsl, lt tn op, c-vc gr, sub ang-sub rdd	0.89
4720-4750	ctgs	80% sh; dk gy, m-dk gy, m orng-rd, lt gy, mica, occ mic xln pyr, occ v sl carb, frm, fss 20% dol; lt tn, lt gy, m gy, vf xln, suc, hd-frm	0.59
4750-4780	ctgs	80% sh; dk gy, m-dk gy, m orng-rd, dk gy-purp, dk rd-brn, mica, occ sl slty, occ sl carb, frm, fss 20% dol; lt tn, lt gy, m gy, vf xln, suc, hd-frm	0.88
4780-4810	ctgs	60% sh; dk gy, m-dk gy, m orng-rd, dk gy-purp, dk rd-brn, mica, occ sl slty, occ sl carb, frm, fss 30% dol; lt tn, lt gy, m gy, vf xln, suc, hd-frm 10% sltst; m orng-rd, mica, occ sdy, frm Pres-sd; lt tn op, wh trnsl, c-vc gr, sub ang-sub rdd	0.54
4810-4840	ctgs	90% sh; dk gy, m-dk gy, m-dk orng-rd, lt gy, m gy-purp, dk rd-brn, mica, occ v sl slty, occ sl carb, frm, fbs 10% dol; lt tn, lt gy, m gy, vf xln, suc, hd-frm Pres-sltst; m orng-rd, mica, occ sdy, frm	0.80/0.77

* TOC = Total Organic Carbon

Table

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
4840-4870	ctgs	90% sh; dk gy, m-dk gy, m-dk orng-rd, lt gy, m gy-purp, dk rd-brn, mica, occ v sl slty, occ sl carb, frm, fss 10% sltst; m orng-rd, mica, frm Pres-dol; lt tn, lc gy, m gy, vf xln, suc, hd-frm	0.93
4870-4900	ctgs	90% sh; dk gy, m-dk gy, m gy-purp, mica, occ v sl carb, frm, mod fss-fss 10% sltst; m orng-rd, mica, frm Tr-dol; lt tn, lt gy, m gy, vf xln, suc, hd-frm; ls; lt tn, vf xln, frm	1.29
4900-4930	ctgs	Sh; dk gy, dk orng-rd, m gy-purp, mica, occ slty, occ v sl carb, frm, sub fss-fss Tr-dol; lt tn, vf-f xln, hd-frm	0.92
4930-4960	ctgs	Sh; dk gy, dk orng-rd, m gy-purp, mica, occ slty, occ v sl carb, frm, sub fss-fss Pres-dol; lt tn, vf-f xln, hd-frm Tr-ls; lt tn, wh, mic xln, hd	0.91
4960-4990	ctgs	60% sh; dk gy, dk orng-rd, m gy-purp, mica, occ slty, occ v sl carb, frm, sub fss-fss 40% ls; lt tn, wh, lt gy, mic-vf xln, occ chky, frm Tr-sltst; m-dk orng-rd, mica, occ sdy, frm	0.57
4990-5020	ctgs	70% sh; dk gy, dk orng-rd, m gy-purp, mica, occ slty, occ v sl carb, frm, sub fss-fss 30% ls; lt tn, wh, lt gy, mic-vf xln, occ chky, frm	0.67
5000-5030	ctgs	90% sh; dk rd-brn, dk gy, dk gy-purp, mica, occ slty, frm, mod fss-fss 10% qtz; wh trnsl, lt pk op, ang Tr-ls; lt tn, wh, lt gy, mic-vf xln, occ chky, frm	0.37

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
5020-5050	ctgs	70% sh; dk gy, dk orng-rd, dk rd-brn, lt gy, mica, occ sl slty, occ sl carb, frm, sub fss-fss 30% ls; lt gy, wh, mic-vf xln, occ chky, hd-frm Tr-sltst; m orng, mica, frm	0.81/0.73
5050-5080	ctgs	80% sh; dk gy, dk orng-rd, dk rd-brn, lt gy, mica, occ sl slty, occ sl carb, frm, sub fss-fss 20% ls; lt gy, wh, mic-vf xln, occ chky, hd-frm Pres-sltst; m orng, mica, occ sdy, frm	0.98
5080-5110	ctgs	Sh; dk gy, dk orng-rd, dk gy-purp, lt gy-gn, mica, occ sl slty, occ v sl carb, frm, blky-fss Pres-ls; lt gy, wh, mic-vf xln, occ chky, hd-frm; sltst; m orng, mica, occ sdy, frm	0.64
5110-5140	ctgs	70% sh; dk gy, dk orng-rd, dk gy-purp, lt gy-gn, mica, occ sl slty, occ v sl carb, frm, blky-fss 30% ls; lt tn, lt pk, wh, mic-vf xln, occ chky, hd-frm	0.76
5140-5170	ctgs	90% sh; dk gy, dk gy-purp, dk orng-rd, mica, occ sl slty, occ v sl carb, frm, sub fss-fss 10% ls; lt tn, lt pk, wh, mic-vf xln, occ chky, hd-frm Pres-sltst; dk orng-rd, mica, hd-frm	1.21
5170-5200	ctgs	80% sh; dk gy, dk orng-rd, mica, occ sl slty, occ v sl carb, frm, mod fss-fss 20% ls; lt tn, lt pk, wh, mic-vf xln, occ chky, hd-frm	1.28

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
5200-5230	ctgs	80% sh; dk gy, dk rd-brn, lt gy-gn, occ sl slty, occ sl carb, frm, sub fss-fss 20% ls; lt tn, mic xln, hd-frm	1.15
5230-5260	ctgs	70% sh; dk gy, dk rd-orng, lt gy-gn, m gy-purp, mica, occ sl slty, occ v sl carb, frm, sub fss-fss 30% ls; lt tn, m purp, wh, mic-vf xln, hd-frm	0.76
5260-5290	ctgs	90% sh; dk gy, dk rd-orng, lt gy-gn, m gy-purp, mica, occ sl slty, occ v sl carb, frm, sub fss-fss 10% ls; lt tn, m purp, wh, mic-vf xln, hd-frm	0.69/0.72
5290-5320	ctgs	Sh; dk gy, m-dk gy, dk rd-orng, mica, occ sl slty, occ sl calc, occ v sl carb, frm, blky-fss Tr-sltst; m orng, mica, hd-frm; dol; lt gy-gn, mic xln, frm	2.03
5320-5350	ctgs	Sh; dk gy, dk rd-orng, m gy-purp, lt gy-gn, mica, occ v sl calc, occ slty, occ v sl carb, frm, sub fss-fss Pres-ls; lt gy, lt tn, mic xln, hd Tr-dol; lt gy-gn, mic xln, frm	1.37
5350-5380	ctgs	Sh; dk gy, dk rd-orng, m gy-purp, lt gy-gn, mica, occ v sl calc, occ slty, occ v sl carb, frm, sub fss-fss Pres-sltst; m orng, mica, hd-frm,	0.68

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
5380-5410	ctgs	80% sh; dk gy, dk rd-orng, m gy-purp, lt gy-gn, mica, occ v sl calc, occ slty, occ v sl carb, frm, sub fbs-fss 10% ls; lt tn, m purp, m pk, mic-vf xln, hd-frm 10% sltst; m orng, mica, hd-frm,	0.56
5410-5440	ctgs	Sh; dk rd-orng, dk gy, dk gy-purp, lt gy, occ mica, occ sl slty, occ calc, occ v sl carb, frm, blky-fss Pres-qtz; wh, lt orng, ang Tr-ls; lt gy-gn, m pk, lt pk, mic xln, hd-frm; sltst; m orng, mica, hd-frm,	0.34
5440-5470	ctgs	Sh; dk gy, dk rd-orng, m-dk gy-purp, occ mot, mica, occ sl slty, occ sl calc, occ v sl carb, frm, mod fss-fss Tr-ls; lt gy-gn, m pk, lt pk, mic xln, hd-frm	1.02
5470-5500	ctgs	Sh; dk gy, dk rd-orng, m-dk gy-purp, occ mot, mica, occ sl slty, occ sl calc, occ v sl carb, frm, mod fss-fss Pres-qtz; wh, lt orng, ang Tr-ls; lt tn, lt gy, mic xln, hd-frm; ss; wh, vf-f gr, mod srtd, sub ang-sub rdd, frm-fri	0.49

* TOC = Total Organic Carbon

Table 11

Results of C_{15+} Extractable Organic Matter (EOM) Analysis

Depth (ft)	Sample Type	TOC (wt %)	EOM (ppm)	HC (ppm)	Composition of C_{15+} Extractable Organic Matter (Normalized Percent) F-1	F-2	F-3	CPI
4150-4240	ctgs	0.68*	570	205	26.5	14.7	58.8	1.22
4240-4510	ctgs	0.70*	521	141	33.3	9.9	56.8	1.17
4600-4690	ctgs	0.47*	526	119	25.4	10.2	64.4	1.30
4750-4840	ctgs	0.61*	468	46	16.2	2.7	81.1	1.25
4870-4960	ctgs	0.60*	257	57	20.7	6.9	72.4	1.21
5020-5110	ctgs	0.50*	312	65	15.8	10.5	73.7	1.20
5140-5230	ctgs	0.70*	327	44	10.7	7.1	82.1	1.21
5290-5350	ctgs	0.95*	326	48	11.5	7.7	80.8	1.20

* TOC on composite sample

TOC = Total Organic Carbon; EOM = Extractable Organic Matter (C_{15+}); HC = C_{15+} Hydrocarbons (saturates + aromatics); CPI = Carbon Preference Index (C_{24}-C_{34} carbon number range); F-1 = saturates; F-2 = aromatics; F-3 = asphaltics

Table III

Geochemical Ratios

Depth (ft)	$\frac{EOM}{TOC} \times 100$	$\frac{HC}{TOC} \times 100$	$\frac{HC}{EOM} \times 100$
4150-4140	8.4	3.0	36.0
4240-4510	7.4	2.0	27.1
4600-4690	11.2	2.5	22.6
4750-4840	7.7	0.8	9.8
4870-4960	4.3	1.0	22.2
5020-5110	6.2	0.5	7.4
5140-5230	4.7	0.6	13.5
5290-5350	3.4	0.5	14.7

TOC = Total Organic Carbon (ppm); EOM = C_{15+} Extractable Organic Matter (ppm); HC = C_{15+} Hydrocarbons (ppm)

Table IV

VISUAL KEROGEN OBSERVATIONS

DATE APRIL 30, 1981
WELL #1 McCONAUGHY
S.B.E.
JOB NO. 80211

THERMAL ALTERATION INDEX: 1 UNALTERED; 1+; 2 SLIGHT ALTERATION; 2+; 3 MODERATE ALTERATION; 3+; 4 STRONG ALTERATION; 4+; 5 SEVERE ALTERATION

COLOR: BRILLIANT YELLOW; YELLOW; YELLOW-ORANGE; ORANGE-BROWN; LIGHT-BROWN; BROWN; DARK-BROWN; BLACK

KEROGEN TYPE: ALGAL DEBRIS; AMORPHOUS DEBRIS; FINELY DISPERSED O.M.; WOOD PLANT DEBRIS; WOODY PLANT DEBRIS; COALY FRAGMENTS; PALYNOMORPHS

SPORINITE FLUORESCENCE COLOR: BRILLIANT YELLOW; YELLOW; YELLOW-ORANGE; ORANGE; BROWN; BLACK

PRES: GOOD; FAIR; POOR; VERY POOR RECOVERY; BARREN OR O.M.

X = >50%
/ = SECONDARY
* = 5-20%
T = TRACE

DENVER BASIN STUDY

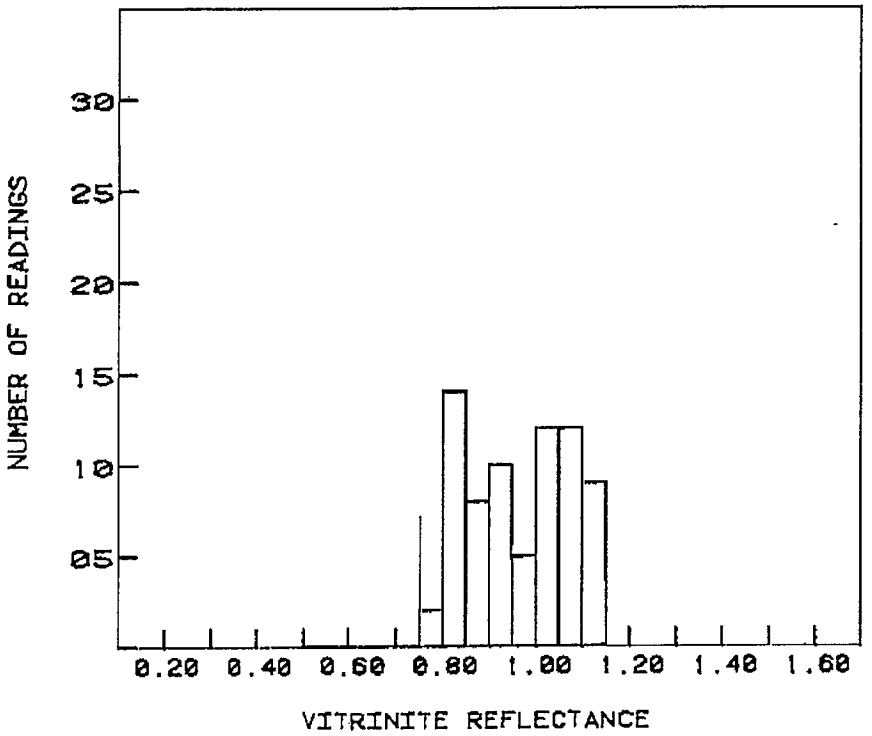
#1 McCONAUGHY

DEPTH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	REMARKS
4240-4510																X								X				/				*	X	T						T				X				
4600-4690																X								X				X	T			/	*	T						T				X				
4870-4960																X								X				X	T			/	*	T						T				X				
5290-5350																X								X				X				*	/	T						T				X				

DEMSHUR AFTER BURGESS (77)

Table V

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

#1 McCONAUGHY

DEPTH: 4240-4510

MEAN REF.: 0.97%

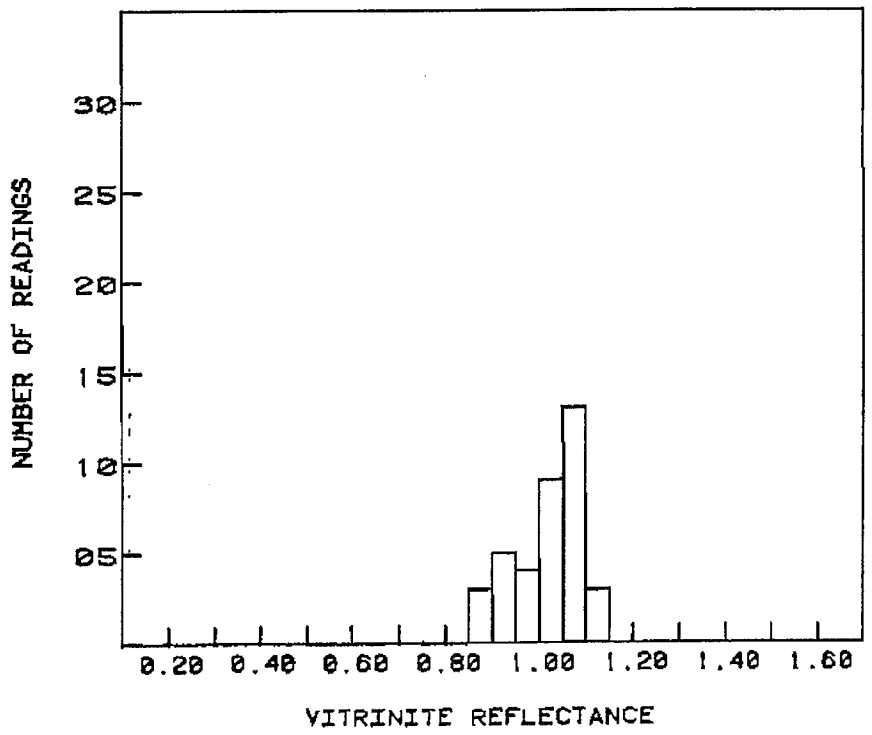
MAX. REF.: 1.13%

MIN. REF.: 0.78%

READINGS: 71

SAMPLE: CUTTINGS

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

#1 McCONAUGHY

DEPTH: 4600-4690

MEAN REF.: 1.01%

MAX. REF.: 1.11%

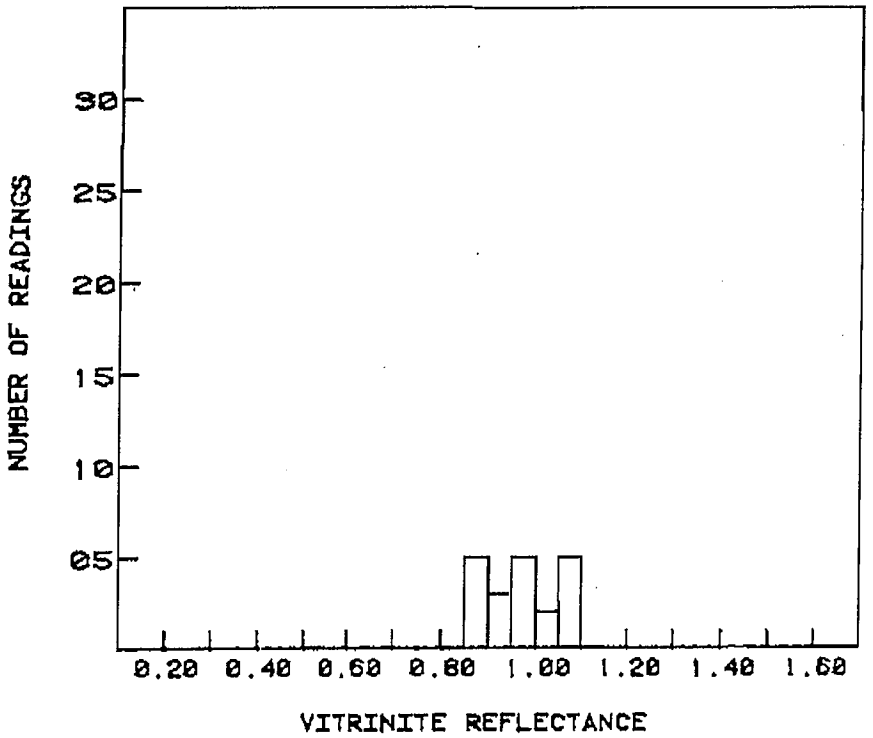
MIN. REF.: 0.87%

READINGS: 37

SAMPLE: CUTTINGS

Table V (cont.)

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

#1 McCONAUGHY

DEPTH: 4870-4960

MEAN REF.: 1.01%

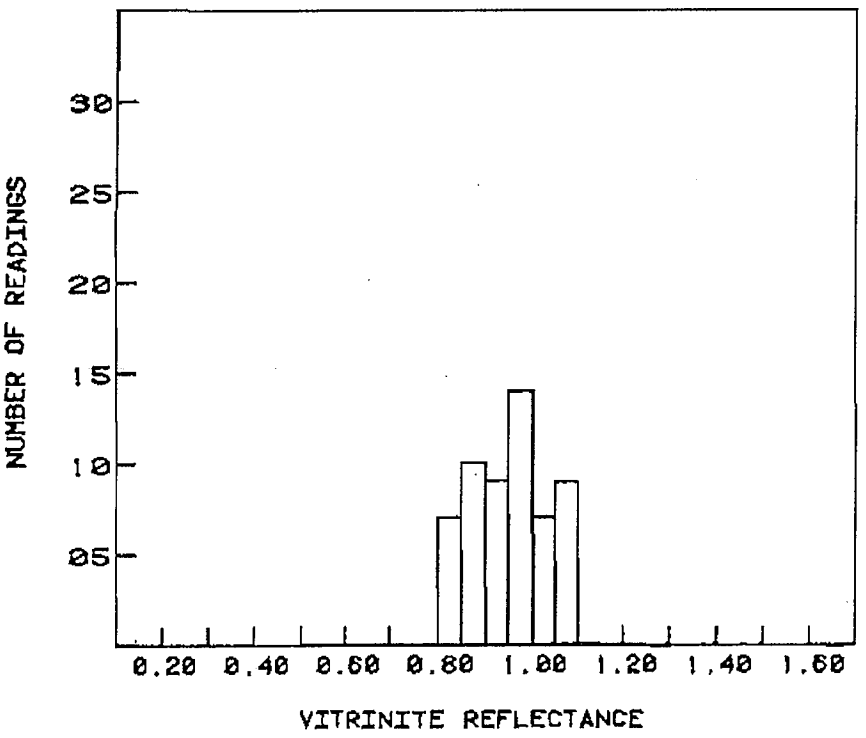
MAX. REF.: 1.09%

MIN. REF.: 0.85%

READINGS: 20

SAMPLE: CUTTINGS

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

#1 McCONAUGHY

DEPTH: 5290-5350

MEAN REF.: 0.95%

MAX. REF.: 1.09%

MIN. REF.: 0.82%

READINGS: 56

SAMPLE: CUTTINGS

Table VI

Elemental Analysis

Depth (ft)	Hydrogen:Carbon Ratio (H/C)
4240-4510	0.73
4600-4690	0.81
4870-4960	0.83
5290-5350	0.86

Table VII

Normalized n-Paraffin Distribution

	4150-4240	4240-4510	4600-4690	4750-4840
C_{15}	24.2	23.8	15.2	19.3
C_{16}	19.6	17.9	18.3	18.0
C_{17}	13.0	12.8	18.5	15.2
Pristane	5.6	6.1	8.5	7.6
C_{18}	6.9	7.2	13.0	9.4
Phytane	3.2	3.5	4.7	3.9
C_{19}	4.5	4.8	7.4	5.3
C_{20}	3.2	3.3	3.8	3.1
C_{21}	2.5	2.7	2.2	2.3
C_{22}	2.5	2.4	1.5	2.0
C_{23}	2.6	2.5	1.2	2.0
C_{24}	2.3	2.2	0.9	1.7
C_{25}	2.1	2.0	0.9	1.7
C_{26}	1.7	1.6	0.7	1.5
C_{27}	1.6	1.6	0.7	1.6
C_{28}	1.0	1.1	0.5	1.0
C_{29}	1.1	1.2	0.6	1.3
C_{30}	0.7	0.9	0.4	0.8
C_{31}	0.7	0.9	0.4	0.9
C_{32}	0.4	0.6	0.2	0.6
C_{33}	0.4	0.6	0.3	0.5
C_{34}	0.2	0.3	0.1	0.3
Pristane/Phytane	1.75	1.74	1.81	1.95
CPI	1.22	1.19	1.30	1.25

Table VII (cont.)

Normalized n-Paraffin Distribution

	4870-4960	5020-5110	5140-5230	5290-5350
C_{15}	18.7	18.5	23.3	26.0
C_{16}	18.2	18.4	20.7	20.9
C_{17}	16.4	15.9	15.5	15.0
Pristane	8.0	7.7	7.8	6.9
C_{18}	10.8	9.6	8.4	7.7
Phytane	4.4	4.1	3.9	3.2
C_{19}	6.1	5.1	4.4	3.8
C_{20}	3.4	2.9	2.6	2.3
C_{21}	2.2	2.1	2.0	1.6
C_{22}	1.9	1.9	1.9	1.8
C_{23}	1.7	2.1	1.8	1.6
C_{24}	1.4	2.0	1.5	1.5
C_{25}	1.2	1.8	1.3	1.4
C_{26}	1.0	1.5	1.0	1.1
C_{27}	1.0	1.5	0.9	1.1
C_{28}	0.7	1.1	0.7	0.8
C_{29}	0.8	1.1	0.7	0.9
C_{30}	0.5	0.7	0.4	0.7
C_{31}	0.6	0.8	0.5	0.7
C_{32}	0.4	0.5	0.3	0.4
C_{33}	0.4	0.5	0.3	0.4
C_{34}	0.2	0.2	0.1	0.2
Pristane/Phytane	1.82	1.88	2.00	2.16
CPI	1.21	1.20	1.21	1.20

Table VIII

Normalized Isoprenoid Distribution

	4150-4240	4240-4510	4600-4690	4750-4840
Ip13	2.7	4.6		2.2
Ip14	5.0	10.3	1.5	4.5
Ip15	13.6	18.0	5.6	12.1
Ip16	30.0	27.3	16.3	24.3
Ip18	15.4	11.6	21.7	17.2
Pristane	21.3	17.9	35.3	26.2
Phytane	12.0	10.3	19.6	13.5

Table VIII (cont.)

Normalized Isoprenoid Distribution

	4870-4960	5020-5110	5140-5230	5290-5350
Ip13	2.1	2.0	2.8	4.2
Ip14	4.0	3.9	5.3	7.3
Ip15	11.2	10.7	13.2	17.1
Ip16	22.5	22.9	26.5	28.3
Ip18	17.8	18.2	15.9	13.7
Pristane	27.4	27.7	24.3	20.2
Phytane	15.0	14.6	12.0	9.2

FIGURE 5

McConaughy #1

C_{10+} Saturated Hydrocarbon Fraction

4150-4240 feet

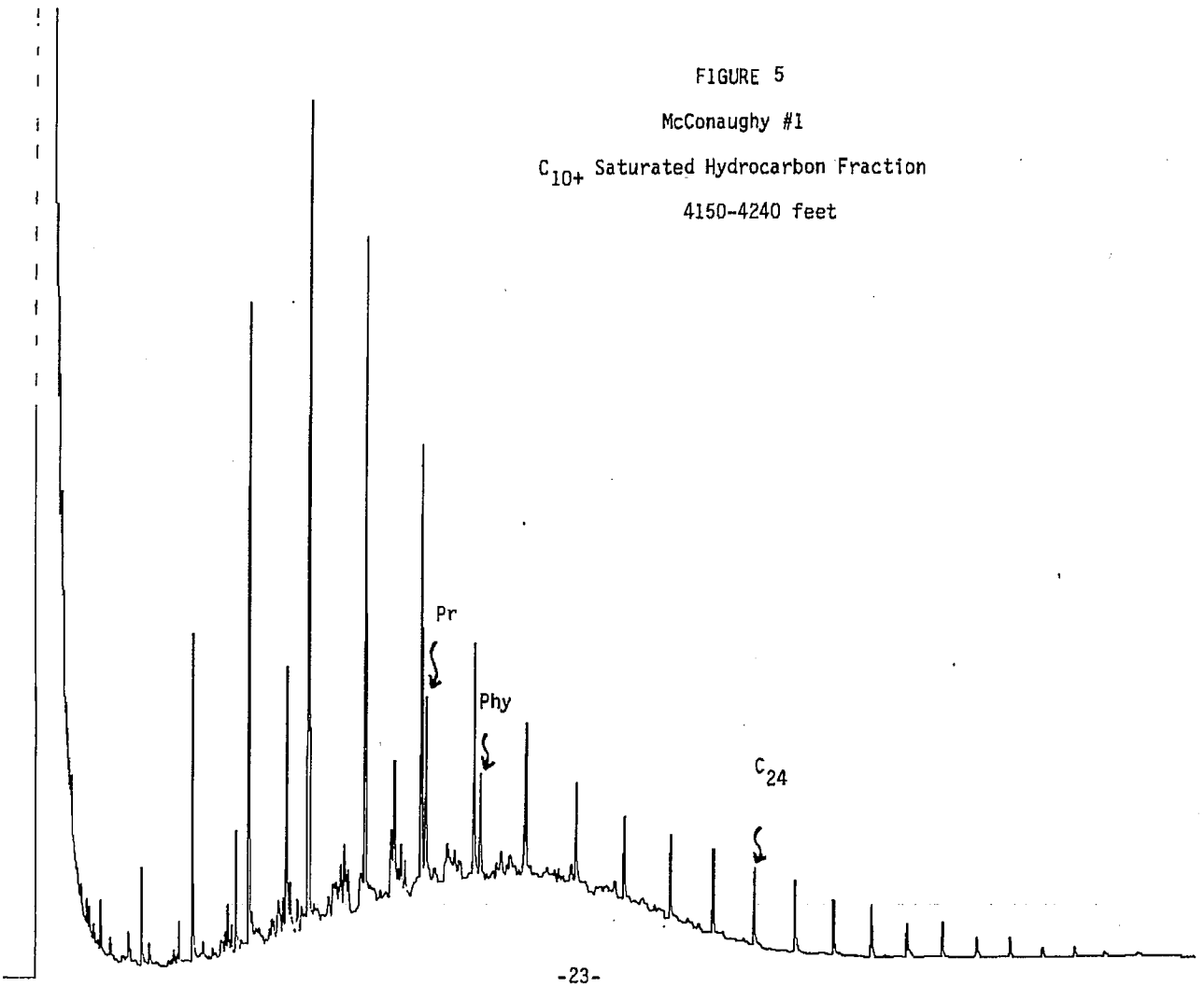
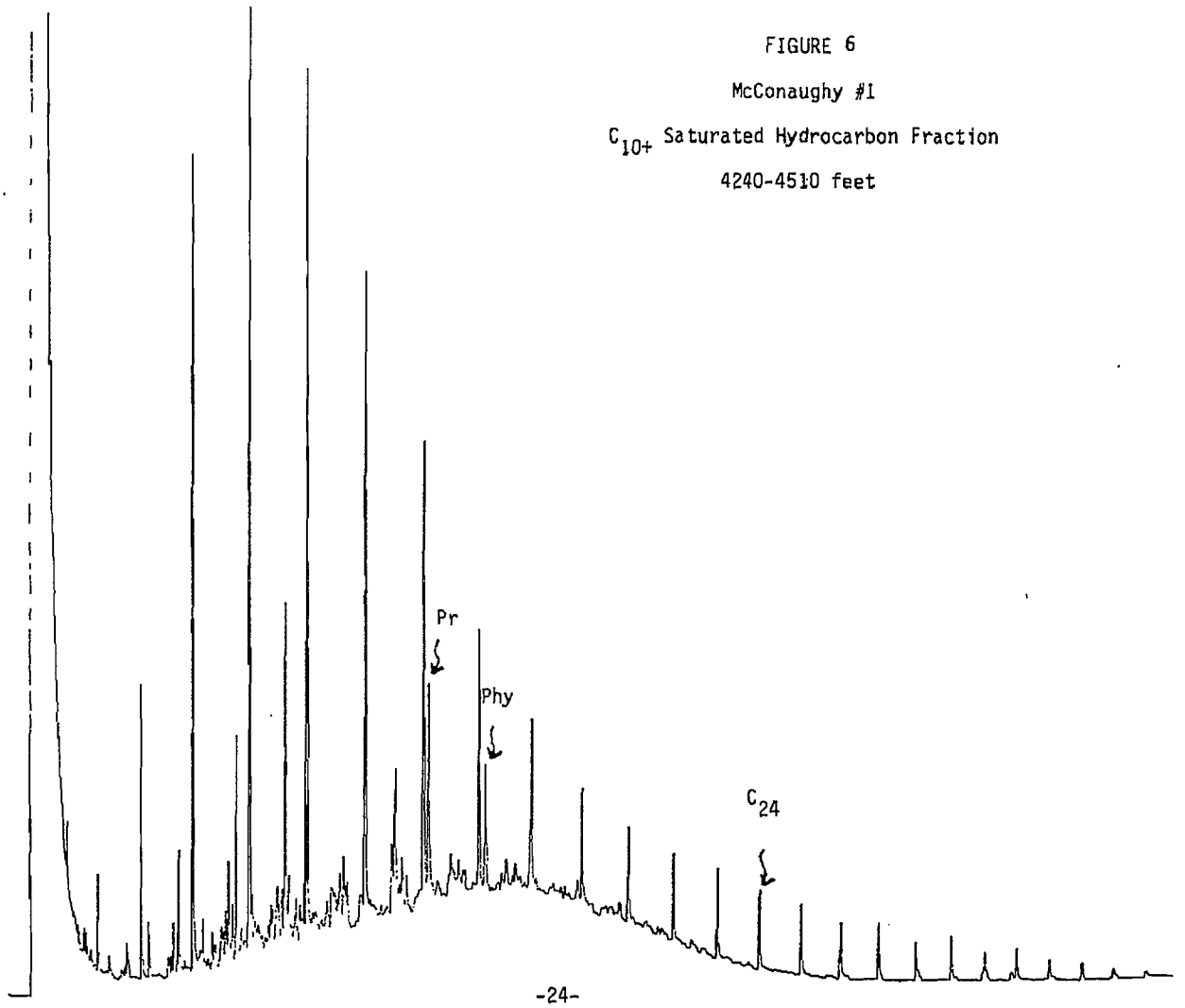


FIGURE 6

McConaughy #1

C_{10+} Saturated Hydrocarbon Fraction

4240-4510 feet



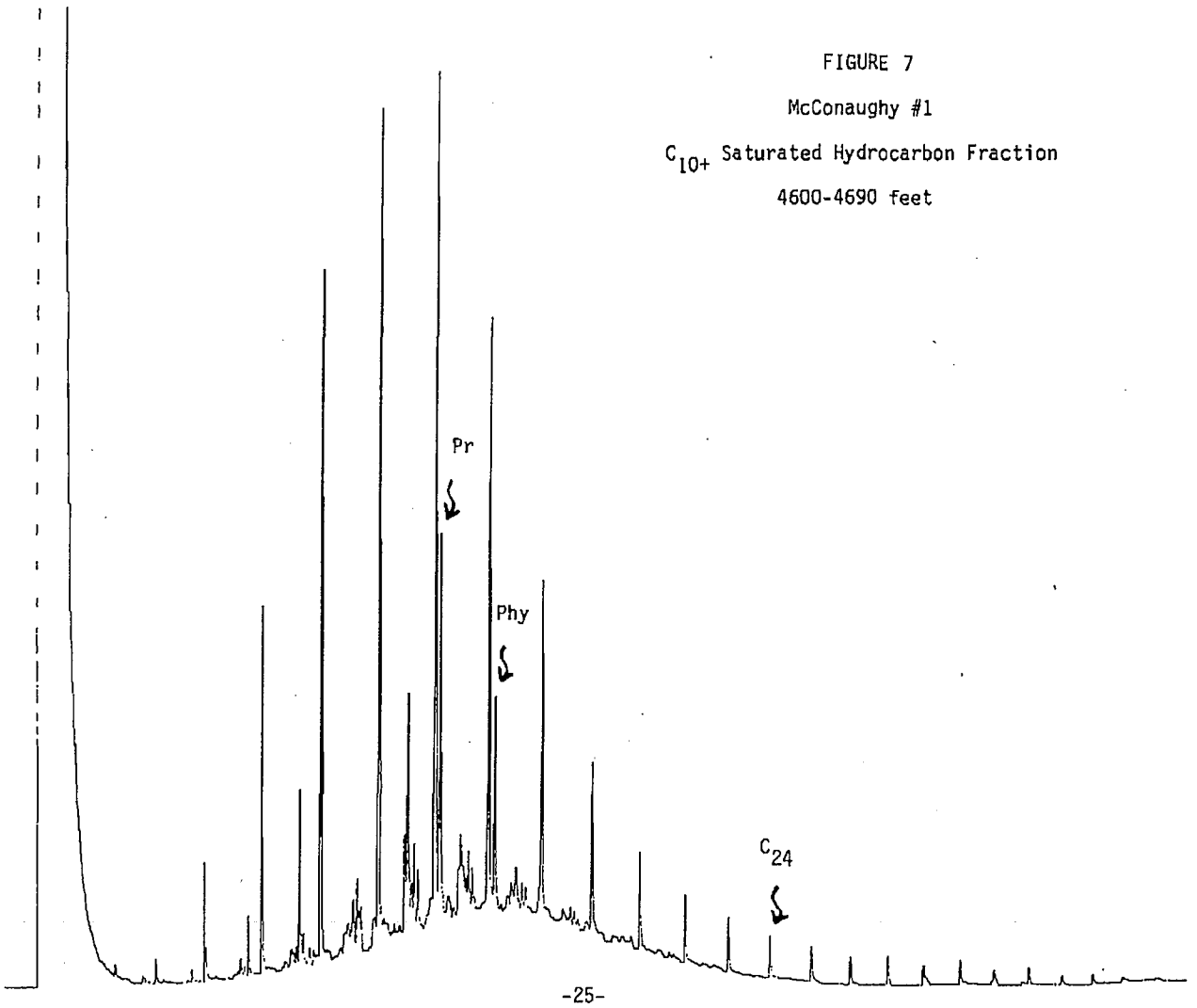


FIGURE 7

McConaughy #1

C_{10+} Saturated Hydrocarbon Fraction

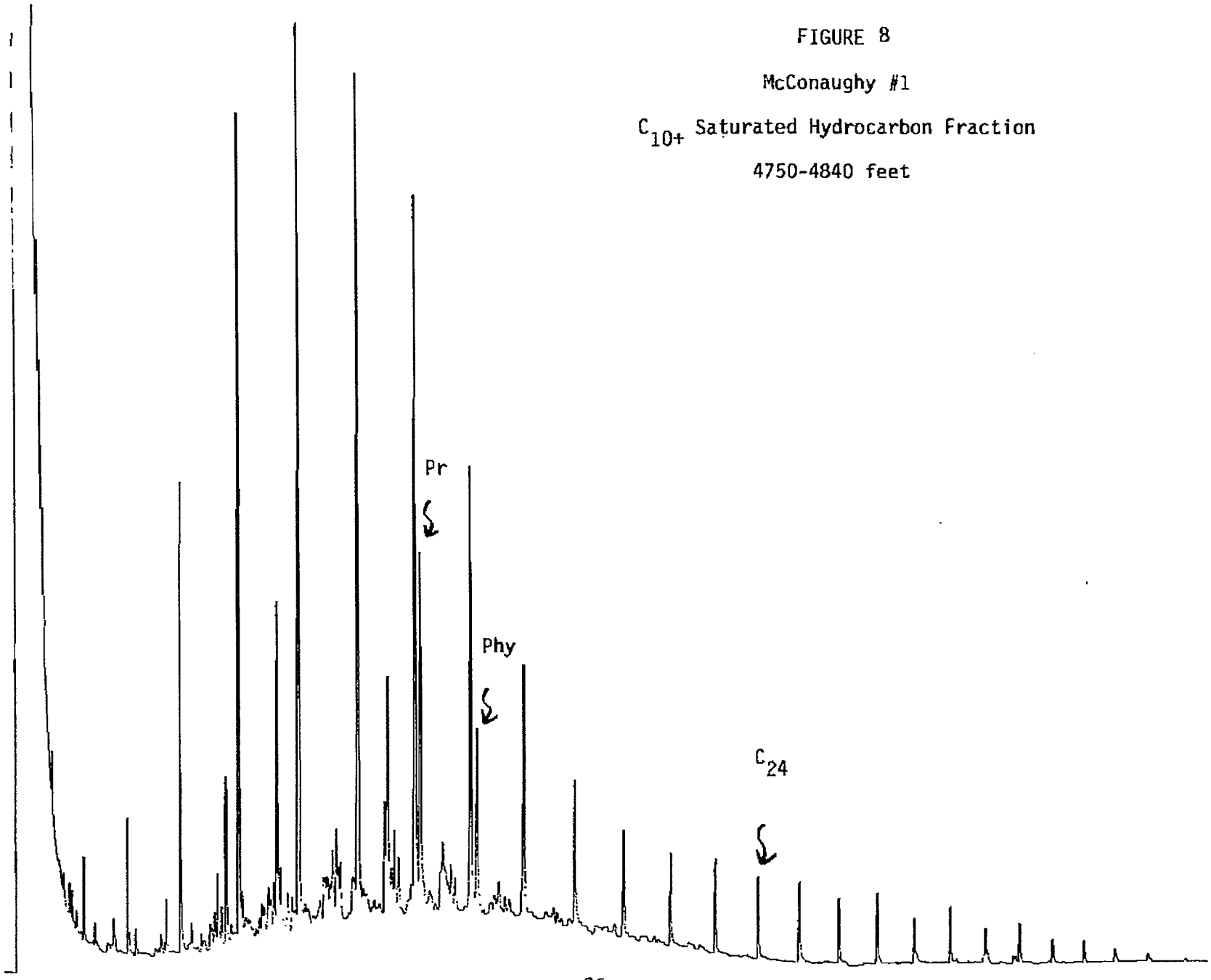
4600-4690 feet

FIGURE 8

McConaughy #1

C_{10+} Saturated Hydrocarbon Fraction

4750-4840 feet



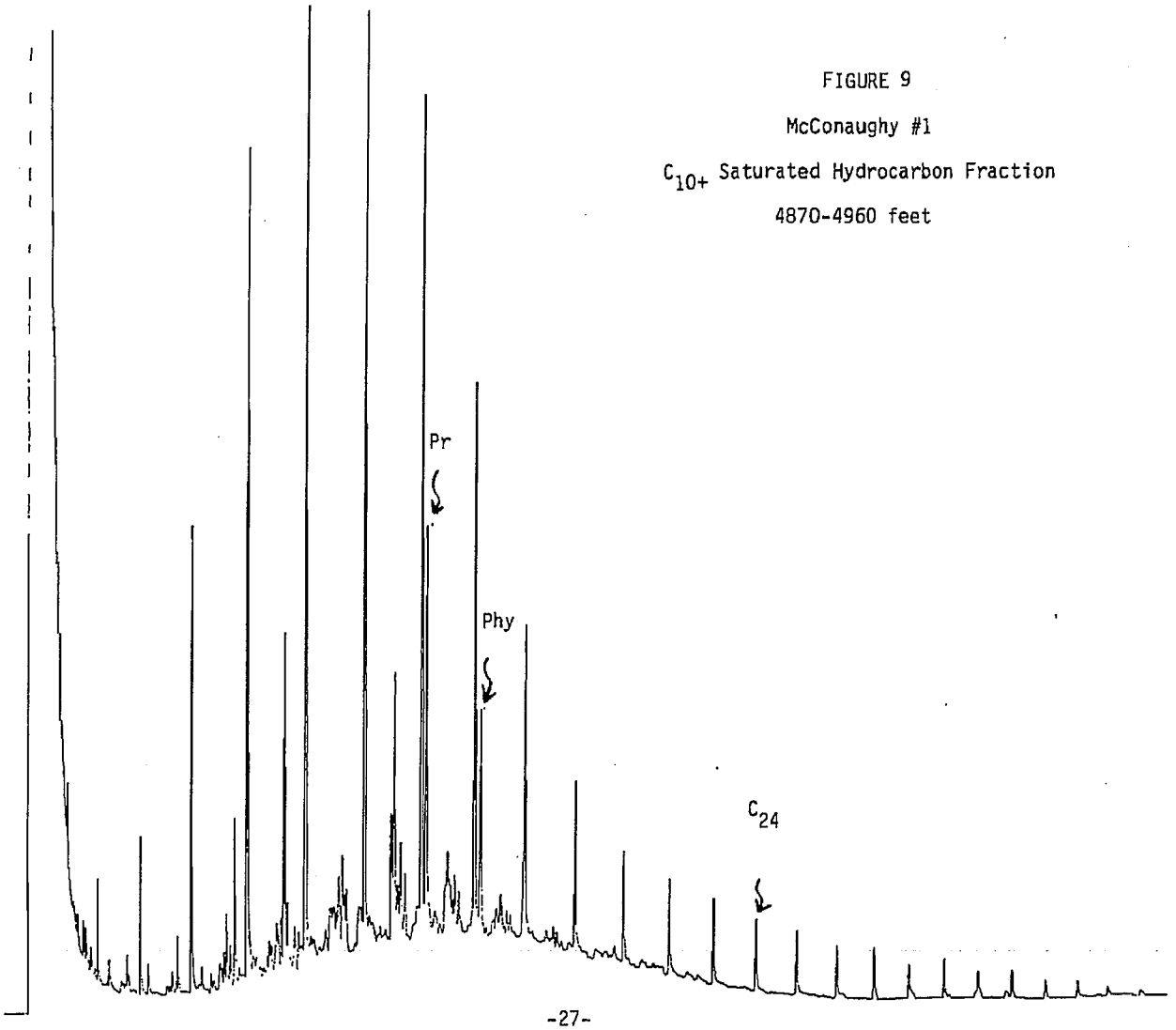


FIGURE 9

McConaughy #1

C_{10+} Saturated Hydrocarbon Fraction

4870-4960 feet

FIGURE 10

McConaughy #1

C_{10+} Saturated Hydrocarbon Fraction

5020-5110 feet

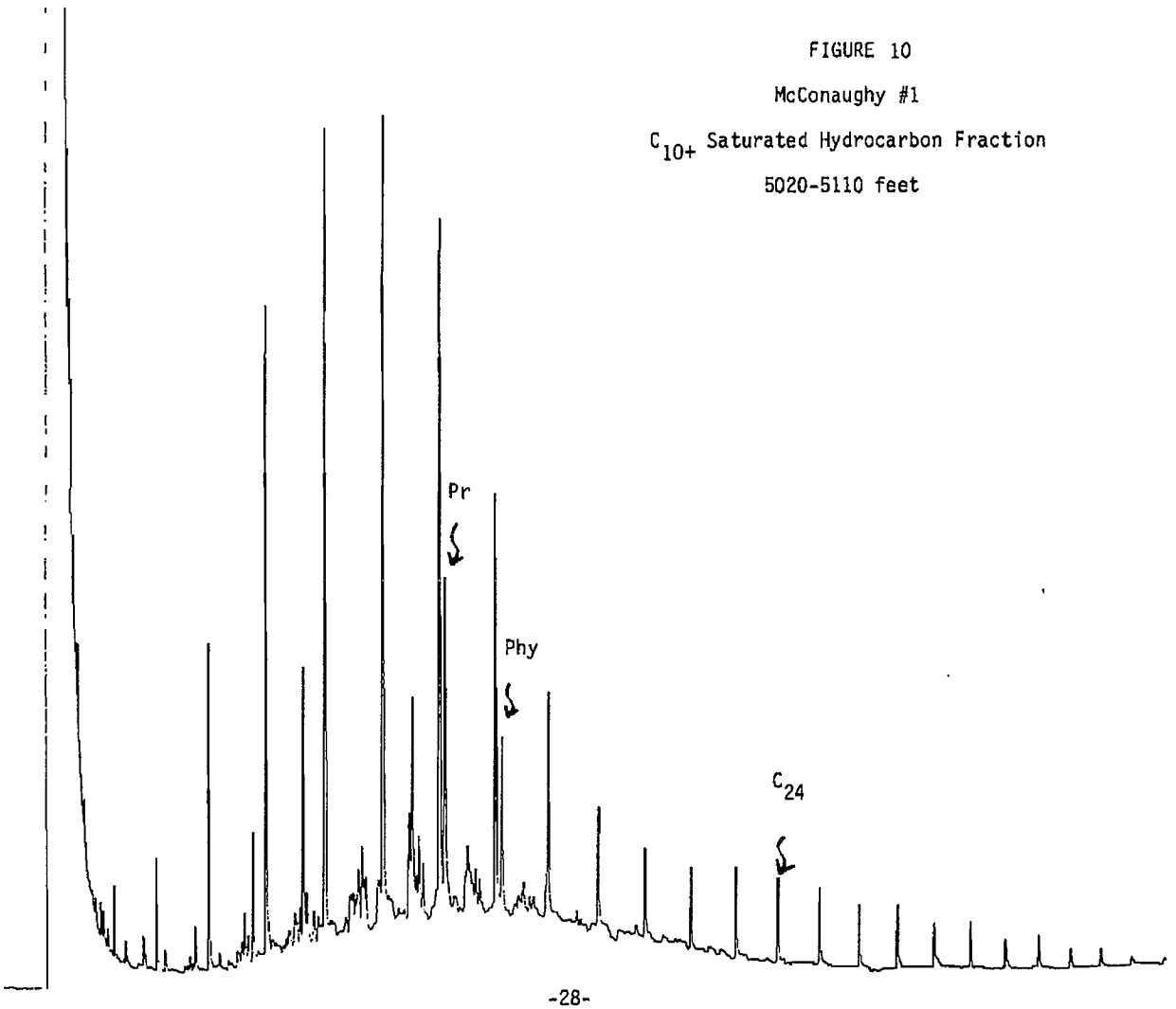


FIGURE 11

McConaughy #1

C_{10+} Saturated Hydrocarbon Fraction

5140-5230 feet

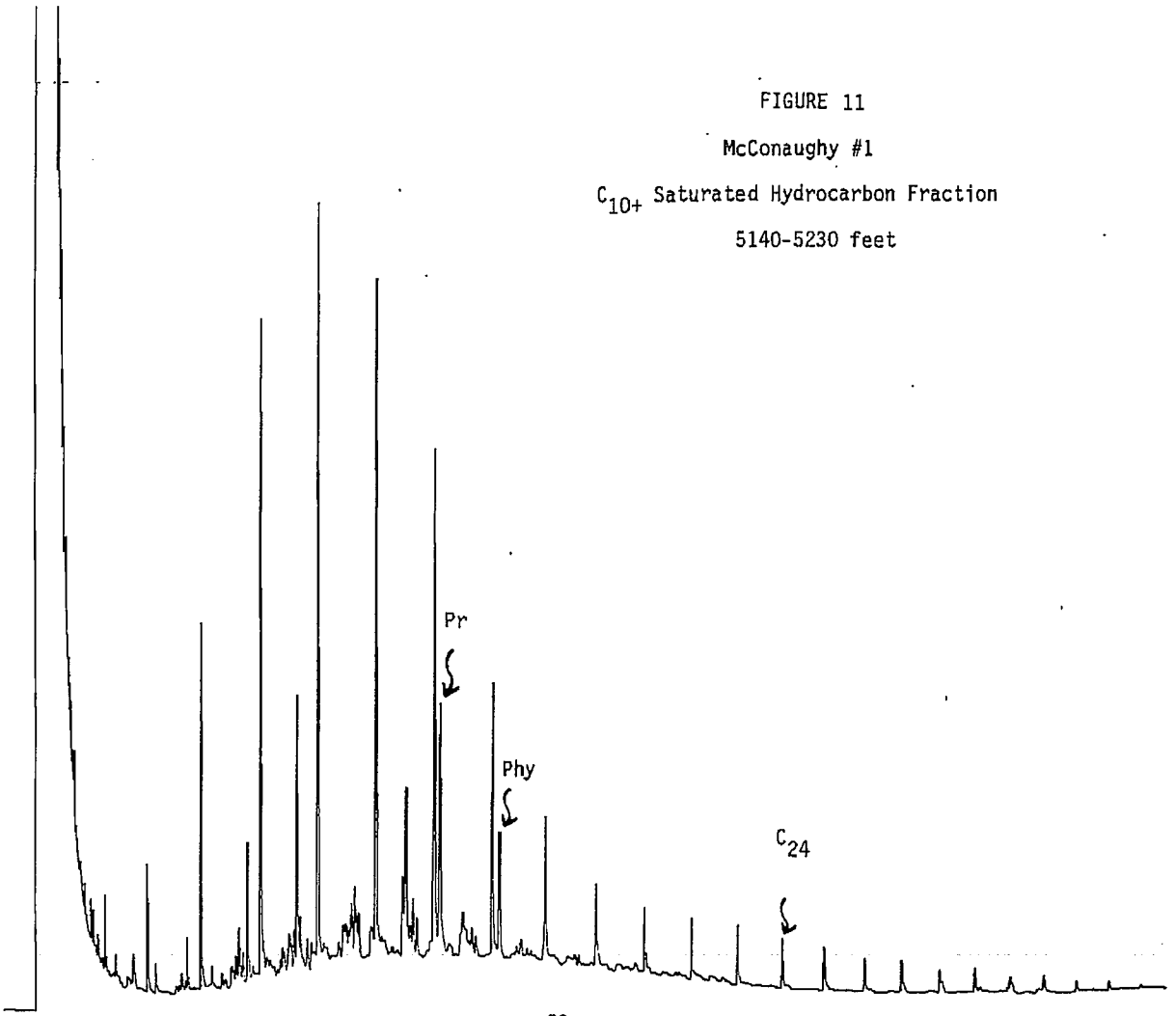
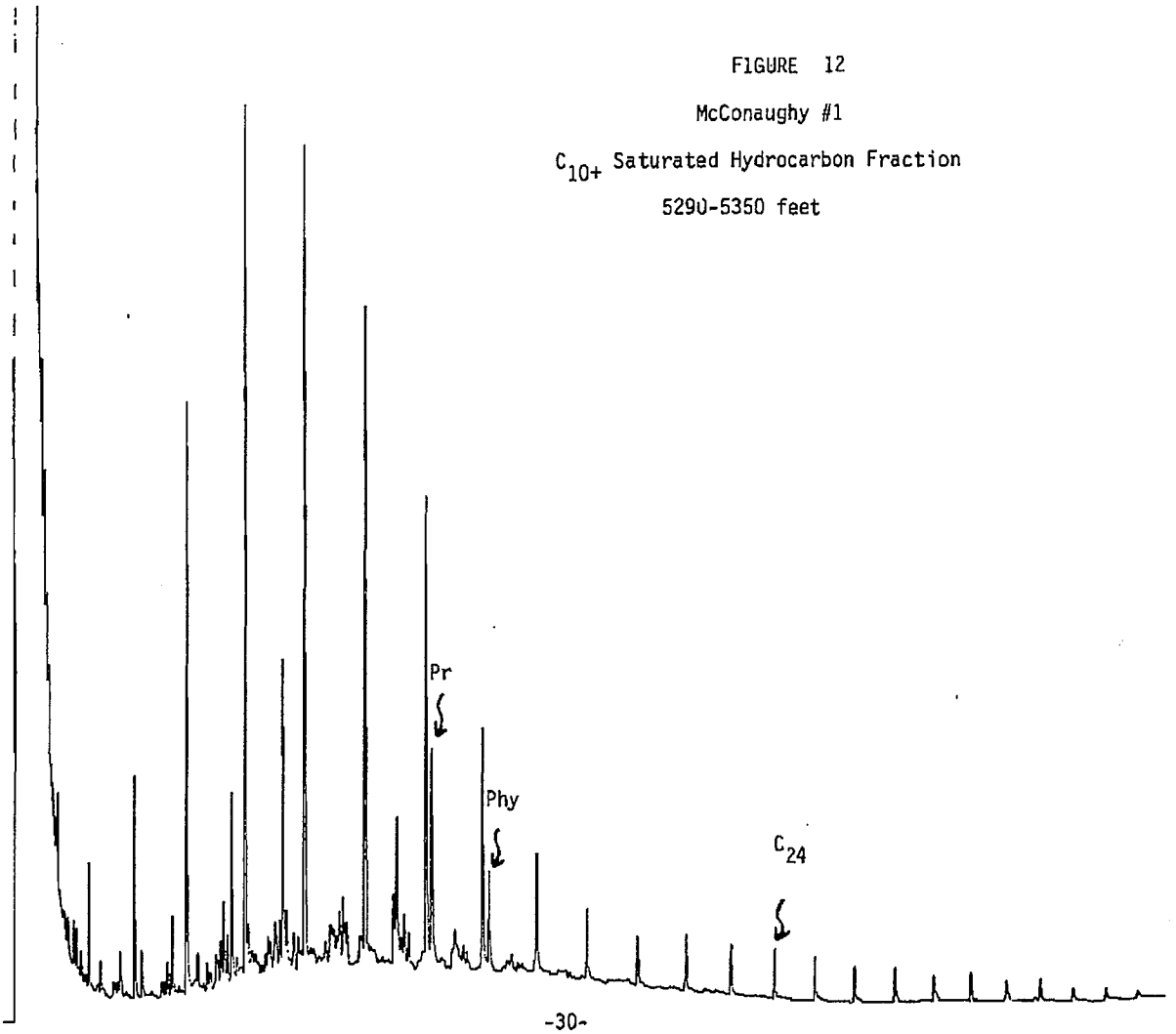


FIGURE 12

McConaughy #1

C_{10+} Saturated Hydrocarbon Fraction

5290-5350 feet



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2

FILE - WELL FILE
DG

Duplicate

Bio Study #962

OIL/SOURCE-ROCK STUDY
NORTHERN DENVER BASIN - PALEOZOIC
REPORT NO. 2

2

SHELL/SCHNEIDER #2
26-15N-56W, KIMBALL CO., NEBRASKA

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I. SUMMARY

The Paleozoic sedimentary section from 6990 to 8120 feet in the Shell Schneider #2 well, 26-15N-56W, Kimball County, Nebraska was analyzed for hydrocarbon source-rock potential. Thirty-eight (38) cuttings samples, composed of shales, coarse-grained clastics and carbonates, were analyzed. Lithologic tops provided by Shell were used to divide the Permian and Pennsylvanian sections into time stratigraphic units.

Guadalupian rocks (6992-7386 feet) are dominated by dark-gray shales which have fair source potential. These rocks are probably in the early stages of oil generation and deeper burial is required to reach optimum thermal maturity. In general, Leonardian rocks (7386-7590 feet) are dominated by coarse-grained, organic-lean lithologies with little or no source potential. Wolfcampian (7590-8017 feet) and Virgilian (8017-8170 feet) rocks have thin intervals with fair potential to generate hydrocarbons. Missourian (8170 feet), Desmoinesian (8323 feet), Atokan, Morrowan (8620 feet) and Precambrian rocks (8837 feet) were penetrated in this well, but samples were not available for analysis.

Migrated hydrocarbons were detected in the Wolfcampian at 7980-8000 feet. These hydrocarbons do not appear to have originated from potential source rocks in this well.

II. INTRODUCTION

Core Laboratories', Inc. geochemical study will determine the regional hydrocarbon source potential of the Permian and Pennsylvanian sections in the northern Denver basin. In addition, nine Permian and Pennsylvanian oils will be characterized to determine oil to oil and oil to source correlations. Fourteen (14) individual preliminary well reports and a crude oil correlation study will form the basis for our regional interpretation. These geochemical data from individual reports will be integrated into a geologic framework for the final report.

The Shell Schneider #2 is located in Kimball County, Nebraska (26-15N-56W). Permian through Precambrian rocks were penetrated from 6992 to 8837 feet. A total of thirty-eight (38) samples from 6992 to 8120 feet were analyzed for organic richness, kerogen type and thermal maturity. Samples from 8120 to 8837 feet were not available for analysis. Analytical techniques include measurement of total organic carbon, soxhlet extraction, liquid chromatographic separation of the extract on a silica gel column, and high resolution gas chromatography of the C_{10+} saturated hydrocarbon fraction performed on a glass capillary column. In addition, the insoluble organic matter (kerogen) was studied by transmitted and fluorescent light microscopy, vitrinite reflectance and elemental analysis.

Our report is organized in three parts: 1) Interpretation, 2) Graphical Displays and 3) Analytical Data. The Interpretation contains the written text of the report. This includes our conclusions stated in a Summary which precedes this Introduction. Following this Introduction is a more detailed Discussion of Results which provides an evaluation of the hydrocarbon source potential of the sedimentary section penetrated by the Shell Schneider #2 well. This is followed by the description of our standard Analytical Procedures. The second part of the report contains Graphical Displays of the geochemical data. Figure 1 shows a graphical summary of the geochemical data. Figure 2 shows lithology and total organic carbon content. The soluble organic matter is characterized in Figure 3. Figure 4 shows kerogen type and thermal maturity levels. The third section of the report contains the Analytical Data. Table I gives lithologic descriptions and total organic carbon content. Table II lists

concentrations and compositions of the extractable organic matter. Significant geochemical ratios are listed in Table III. Tables IV and V contain data on kerogen observations and vitrinite reflectance measurements, respectively. Table VI shows elemental hydrogen to carbon ratios for the kerogen. Table VII lists normalized n-paraffin distributions for the C_{15+} saturated hydrocarbons and Table VIII lists the normalized isoprenoid distributions. Figures 5 through 11 are gas chromatograms of the C_{10+} saturated hydrocarbon distributions.

III. DISCUSSION OF RESULTS

Guadalupian 6992-7386 feet

The thirteen (13) Guadalupian age cuttings samples consist primarily of gray shales with minor intervals of carbonates and sandstones. These intervals contain an average of 0.95% total organic carbon and have fair hydrocarbon source potential. Guadalupian intervals from the Schneider #2 well contain potential oil-generating amorphous organic matter with also the presence of significant quantities of woody and coaly kerogen. The elemental hydrogen to carbon ratio for sample 7230-7260 feet is 0.90 indicating some potential to generate liquid hydrocarbons. These sediments are in the early stages of petroleum generation based on a thermal alteration index of 2+ and a 0.88% mean vitrinite reflectance measurement. Deeper burial and associated higher temperatures are required for this interval to reach optimum maturity and maximum hydrocarbon generation.

Concentrations of extractable organic matter for Guadalupian intervals are below those usually associated with good petroleum source rock facies. Gas chromatograms of the saturated hydrocarbon fraction generally show the characteristics of marginally mature sediments. Carbon preference indices average 1.14 and indicate higher temperatures are required for Guadalupian intervals to reach the main stage of oil generation.

Leonardian 7386-7590 feet

In general, the Leonardian cuttings samples analyzed are composed of organic-lean red shales, siltstones and sandstones with no hydrocarbon source potential. Two intervals containing gray shales, however, 7420-7440 and 7480-7500 feet contain sufficient total organic carbon for fair hydrocarbon source potential.

Extractable organic matter concentrations for Leonardian intervals are below those required for favorable liquid hydrocarbon source rock facies. Saturated hydrocarbon distributions are similar to those of Guadalupian rocks and indicate deeper burial and associated higher temperatures are required before these intervals reach optimum maturity.

Wolfcampian 7590-8017 feet

The upper Wolfcampian rocks, 7600-7680 feet, are composed of gray shales while carbonates dominate the lithologies below 7700 feet. The fourteen (14) cuttings samples analyzed contain an average of 0.59% total organic carbon and have fair potential to generate petroleum hydrocarbons. These shales and limestones are dominated by oil-prone amorphous organic matter with some quantities of hydrogen-deficient woody and coaly kerogen. The elemental hydrogen to carbon ratio for sample 7630-7650 feet is 0.85 indicating only minor oil generating potential. Wolfcampian rocks are probably in the main stage of petroleum generation based on a thermal alteration index of 2+ and a 0.97% vitrinite reflectance measurement.

Concentrations of extractable organic matter and associated total hydrocarbons for intervals from 7660 to 7940 feet are below those necessary for good petroleum source facies. These low levels may be due to the presence of significant quantities of low-yielding woody and coaly kerogen. One sample from 7980 to 8000 feet contains 1874 ppm extractable organic matter. The extractability (EOM/TOC x 100) ratio, however, is 24.0 indicating the presence of non-indigenous migrated hydrocarbons. The gas chromatogram for this interval contains the full range of normal paraffins characteristic of a mature non-biologically altered crude oil. This migrated petroleum is not related to local Wolfcampian potential source rocks based on comparison of saturated hydrocarbon distributions. It may have originated in downdip more deeply buried laterally equivalent facies or have migrated vertically into Wolfcampian rocks.

Virgilian 8017-8170 feet

Virgilian cuttings are composed primarily of carbonates with shale intervals occurring in the upper 40 feet. These intervals contain an average of 0.47% total organic carbon and may have fair source potential. Virgilian strata contain predominantly amorphous organic matter with the presence of smaller but significant quantities of hydrogen-poor woody and coaly kerogen. The elemental hydrogen to carbon ratio is 0.80 indicating only limited potential to generate liquid hydrocarbons. The organic matter is thermally mature and in the main stage of petroleum generation based on a thermal alteration index of 2+ to 3 and a 1.07 mean vitrinite reflectance measurement.

Soluble organic matter concentrations are below those required for favorable petroleum source rocks. Gas chromatograms lack the full range of normal paraffins characteristic of a mature petroleum mixture. This indicates local Virgilian shales are not genetically related to the non-indigenous migrated hydrocarbons present in Wolfcampian intervals.

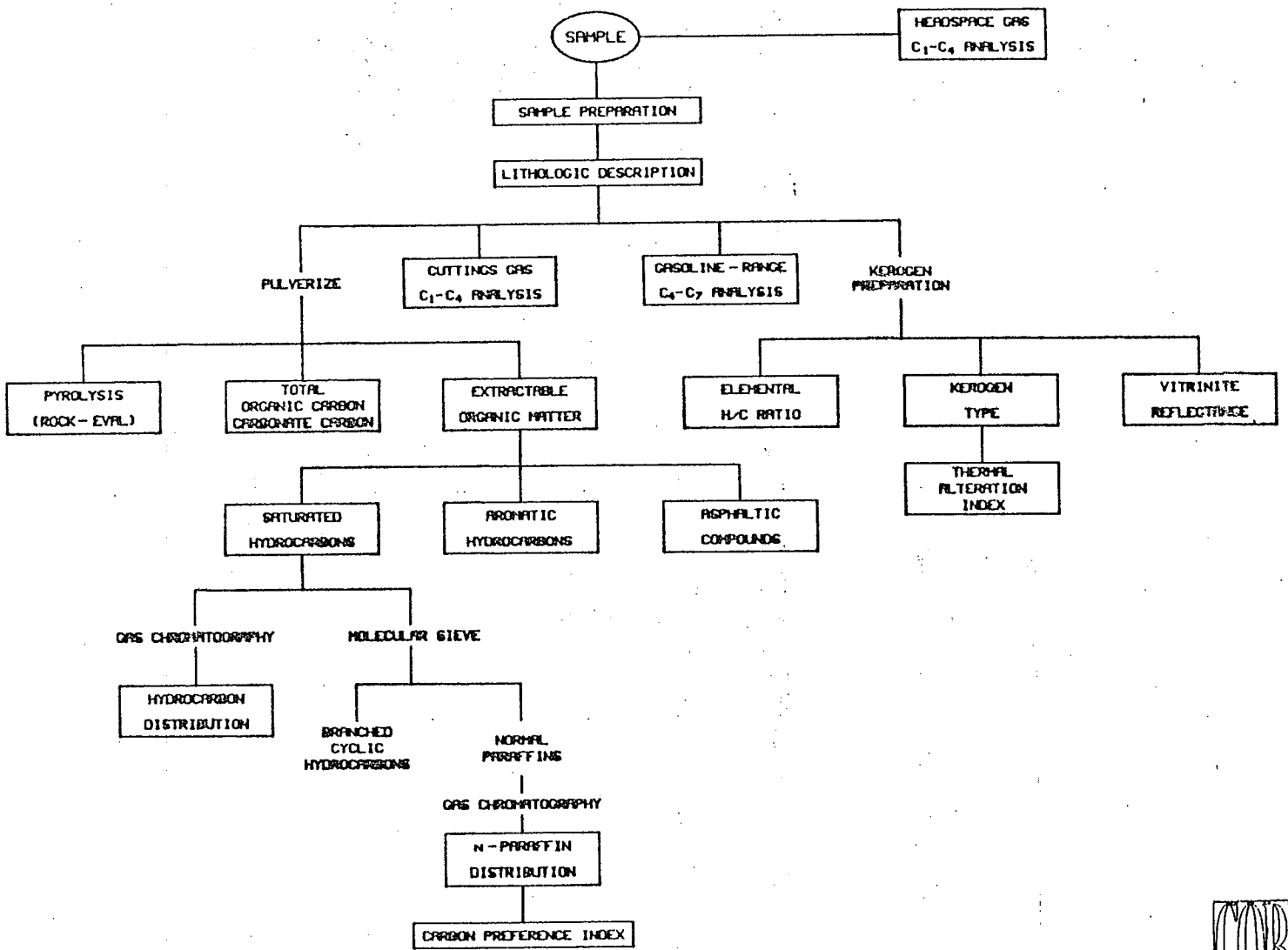
Missourian (8170 feet), Desmoinesian (8323 feet) Atokan, Morrowan (8620 feet) and Precambiran rocks (8837 feet) were penetrated in this well, but samples were not available for analyses.

IV. ANALYTICAL PROGRAM

The following analytical program, with appropriate screening techniques, was used in determining the hydrocarbon source potential of Paleozoic intervals in the Denver basin.

The quantity of total organic carbon is determined by combustion of pre-treated, carbonate-free, pulverized samples in a Leco WR-12 Analyzer. Generally, no further analyses are performed on samples having total organic carbon content values of less than 0.3% for carbonates and 0.5% for fine-grain clastic sediments. Samples with total organic carbon values greater than the above values proceed to kerogen, vitrinite reflectance and C_{15+} extractable organic matter analyses. If the concentration of the extractable organic matter is less than 200 ppm, no further analyses are performed on the samples. Samples with extractable organic matter concentrations greater than 200 ppm proceed to liquid and gas chromatography analyses. The above analytical scheme, with appropriate screening techniques, provides detailed information at a minimal cost to the client.

A description of the analytical procedures used by Core Labs' Geochemical Services Department follows this analytical program.



ANALYTICAL SCHEME FOR SOURCE-BED EVALUATION

IV. DESCRIPTION OF ANALYTICAL PROCEDURES

SAMPLE PREPARATION

Cutting samples are thoroughly washed to remove drilling mud, and if necessary are placed in a solvent to float off contaminants, such as coals or drilling additives. The samples are then air-dried and are examined under a binocular microscope to remove any remaining contaminants. A magnet is used to remove any metal which may be present. The outside surface of sidewall and conventional core samples is removed and then the samples are thoroughly washed with water and allowed to air dry.

LITHOLOGICAL DESCRIPTION

A complete lithological description of each sample is made under a binocular microscope. All obvious cave material is removed and the sample submitted for total organic carbon analysis. The description includes an examination for migrated hydrocarbons under ultraviolet light.

TOTAL ORGANIC CARBON ANALYSIS (TOC)

Total organic carbon analysis measures the organic richness of a rock in weight percent organic carbon. Organic richness is the first requirement for an oil or gas source rock. The analysis is also used as a screening technique to determine which samples merit more detailed analysis. The dried rock samples are pulverized and treated with hot and cold hydrochloric acid to remove carbonates (inorganic carbon). After acid treatment, the organic carbon content is determined by combustion of the sample in a Leco WR-12 Carbon Analyzer. Blanks, standards, and duplicates are routinely run to insure highly reliable results.

EXTRACTION OF SOLUBLE ORGANIC MATTER (BITUMEN)

Soluble organic matter in a rock can result from the organic matter deposited with the rock or from the introduction of non-indigenous migrated hydrocarbons. It is important to know how much soluble organic matter is present for evaluating potential oil source rocks. The amount of indigenous soluble organic matter reflects the rock's total organic matter, type of organic matter, and thermal history. To determine

soluble organic matter concentration, powdered rock samples are placed in Soxhlet thimbles and extracted for 24 hours with chloroform. An aliquot of extracted material is then transferred to a pre-weighed container and the chloroform solvent is evaporated under nitrogen at 40°C. The concentration of the stabilized extract (soluble organic matter) residue is reported in parts per million.

LIQUID CHROMATOGRAPHIC SEPARATION

The composition of the soluble organic matter is determined by liquid chromatographic separation into saturated hydrocarbons, aromatic hydrocarbons, and asphaltic compounds. Compositional data is useful in evaluating oil source quality and thermal maturation. An aliquot of the soluble organic matter extract in chloroform is concentrated and iso-octane solvent is added. Concentration and addition of iso-octane is repeated until all chloroform has been removed without complete evaporation to dryness. The extract in iso-octane is then placed on a silica gel column and successively eluted with hexane, benzene, and benzene/methanol to determine % saturates, % aromatics, and % asphaltics.

GAS CHROMATOGRAPHY OF C_{10+} SATURATED HYDROCARBONS

The saturated hydrocarbon fraction from liquid chromatography is analyzed by gas chromatography before it is evaporated to dryness. This allows analysis of hydrocarbons below C_{15}. The distribution of C_{10+} saturated hydrocarbons documents whether petroleum-like hydrocarbons are present in a rock sample. A high resolution glass capillary column is used to separate the hydrocarbons. The temperature-programmed analysis is performed on a Hewlett Packard gas chromatograph equipped with a flame ionization detector. From the distribution of n-paraffins the Carbon Preference Index (CPI) is calculated according to the following equation:

$$C.P.I. = \frac{1}{2}\left[\frac{\sum_{25}^{33} \text{Odd-Carbon n-Paraffins}}{\sum_{26}^{34} \text{Even-Carbon n-Paraffins}} + \frac{\sum_{25}^{33} \text{Odd-Carbon n-Paraffins}}{\sum_{24}^{32} \text{Even-Carbon n-Paraffins}}\right]$$

The CPI is used to evaluate thermal maturity. Saturated hydrocarbon distributions are also useful for oil-to-source rock correlations. In addition to a gas chromatogram, the percent composition of n-paraffins, percent composition of isoprenoids, pristane/phytane ratio and Carbon Preference Index are reported from this analysis.

VISUAL KEROGEN ANALYSIS

High-powered microscope examination of kerogen in transmitted light and under ultraviolet light determines thermal maturation state and whether the type of organic matter is favorable for petroleum generation. The kerogen composition is reported as % alginite (algal and amorphous debris), % exinite (herbaceous plant debris and palynomorphs), % woody plant debris, and % coaly fragments. The ability of the various kerogen types to yield oil decreases in the following order: alginite - exinite - woody - coaly. The color (Thermal Alteration Index) of the spore and pollen grains present is also used as an indicator of thermal maturation level.

For visual kerogen analysis, standard palynological techniques are used to separate the kerogen from the rock matrix. The isolated organic matter (kerogen) is mounted on a glass slide and examined under a high-powered Leitz microscope.

VITRINITE REFLECTANCE

Vitrinite reflectance provides a method for determining the thermal alteration history of a sediment. Vitrinite particles, originating from wood, are found dispersed throughout most sedimentary rock samples which are younger than Silurian. Since vitrinite reflectance increases regularly with increased thermal alteration, a reflectance measurement can be used to determine the degree of thermal maturation of that sediment.

Kerogen is prepared for vitrinite reflectance by imbedding the isolated kerogen in a bioplastic plug. The hardened plug is polished and the reflectance of the individual vitrinite particles are measured under a microscope. A histogram of reflectance values for each sample is reported.

ELEMENTAL ANALYSIS OF KEROGEN (H/C)

Chemical analysis of kerogen is used to characterize the type of organic matter present in a sediment in terms of its oil or gas generating potential. Kerogens with a high hydrogen content or high H/C ratio tend to generate oil. To measure the elemental composition, isolated kerogen is combusted in a Perkin-Elmer Elemental Analyzer. This method provides a direct, calibrated measurement for characterizing the kerogen type present in a sediment. The results are reported as % hydrogen, % carbon, % nitrogen and H/C ratio.

FIGURE 1

GEOCHEMICAL SUMMARY PROFILE

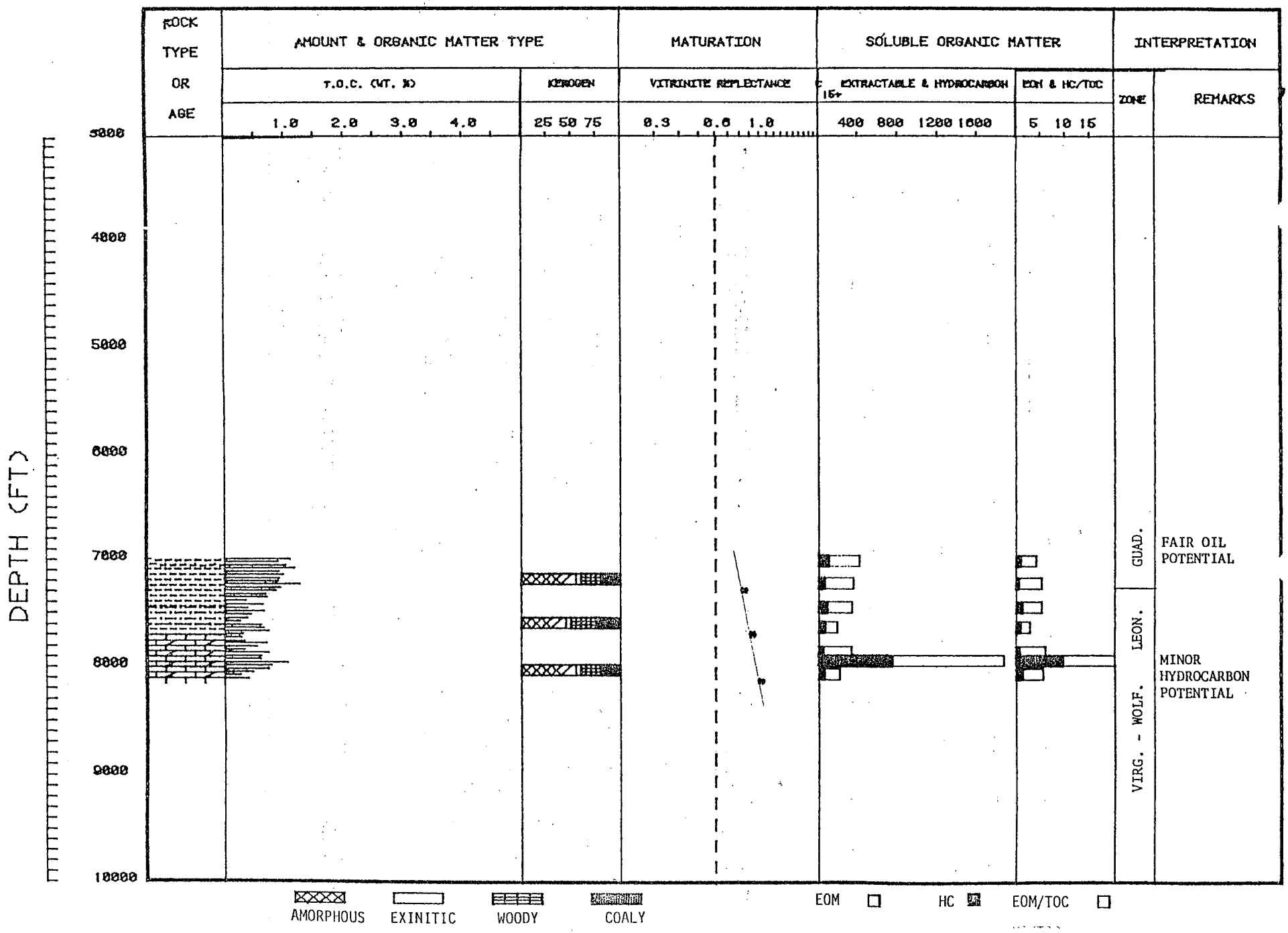


FIGURE 2

TOTAL ORGANIC CARBON CHARACTERIZATION

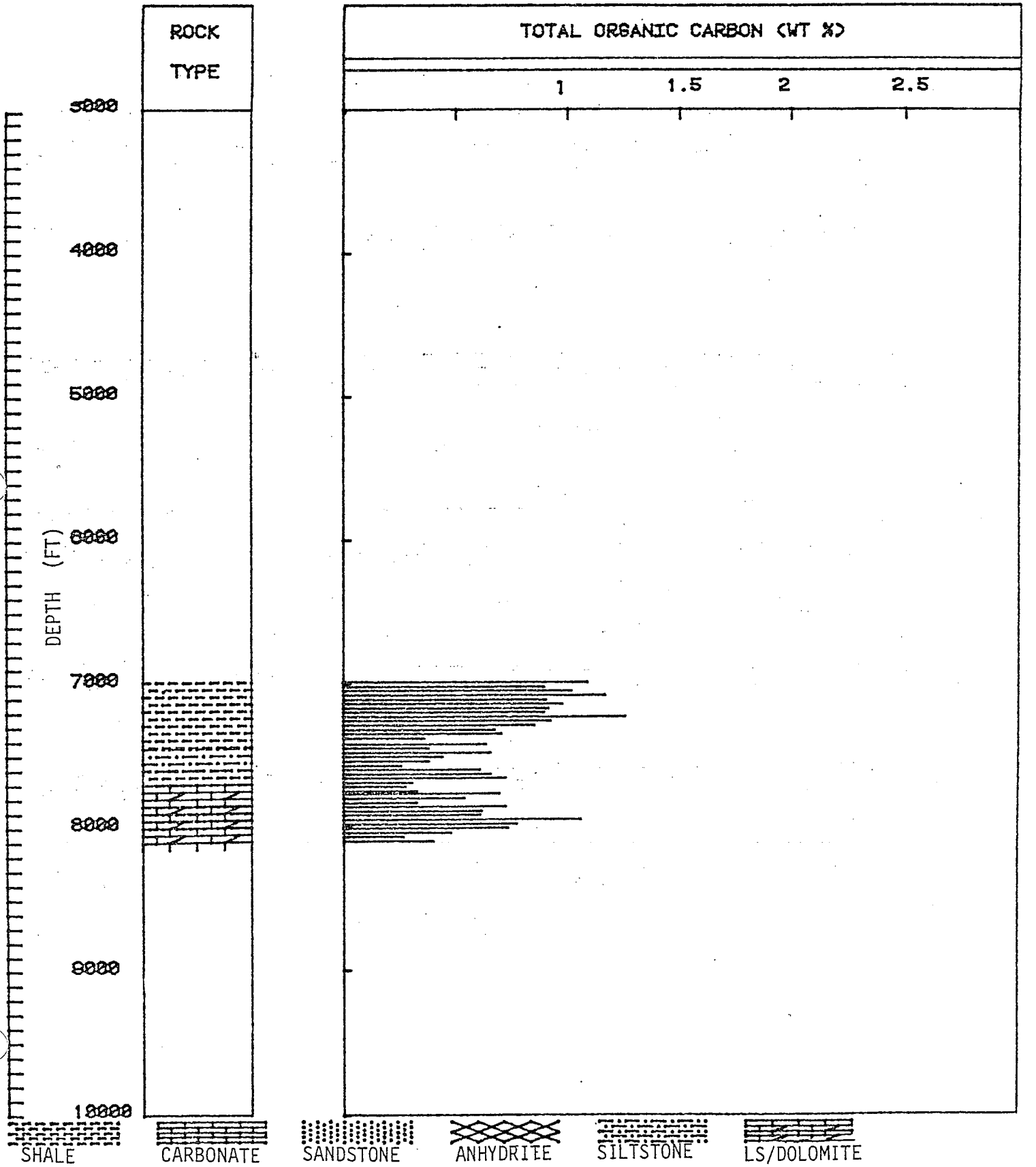


FIGURE 3

SOLUBLE ORGANIC MATTER CHARACTERIZATION

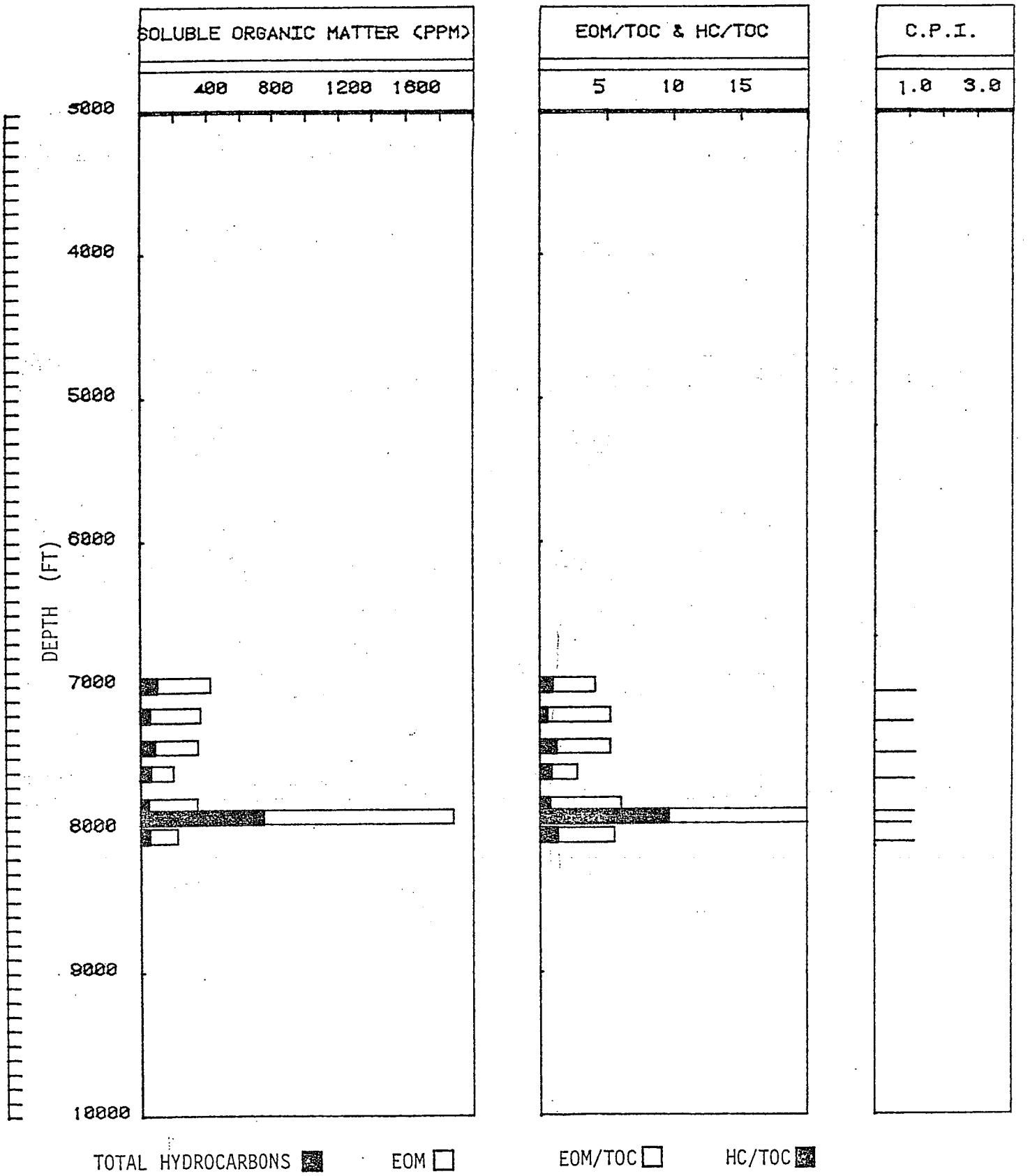


FIGURE 4

KEROGEN TYPE

THERMAL MATURITY

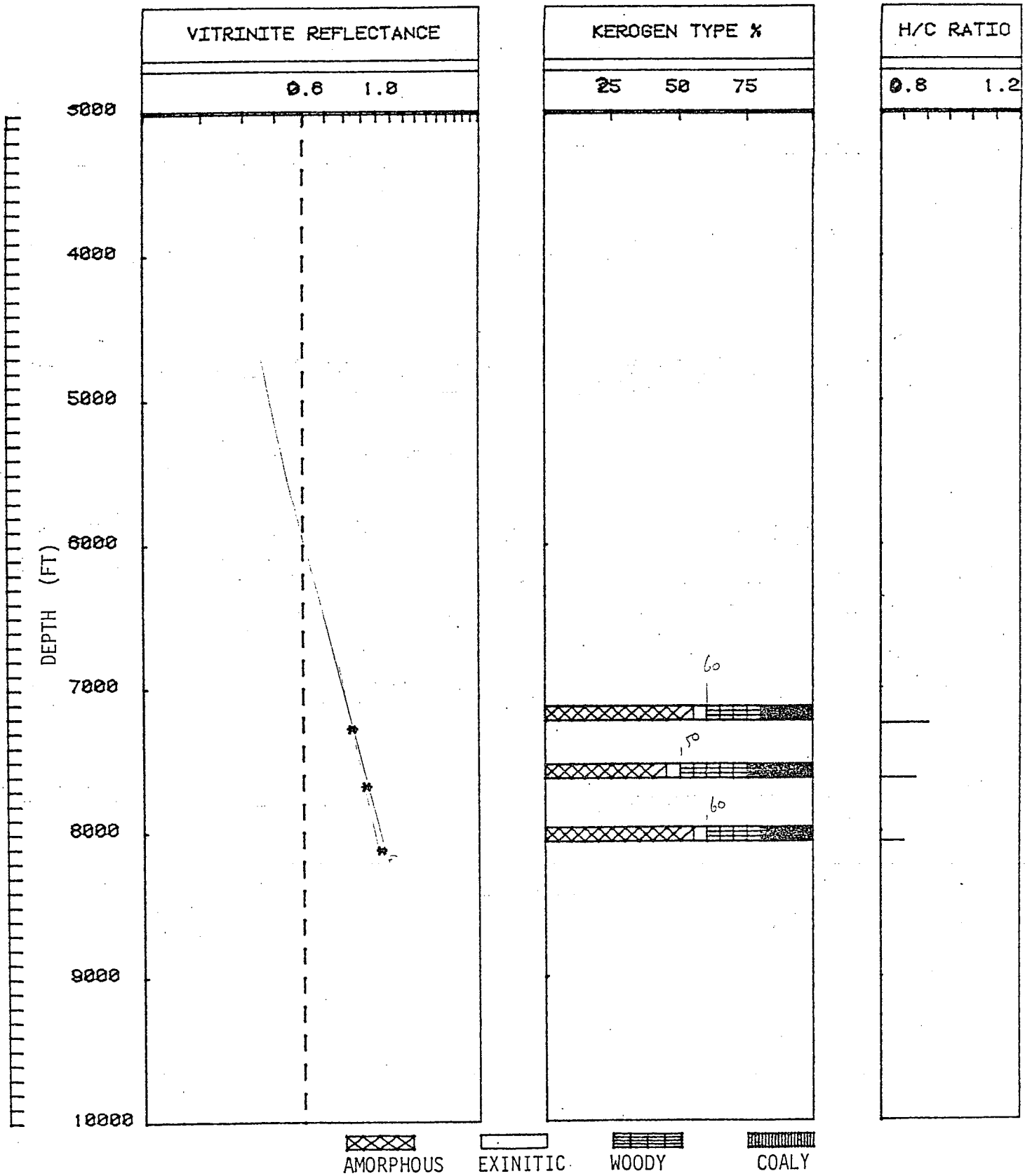
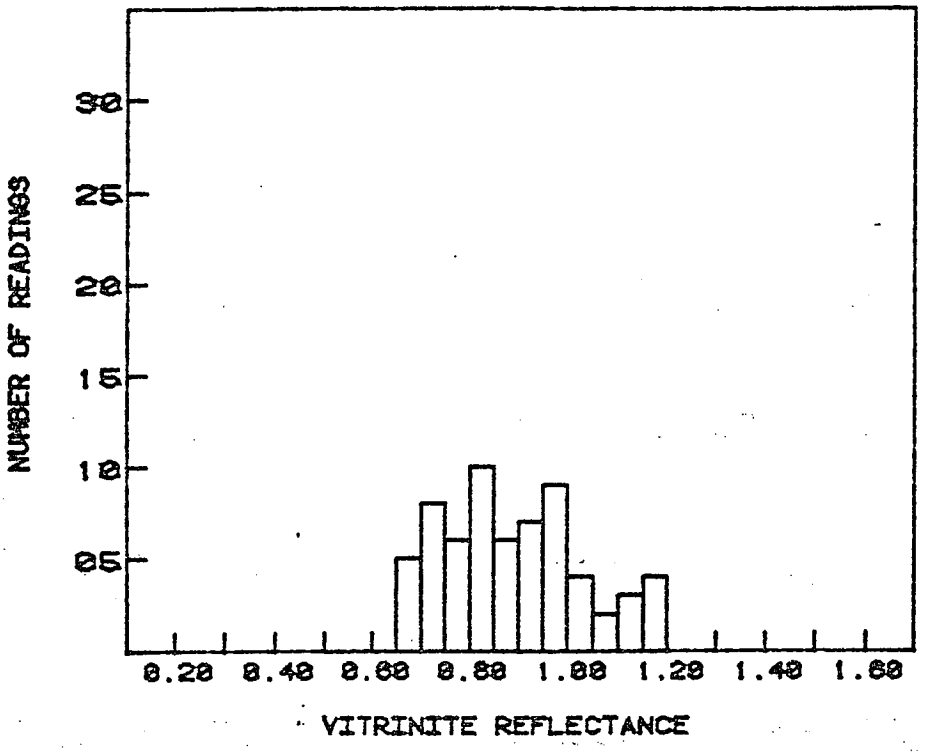


Table VI

Elemental Analysis

Depth (ft)	H/C
7230-7260	0.90
7630-7650	0.85
8070-8090	0.80

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

SCHNIEDER #2

DEPTH:7230-7260

MEAN REF.:0.88%

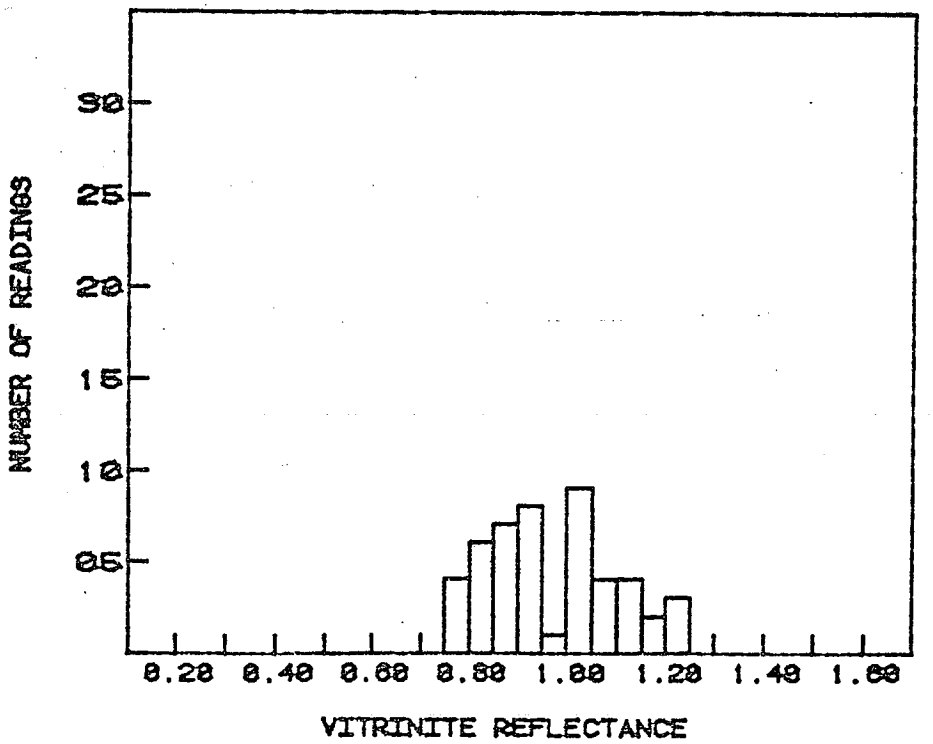
MAX. REF.:1.18%

MIN. REF.:0.66%

READINGS:64

SAMPLE:CUTTINGS

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

SCHNIEDER #2

DEPTH:7630-7650

MEAN REF.:0.97%

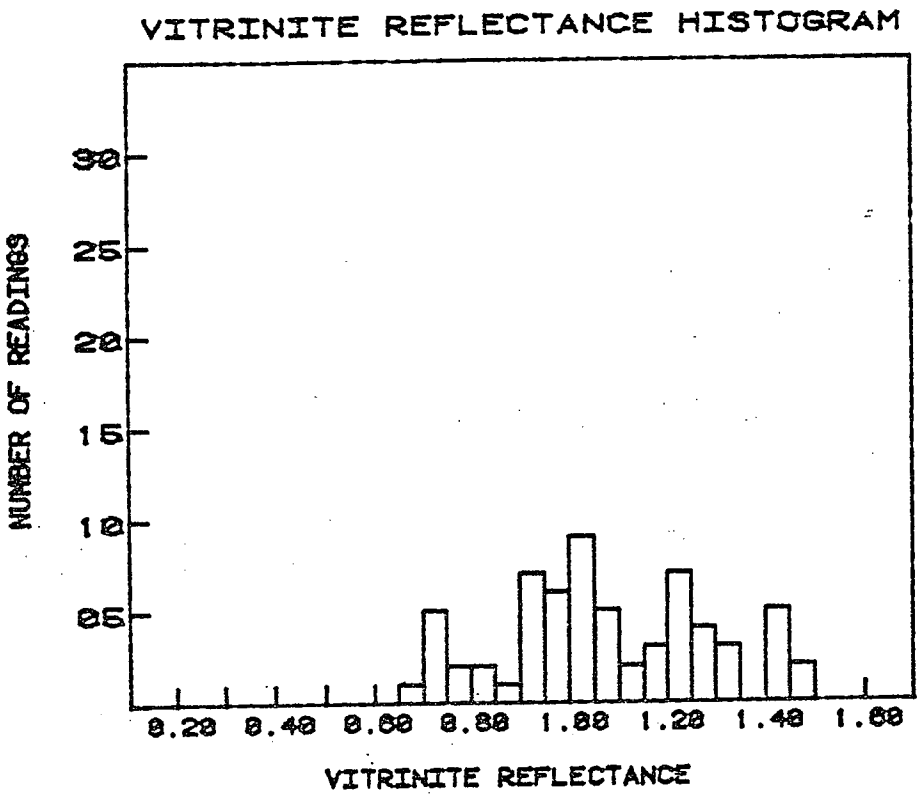
MAX. REF.:1.23%

MIN. REF.:0.76%

READINGS:48

SAMPLE:CUTTINGS

Table V (cont.)



DENVER BASIN STUDY

SCHNIEDER #2

DEPTH: 8070-8090

MEAN REF.: 1.07%

MAX. REF.: 1.48%

MIN. REF.: 0.68%

READINGS: 64

SAMPLE: CUTTINGS

Table VII

Normalized n-Paraffin Distribution

	7050-7070	7260-7310	7480-7500	7660-7680
C_{15}	17.6	20.0	19.8	14.0
C_{16}	15.0	15.8	18.8	9.0
C_{17}	13.2	13.0	15.9	6.4
Pristane	6.7	5.5	6.4	3.0
C_{18}	9.3	7.6	8.6	3.9
Phytane	3.7	2.9	3.5	1.4
C_{19}	7.1	5.3	5.3	3.6
C_{20}	5.5	4.4	3.5	5.3
C_{21}	5.0	5.0	3.6	9.0
C_{22}	4.3	5.1	3.7	12.5
C_{23}	3.2	4.5	3.0	11.1
C_{24}	1.9	3.1	1.9	7.1
C_{25}	1.5	2.1	1.4	4.4
C_{26}	1.1	1.4	1.0	2.7
C_{27}	1.3	1.2	1.0	2.1
C_{28}	1.0	0.9	0.7	1.4
C_{29}	1.0	0.8	0.7	1.2
C_{30}	0.7	0.6	0.5	0.9
C_{31}	0.6	0.5	0.5	0.7
C_{32}	0.3	0.3	0.2	0.3
C_{33}	- -	- -	- -	- -
C_{34}	- -	- -	- -	- -
Pristane/Phytane	1.81	1.90	1.83	2.14
CPI	1.18	1.10	1.18	1.13

Table VII (cont.)

Normalized n-Paraffin Distribution

	7890-7940	7980-8000	8100-8120
C_{15}	21.4	4.7	18.6
C_{16}	16.2	6.1	15.1
C_{17}	12.2	7.9	11.2
Pristane	5.1	3.1	4.4
C_{18}	6.8	7.5	6.1
Phytane	2.7	2.2	2.2
C_{19}	5.2	8.2	4.0
C_{20}	4.5	7.8	3.6
C_{21}	5.2	7.4	5.0
C_{22}	5.7	6.7	7.5
C_{23}	4.3	5.8	7.1
C_{24}	2.3	4.9	4.8
C_{25}	1.5	4.5	3.1
C_{26}	1.0	4.0	2.0
C_{27}	1.1	3.7	1.5
C_{28}	0.9	3.1	1.0
C_{29}	0.9	3.0	0.9
C_{30}	0.9	2.5	0.7
C_{31}	1.0	2.3	0.6
C_{32}	0.5	2.0	0.3
C_{33}	0.4	1.5	0.2
C_{34}	0.2	1.1	0.1
Pristane/Phytane	1.89	1.41	2.00
CPI	1.13	1.05	1.13

Table VIII

Normalized Isoprenoid Distribution

	7050-7070	7260-7310	7480-7500	7660-7680	7890-7940	7980-8000	8100-8120
Ip13	5.9	5.5	3.0	8.0	3.8	0.9	2.5
Ip14	4.9	5.4	3.0	8.2	3.9	1.2	2.3
Ip15	12.2	14.4	9.3	21.6	11.5	5.6	10.0
Ip16	21.1	24.2	21.3	26.6	25.9	12.4	24.8
Ip18	15.0	15.0	18.5	10.2	16.5	19.3	19.5
Pristane	26.3	23.4	29.0	17.1	25.2	35.0	27.4
Phytane	14.6	12.1	15.9	8.3	13.2	25.5	13.5

FIGURE 5

Shell Oil Company

C_{10+} Saturated Hydrocarbon Fraction

Schneider #2

7050-7070 feet

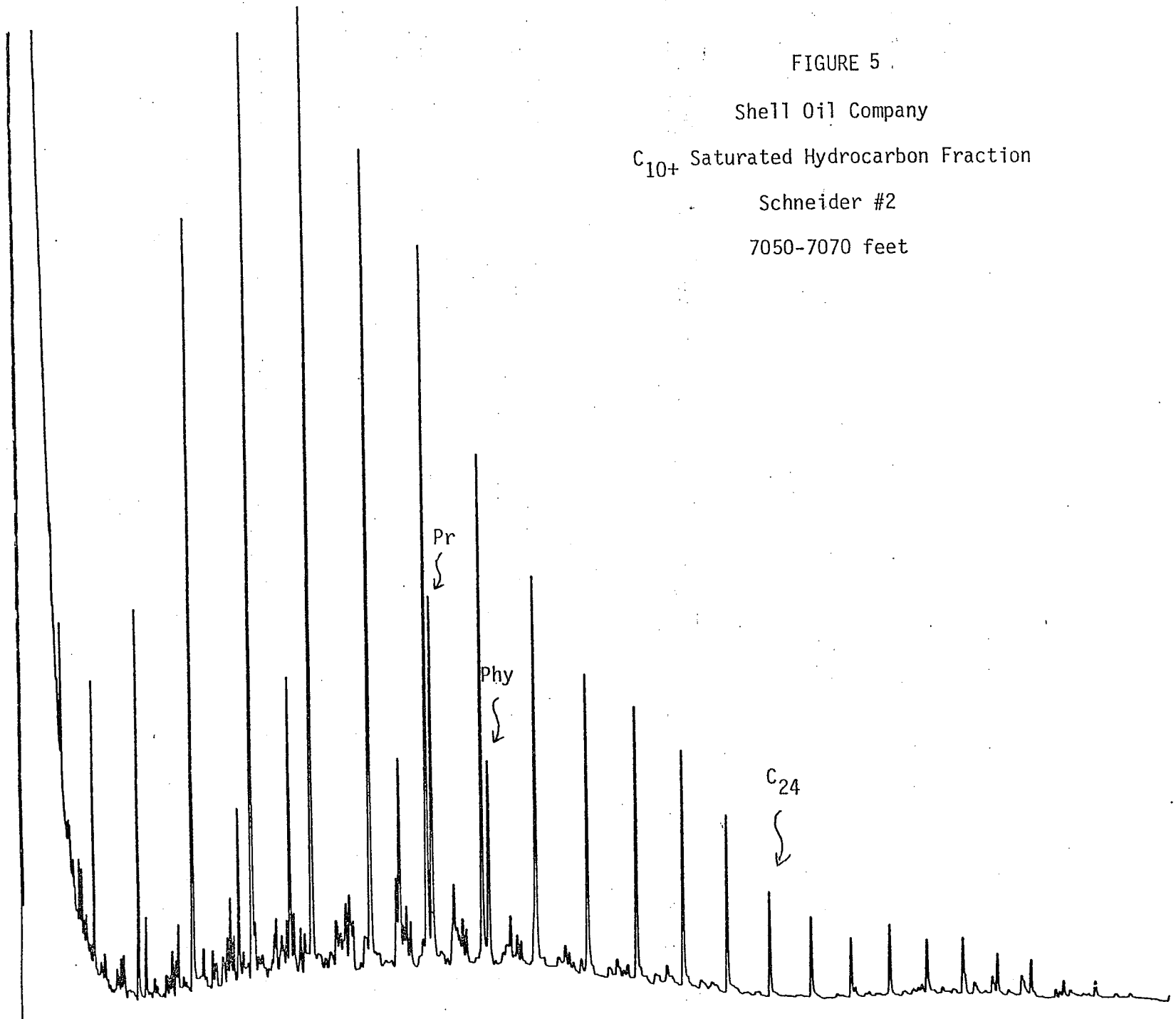


FIGURE 6

Shell Oil Company

C_{10+} Saturated Hydrocarbon Fraction

Schneider #2

7260-7310 feet

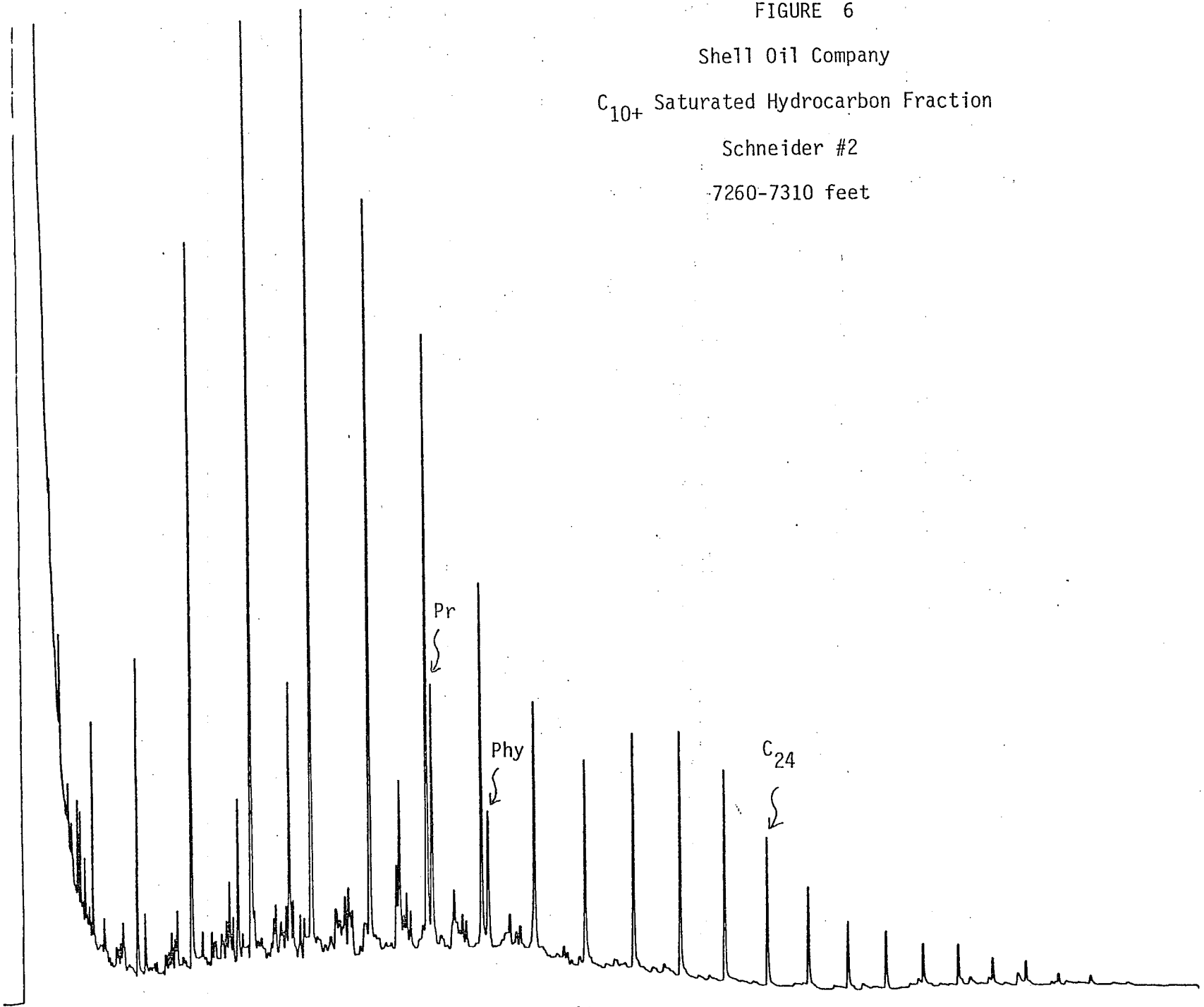


FIGURE 7

Shell Oil Company

C_{10+} Saturated Hydrocarbon Fraction

Schneider #2

7480-7500 feet

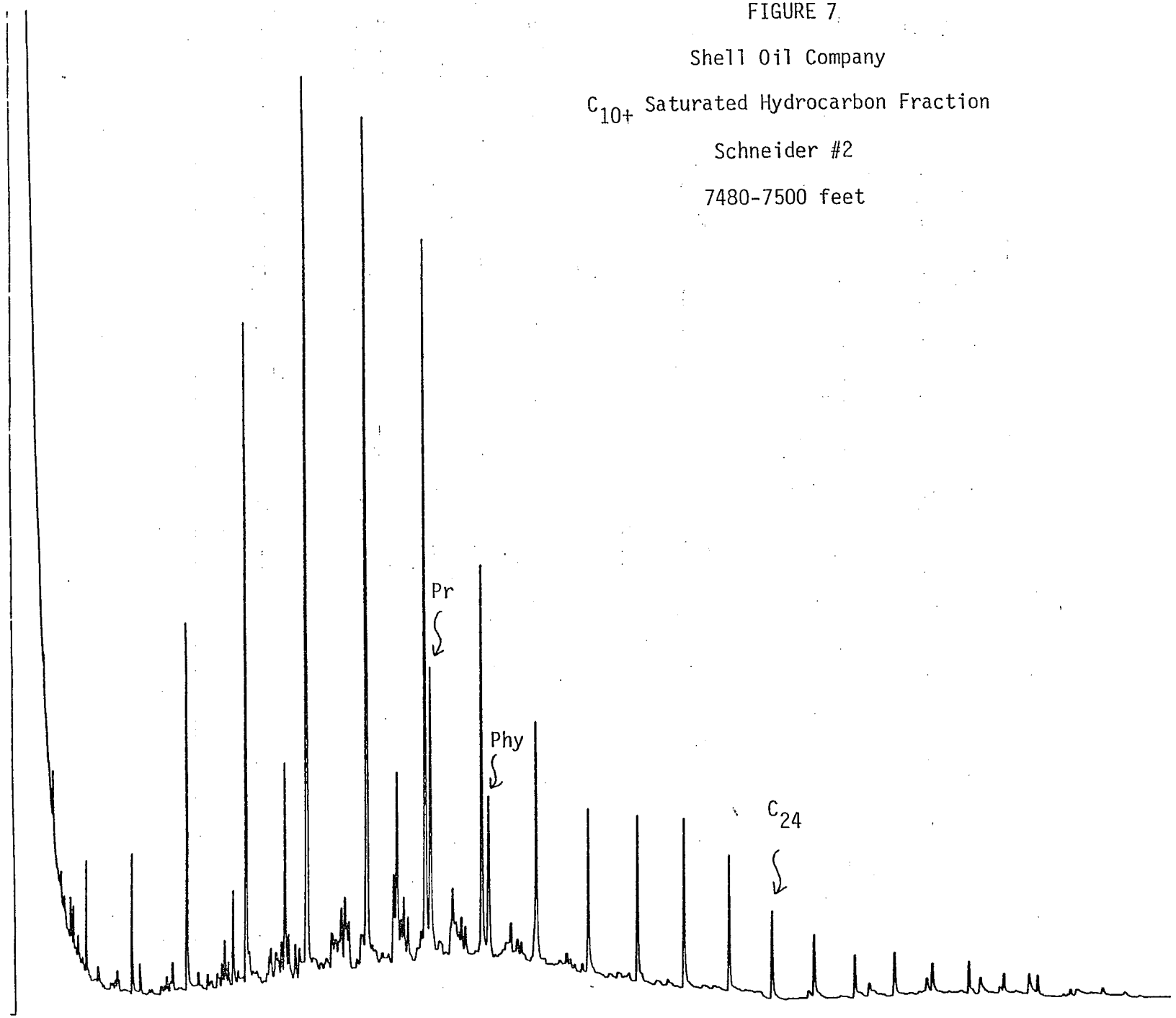


FIGURE 8

Shell Oil Company

C_{10+} Saturated Hydrocarbon Fraction

Schneider #2

7660-7680 feet

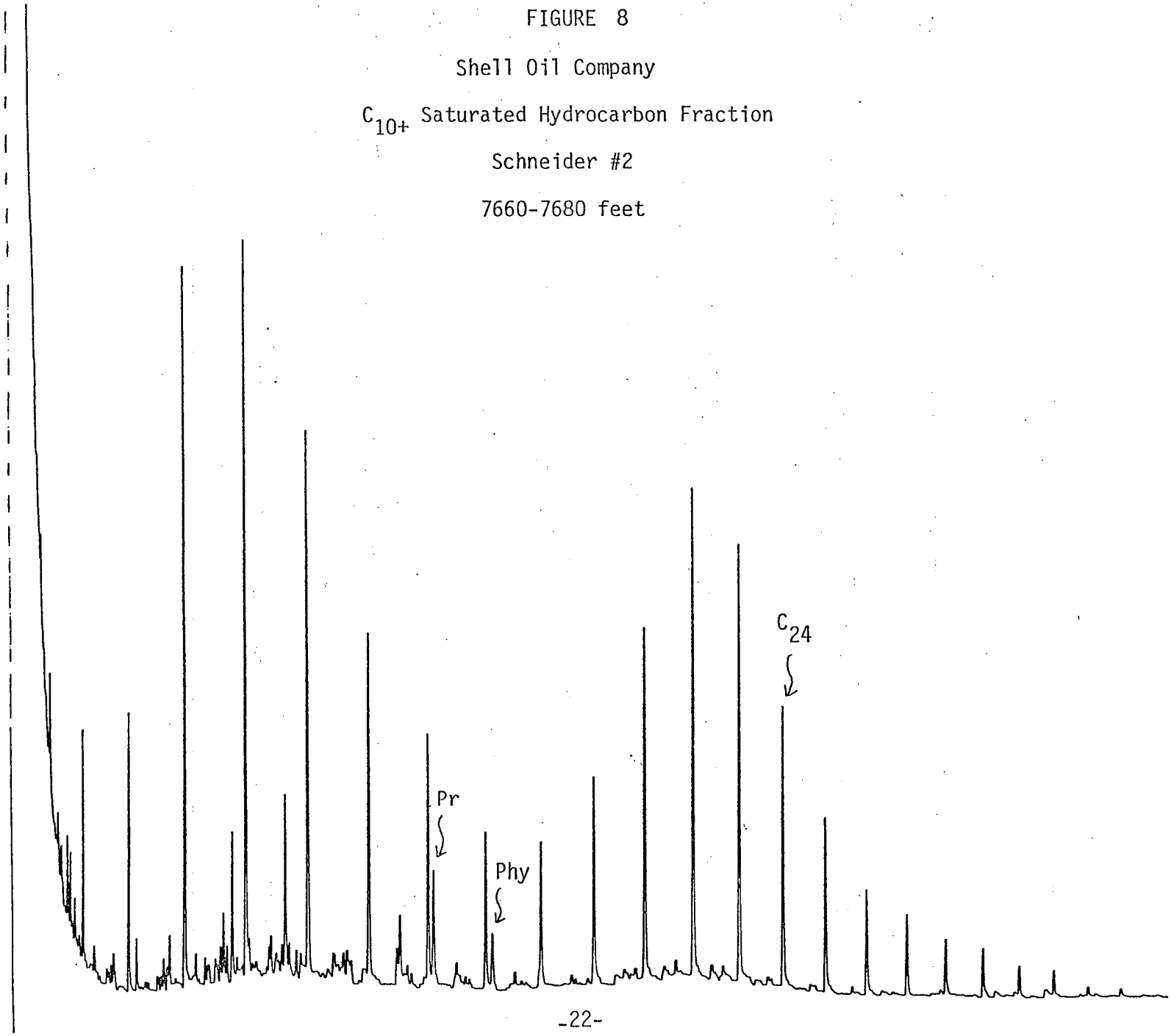


FIGURE 9

Shell Oil Company

C_{10+} Saturated Hydrocarbon Fraction

Schneider #2

7890-7940 feet

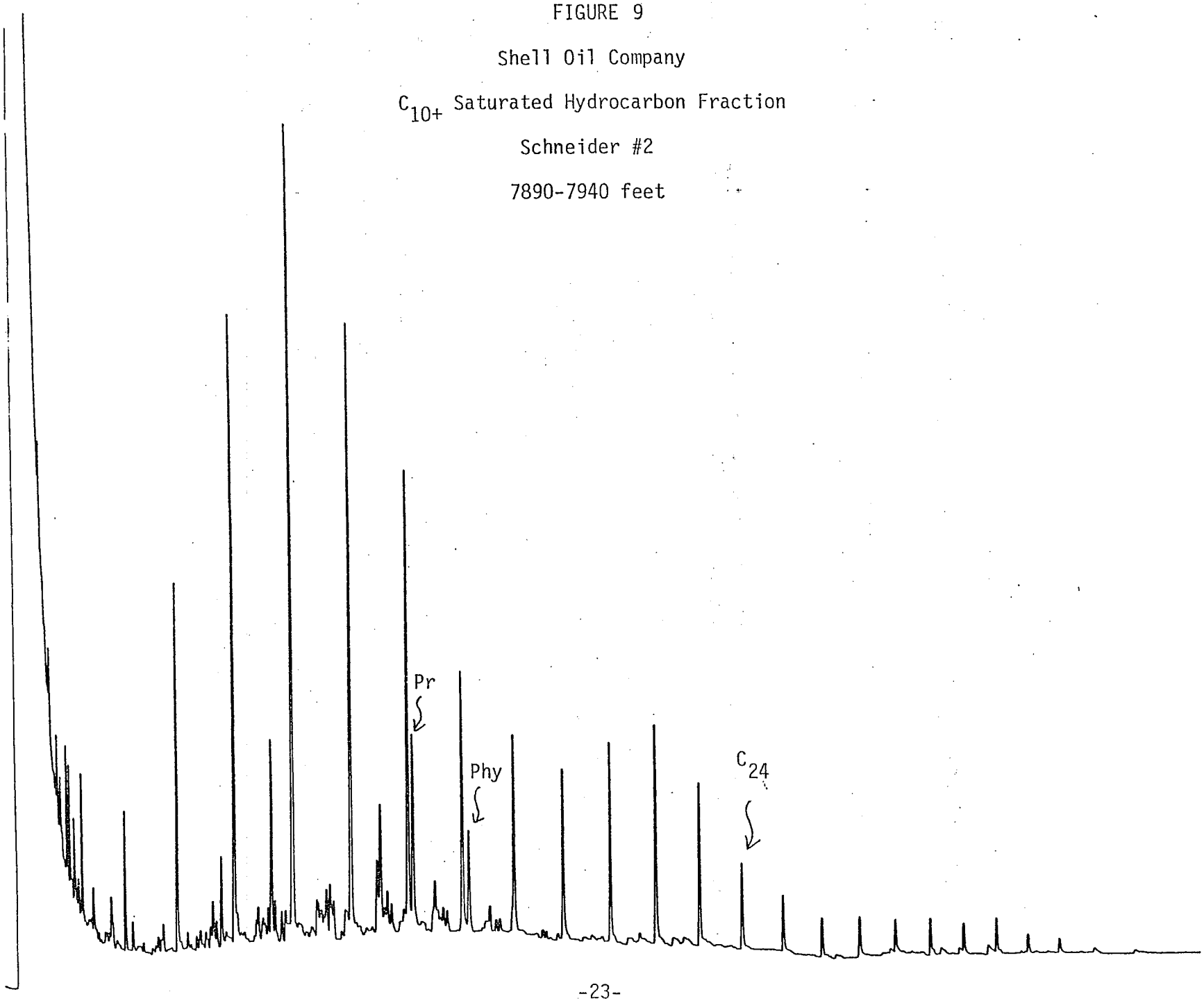


FIGURE 10

Shell Oil Company

C_{10+} Saturated Hydrocarbon Fraction

Schneider #2

7980-8000 feet

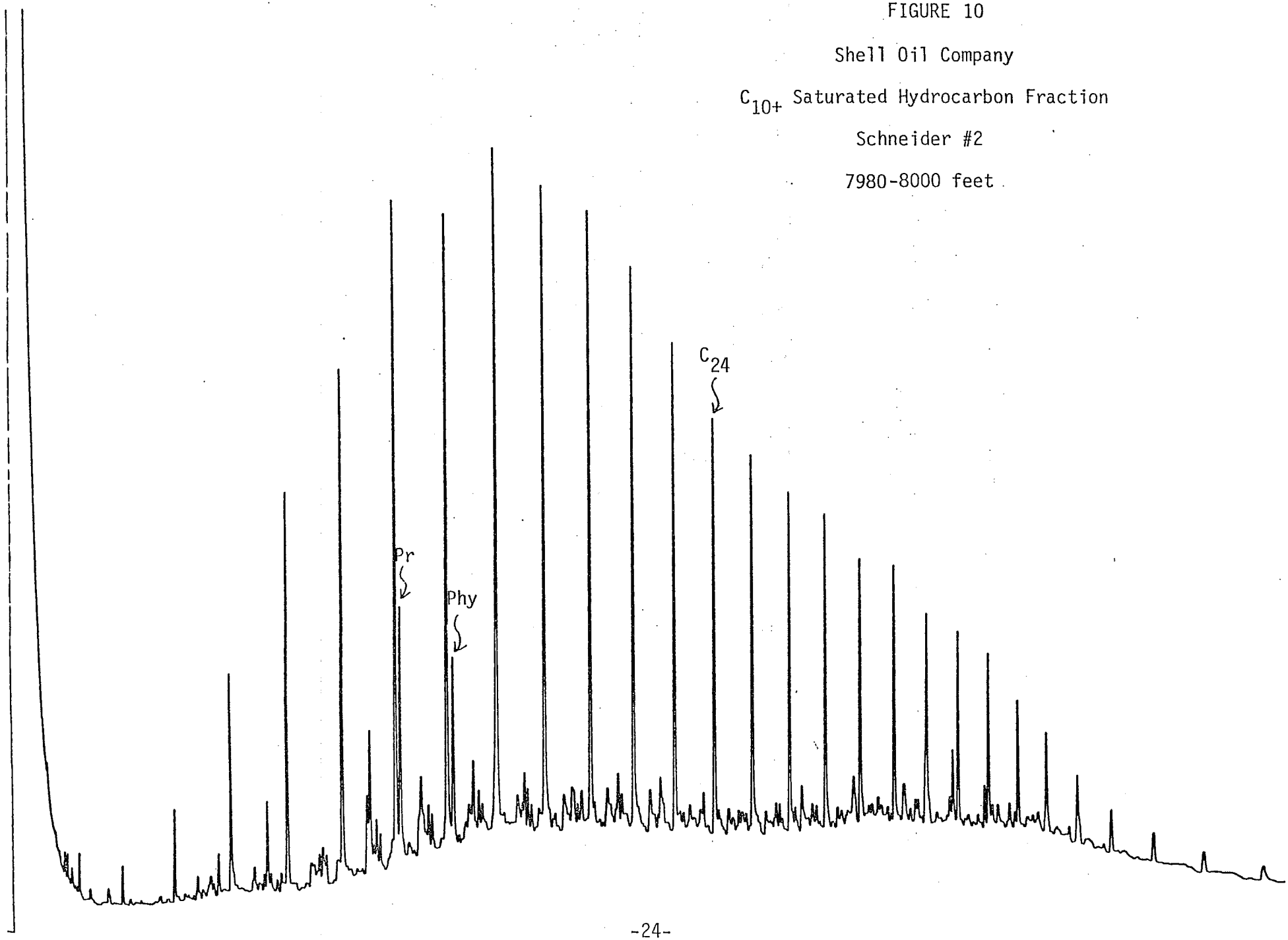


FIGURE 11

Shell Oil Company

C_{10+} Saturated Hydrocarbon Fraction

Schneider #2

8100-8120 feet

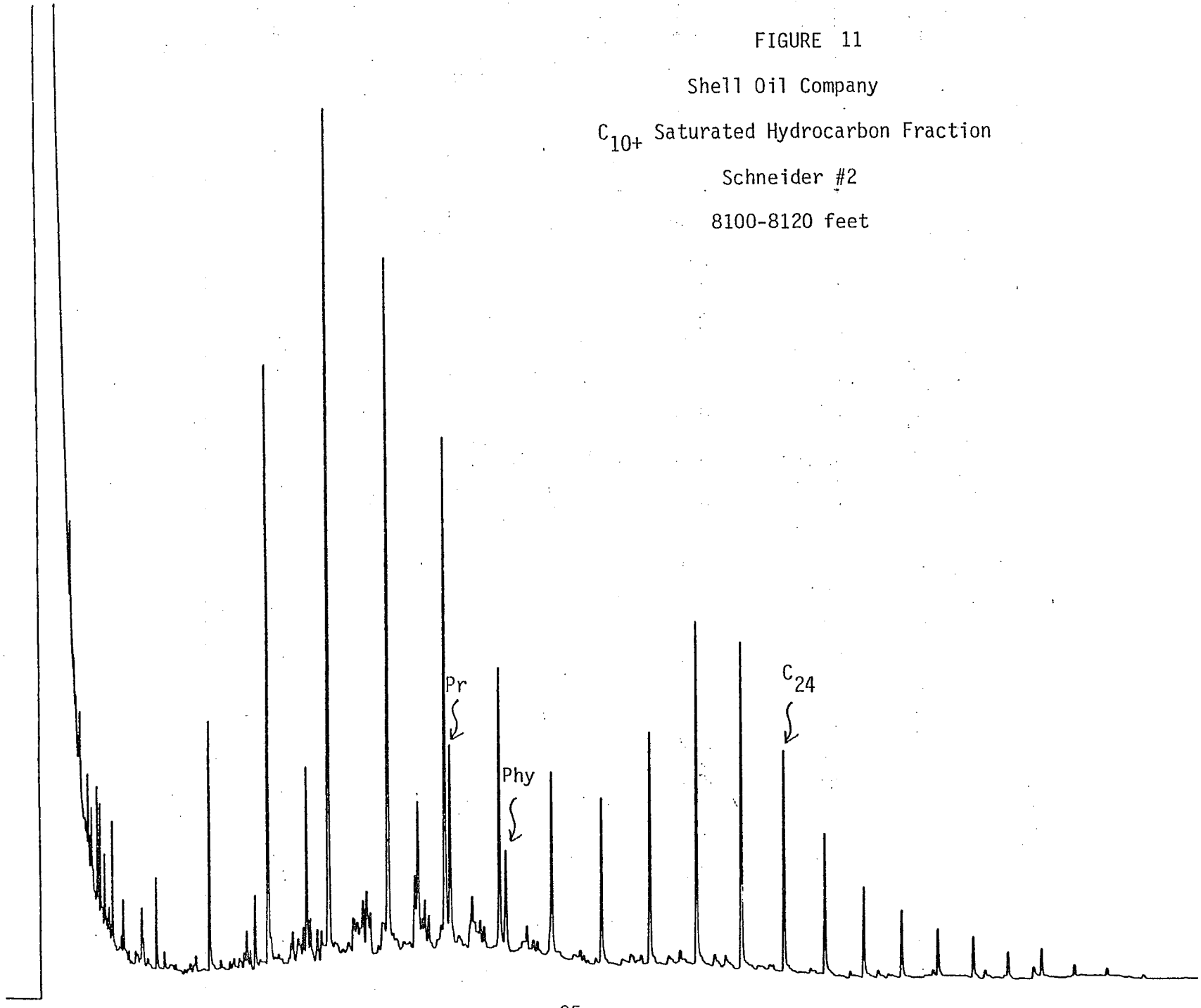


Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
7450-7470	ctgs	60% sltst; rd, n calc, v sft 40% sh; gy, n calc, slty in pt, blky Tr-anhy; wh, sft, occ sug	0.38
7480-7500	ctgs	50% sltst; rd, n calc, v sft 50% sh; gy, n calc, slty in pt, blky Tr-anhy; wh, sft, occ sug	0.66
7510-7530	ctgs	70% sltst; rd, n calc, v sft 30% sh; gy, n calc, slty in pt, blky Tr-anhy; wh, sft, occ sug	0.44
7540-7560	ctgs	70% sltst; rd, n calc, v sft 30% sh; gy, n calc, slty in pt, blky	0.38
7570-7590	ctgs	80% ss; rd, f gr, m fri 20% sh; gy, occ dk gy, occ red, n calc, sb-fss blky Tr-anhy	0.26
7600-7620	ctgs	75% sh; gy-dk gy, n calc, sb fss-blky 20% ss; rd, f gr, m fri, grdg in pt to sh 5% anhy; wh, sft, occ suc	0.61/0.63
7630-7650	ctgs	75% sh; gy, occ dk gy, n calc, sb fss-blky 25% sh; red, n calc, blky, slty in pt Tr-anhy	0.66
7660-7680	ctgs	75% sh; gy, occ dk gy, n calc, sb fss-blky 25% sh; red, n calc, blky, slty in pt	0.73
7690-7710	ctgs	60% ls/dol; cff wh-lt buff, f xln 20% sltst; red, n calc, blky 20% sh; gy-lt gy, n calc, sb fis-blky Tr-anhy; wh, sft	0.31

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
7720-7740	ctgs	80% ls/dol; off wh-lt buff, f xln 10% sltst; red, n calc, blky 10% sh; gy-lt gy, n calc, sb fis-blky Tr-anhy; wh, sft	0.28
7750-7770	ctgs	70% ls/dol; off wh-lt buff, f xln 10% sltst; red, n calc, blky 10% sh; gy-lt gy, n calc, sb fis-blky 10% anhy; wh, sft	0.33
7770-7790	ctgs	60% sh; lt gy-gy, sl calc, sb fss-blky 20% sh; red, n calc, blky, slty 20% ss; wh, f-m gr, fri Tr- ls/dol; lt gy-lt brn, mic xln-xln	0.70
7800-7820	ctgs	50% sh; lt gy-gy, sl calc, sb fss-blky 20% anhy; wh, sft 20% ls/dol; lt gy-lt brn, mic xln-xln 10% sltst; red, n calc, blky	0.54
7830-7850	ctgs	50% ls/dol; lt gy-lt brn, mic xln-xln 30% sltst; red, n calc, blky 20% sh; lt gy-gy, sl calc, sb fss-blky Tr-ss; wh; anhy; wh, sft	0.33/0.31
7860-7880	ctgs	50% sh; lt gy, gy brn, sl calc-n calc, sb fis-blky 35% ls/dol; lt gy-lt brn, mic xln-xln 10% sltst; red, n calc, blky 5% anhy; wh, sft Tr-ss; wh, f-m gr, fri	0.73
7890-7910	ctgs	40% sh; lt gy, gy brn, sl calc-n calc, sb fis-blky 30% sltst; red, n calc, blky 10% ls/dol; off wh-lt brn, xln, suc in pt 10% anhy; wh, sft Tr-ss; wh, f-m gr, fri	0.62

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
7920-7940	ctgs	45% ls/dol; off wh-lt brn, xln, suc in pt 35% sh; lt gy, gy brn, sl calc-n calc, sb fis-blky 10% sltst; red, n calc, blky 10% anhy; wh, sft, suc	0.61
7950-7970	ctgs	40% sh; lt gy, gy brn, sl calc-n calc, sb fis-blky 30% sltst; red, n calc, blky 25% ls/dol; off wh-brn, xln, suc in pt, yel fluor 5% anhy; wh, sft, suc	1.06
7980-8000	ctgs	40% ls; lt brn, f xln, yel fluor 40% sh; lt gy, gy brn, sl calc-n calc, sb fis-blky 10% ls/dol; off wh-lt brn, xln, suc in pt 5% sltst; red, n calc, blky 5% anhy; wh, sft, suc	0.78
8010-8030	ctgs	90% sh-sltst; gy brn, n calc, blky 5% sltst; red, n calc, blky 5% ls/dol; off wh-lt brn, xln, suc in pt	0.74
8040-8060	ctgs	50% sh; lt gy-lt gy brn, n calc, blky 35% ls; off wh, gy, lt brn, xln-mic xln 10% sltst; red, n calc, blky 5% anhy; wh, sft, suc	0.48
8070-8090	ctgs	80% ls/dol; off wh, gy, buff, xln-mic xln 10% sh; lt gy-gy, n calc, blky 5% sltst; red, n calc, blky 5% anhy	0.27/0.28
8100-8120	ctgs	50% ls/dol; off wh, gy, buff, xln-mic xln 40% sh; gy, brn gy, n calc, occ f lam 10% anhy	0.40

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
7230-7260	ctgs	95% sh; gy-lt gy, gy brn, occ red brn, n calc-sl calc, blky-sb fss 5% sltst; red, sl calc, blky Tr-anhy; dol; wh	1.26
7260-7280	ctgs	70% sh; gy-lt gy, gy brn, occ red brn, n calc-sl calc, blky-sb fss 30% sltst; red, n calc, blky Tr-anhy	0.93
7290-7310	ctgs	70% sh; gy-lt gy, gy brn, occ red brn, n calc-sl calc, blky-sb fss 20% sltst; red, n calc, blky 10% ss; wh-lt gy, fri	0.86
7320-7340	ctgs	60% sh; gy-gy brn, occ dk gy, n calc, fss-blky 35% sltst; rd, n calc 5% anhy; wh, sft, occ sug	0.68
7350-7370	ctgs	60% sh; rd, n calc, slty in pt, blky 40% sh; gy-gy brn, occ dk gy, n calc, fss-blky Tr-anhy; wh, sft, occ sug	0.71/0.70
7380-7400	ctgs	50% sh; rd, n calc, slty in pt, blky 50% sh; gy, occ dk gy, n calc fss-blky Tr-anhy; wh, sft, occ sug	0.36
7420-7440	ctgs	60% sh; gy-gy brn, occ dk gy, n calc, fss-blky 35% sh; rd, n calc, slty in pt, blky 5% anhy; wh, sft, occ sug	0.64

* TOC = Total Organic Carbon

Table I

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
6990-7010	ctgs	85% sh; gy, gy brn, occ red brn, n calc 15% ls; off wh, lt gy, gy brn, xln	1.09
7020-7040	ctgs	90% sh; gy-lt gy, gy brn, red brn, occ gn, n calc, sb fss-blky 10% ss; wh-lt gy Tr-qtz; orng; ls; brn, gy brn, mic xln	0.90
7050-7070	ctgs	Sh; gy-lt gy, gy brn, occ red brn, n calc-sl calc, blky-sb fss Tr-ss; wh; anhy; wh, sft	1.02
7080-7100	ctgs	Sh; gy-lt gy, gy brn, occ red brn, n calc-sl calc, blky-sb fss	1.17
7110-7140	ctgs	85% sh; gy-lt gy, gy brn, occ red brn, n calc-sl calc, blky-sb fss 15% sltst; red, sl calc, blky Tr-anhy	0.91/0.91
7140-7170	ctgs	90% sh; gy-lt gy, gy brn, occ red brn, n calc-sl calc, blky-sb fss 10% sltst; red, sl calc, blky Tr-anhy	0.98
7170-7200	ctgs	90% sh; gy-lt gy, gy brn, occ red brn, n calc-sl calc, blky-sb fss 10% sltst; red, sl calc, blky	0.92
7200-7230	ctgs	90% sh; gy-lt gy, gy brn, occ red brn, n calc-sl calc, blky-sb fss 10% sltst; red, sl calc, blky Tr-anhy	0.90

* TOC = Total Organic Carbon

CORE LAB

Table IV

VISUAL KEROGEN OBSERVATIONS

DATE FEB. 4, 1981

WELL SCHNEIDER #2

S.B.E.
JOB NO. 80201

DENVER BASIN STUDY

SCHNEIDER #2

X = >80%
/ = SECONDARY
* = ± 5-20%
T = TRACE

DEPTH	THERMAL ALTERATION INDEX						COLOR						KEROGEN TYPE						SPORINITE FLUORESCENCE COLOR						PRES			REMARKS
	1 UNALTERED	1+	2 SLIGHT ALTERATION 2+	3 MODERATE ALTERATION 3+	4 STRONG ALTERATION 4+	5 SEVERE ALTERATION	GREENISH LIGHT YELLOW	YELLOW	YELLOW - ORANGE	ORANGE - BROWN	LIGHT - BROWN	BROWN	DARK - BROWN	BLACK	ALGAL DEBRIS	AMORPHOUS DEBRIS	FINELY DISSEM. O.M.	HERB PLANT DEBRIS	WOODY PLANT DEBRIS	COALY FRAGMENTS	PALYNOMORPHS	GREEN	GREENISH YELLOW	YELLOW	SALLOW YELLOW	ORANGE	BROWN	BLACK	GOOD	FAIR	POOR	VERY POOR RECOVERY	BARREN OR O.M.	
7230 - 7260			X	.				X							X	T		*	*	T						T			X				
7630 - 7650			X	;				X							X	T		/	/	T					T				X				
8070 - 8090			X	?				X	?						X	T		*	*	T							T			X				

DEMSHUR AFTER BURGES (77)

Table II

Results of C_{15+} Extractable Organic Matter (EOM) Analysis

Depth (ft)	Sample Type	TOC (wt %)	EOM (ppm)	HC (ppm)	Composition of C_{15+} Extractable Organic Matter (Normalized Percent) F-1	F-2	F-3	CPI
7050-7070	ctgs	1.02	420	105	17.1	15.2	67.6	1.18
7260-7310	ctgs	0.95	360	60	13.0	11.7	75.3	1.10
7480-7500	ctgs	0.66	345	86	24.0	10.0	66.0	1.18
7660-7680	ctgs	0.70	195	64	30.3	11.8	57.9	1.13
7890-7940	ctgs	0.57	341	46	13.0	7.4	79.6	1.13
7980-8000	ctgs	0.78	1874	748	28.6	17.5	53.9	1.05
8100-8120	ctgs	0.40	221	57	33.9	8.9	57.1	1.13

TOC = Total Organic Carbon; EOM = Extractable Organic Matter (C_{15+}); HC = C_{15+} Hydrocarbons (saturates + aromatics); CPI = Carbon Preference Index (C_{24}-C_{34} carbon number range); F-1 = saturates; F-2 = aromatics; F-3 = asphaltics

Table III

Geochemical Ratios

Depth (ft)	$\frac{EOM}{TOC} \times 100$	$\frac{HC}{TOC} \times 100$	$\frac{HC}{EOM} \times 100$
7050-7070	4.1	1.0	25.0
7260-7310	5.2	0.6	16.7
7480-7500	5.2	1.3	24.9
7660-7680	2.8	0.9	32.8
7890-7940	6.0	0.8	13.5
7980-8000	24.0	9.6	39.9
8100-8120	5.5	1.4	25.8

TOC = Total Organic Carbon (ppm); EOM = C_{15+} Extractable Organic Matter (ppm); HC = C_{15+} Hydrocarbons (ppm)

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DC

Duplicate

Bio Study #962

OIL/SOURCE-ROCK STUDY

NORTHERN DENVER BASIN - PALEOZOIC

REPORT NO. 14

#3 14

SHELL/TRAVIS #18

15-16N-54W KIMBALL CO., NEBRASKA

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II. INTRODUCTION

Core Laboratories', Inc. geochemical study will determine the regional hydrocarbon source potential of the Permian and Pennsylvanian sections in the northern Denver basin. In addition, nine Permian and Pennsylvanian oils will be characterized to determine oil to oil and oil to source correlations. Fourteen (14) individual preliminary well reports and a crude oil correlation study will form the basis for our regional interpretation. These geochemical data from individual reports will be integrated into a geologic framework for the final report.

The Shell Travis #18 is located in Kimball County, Nebraska (15-16N-54W). Permian through Precambrian rocks were penetrated and a total of forty-one (41) samples from 6460 to 8440 feet were analyzed for organic richness, kerogen type and thermal maturity. Analytical techniques include measurement of total organic carbon, soxhlet extraction, liquid chromatographic separation of the extract on a silica gel column, and high resolution gas chromatography of the C_{10+} saturated hydrocarbon fraction performed on a glass capillary column. In addition, the insoluble organic matter (kerogen) was studied by transmitted and fluorescent light microscopy, vitrinite reflectance and elemental analysis.

Our report is organized in three parts: 1) Interpretation, 2) Graphical Displays and 3) Analytical Data. The Interpretation contains the written text of the report. This includes our conclusions stated in a Summary which precedes this Introduction. Following this Introduction is a more detailed Discussion of Results which provides an evaluation of the hydrocarbon source potential of the sedimentary section penetrated by the Shell Travis #18 well. This is followed by the description of our standard Analytical Procedures. The second part of the report contains Graphical Displays of the geochemical data. Figure 1 shows a graphical summary of the geochemical data. Figure 2 shows lithology and total organic carbon content. Figure 3 shows kerogen type and thermal maturity levels. The third section of the report contains the Analytical Data. Table I gives lithologic descriptions and total organic carbon content. Table II lists concentrations and compositions of the extractable organic

matter. Significant geochemical ratios are listed in Table III. Tables IV and V contain data on kerogen observations and vitrinite reflectance measurements, respectively. Table VI lists normalized n-paraffin distributions for the C_{15+} saturated hydrocarbons and Table VII lists the normalized isoprenoid distributions. Figure 4 is a gas chromatogram of the C_{10+} saturated hydrocarbon distribution.

I. SUMMARY

The Paleozoic sedimentary section from 6462 to 8440 feet in the Shell Travis #18 well, 15-16N-54W, Kimball County, Nebraska, was analyzed for hydrocarbon source potential. Forty-one (41) cuttings samples, composed primarily of red shales and carbonates, were analyzed. Lithologic tops provided by Shell were used to divide the Permian and Pennsylvanian sections into time stratigraphic units.

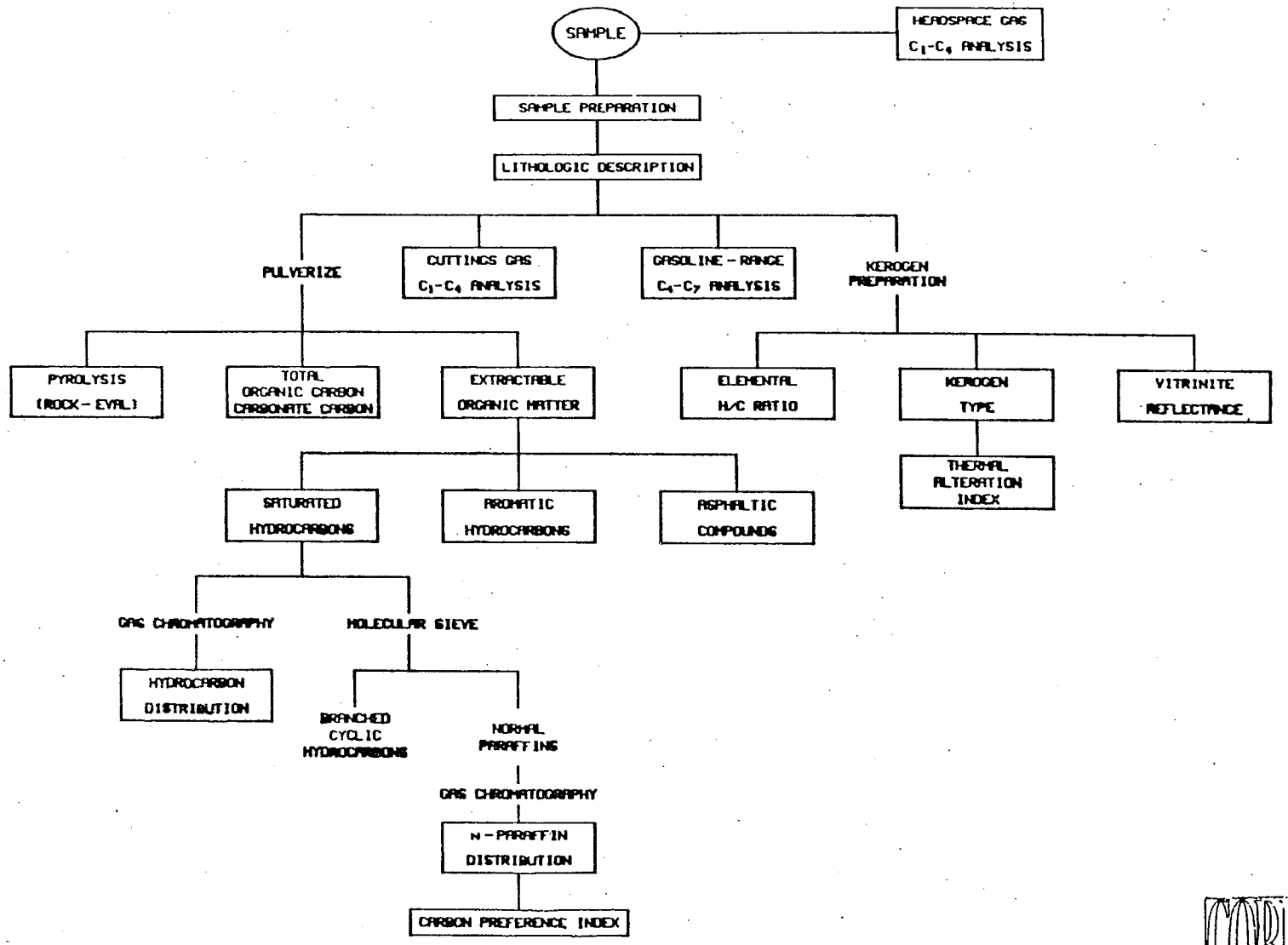
Guadalupian/Leonardian (6462-7190 feet), Wolfcampian (7190-7631 feet), Virgilian (7631-7732 feet) and Missourian (7732-7952 feet) sediments are organic-lean and have no hydrocarbon source potential. A Desmoinesian (7952-8428 feet) interval at 8030 to 8060 feet contains amorphous organic matter that is in the main phase of liquid hydrocarbon generation. This interval has a fair potential to generate petroleum. Precambrian (8428-8440 feet total depth) rocks are organic-lean and have no hydrocarbon source potential.

Geochemical data did not indicate the presence of migrated hydrocarbons in Permian or Pennsylvanian strata.

of the saturated hydrocarbon distribution for 8030-8060 feet contains a relatively narrow distribution and is not characteristic of most thermally mature, non-biologically altered crude oils.

Precambrian 8428-8440 feet total depth

The one Precambrian sample analyzed consists of shale and granite. These lithologies are organic-lean and have no hydrocarbon source potential.



ANALYTICAL SCHEME FOR SOURCE-BED EVALUATION

IV. DESCRIPTION OF ANALYTICAL PROCEDURES

SAMPLE PREPARATION

Cutting samples are thoroughly washed to remove drilling mud, and if necessary are placed in a solvent to float off contaminants, such as coals or drilling additives. The samples are then air-dried and are examined under a binocular microscope to remove any remaining contaminants. A magnet is used to remove any metal which may be present. The outside surface of sidewall and conventional core samples is removed and then the samples are thoroughly washed with water and allowed to air dry.

LITHOLOGICAL DESCRIPTION

A complete lithological description of each sample is made under a binocular microscope. All obvious cave material is removed and the sample submitted for total organic carbon analysis. The description includes an examination for migrated hydrocarbons under ultraviolet light.

TOTAL ORGANIC CARBON ANALYSIS (TOC)

Total organic carbon analysis measures the organic richness of a rock in weight percent organic carbon. Organic richness is the first requirement for an oil or gas source rock. The analysis is also used as a screening technique to determine which samples merit more detailed analysis. The dried rock samples are pulverized and treated with hot and cold hydrochloric acid to remove carbonates (inorganic carbon). After acid treatment, the organic carbon content is determined by combustion of the sample in a Leco WR-12 Carbon Analyzer. Blanks, standards, and duplicates are routinely run to insure highly reliable results.

EXTRACTION OF SOLUBLE ORGANIC MATTER (BITUMEN)

Soluble organic matter in a rock can result from the organic matter deposited with the rock or from the introduction of non-indigenous migrated hydrocarbons. It is important to know how much soluble organic matter is present for evaluating potential oil source rocks. The amount of indigenous soluble organic matter reflects the rock's total organic matter, type of organic matter, and thermal history. To determine

soluble organic matter concentration, powdered rock samples are placed in Soxhlet thimbles and extracted for 24 hours with chloroform. An aliquot of extracted material is then transferred to a pre-weighed container and the chloroform solvent is evaporated under nitrogen at 40°C. The concentration of the stabilized extract (soluble organic matter) residue is reported in parts per million.

LIQUID CHROMATOGRAPHIC SEPARATION

The composition of the soluble organic matter is determined by liquid chromatographic separation into saturated hydrocarbons, aromatic hydrocarbons, and asphaltic compounds. Compositional data is useful in evaluating oil source quality and thermal maturation. An aliquot of the soluble organic matter extract in chloroform is concentrated and iso-octane solvent is added. Concentration and addition of iso-octane is repeated until all chloroform has been removed without complete evaporation to dryness. The extract in iso-octane is then placed on a silica gel column and successively eluted with hexane, benzene, and benzene/methanol to determine % saturates, % aromatics, and % asphaltics.

GAS CHROMATOGRAPHY OF C_{10+} SATURATED HYDROCARBONS

The saturated hydrocarbon fraction from liquid chromatography is analyzed by gas chromatography before it is evaporated to dryness. This allows analysis of hydrocarbons below C_{15}. The distribution of C_{10+} saturated hydrocarbons documents whether petroleum-like hydrocarbons are present in a rock sample. A high resolution glass capillary column is used to separate the hydrocarbons. The temperature-programmed analysis is performed on a Hewlett Packard gas chromatograph equipped with a flame ionization detector. From the distribution of n-paraffins the Carbon Preference Index (CPI) is calculated according to the following equation:

$$C.P.I. = \frac{1}{2}\left[\frac{\sum_{25}^{33} \text{Odd-Carbon n-Paraffins}}{\sum_{26}^{34} \text{Even-Carbon n-Paraffins}} + \frac{\sum_{25}^{33} \text{Odd-Carbon n-Paraffins}}{\sum_{24}^{32} \text{Even-Carbon n-Paraffins}}\right]$$

The CPI is used to evaluate thermal maturity. Saturated hydrocarbon distributions are also useful for oil-to-source rock correlations. In addition to a gas chromatogram, the percent composition of n-paraffins, percent composition of isoprenoids, pristane/phytane ratio and Carbon Preference Index are reported from this analysis.

VISUAL KEROGEN ANALYSIS

High-powered microscope examination of kerogen in transmitted light and under ultraviolet light determines thermal maturation state and whether the type of organic matter is favorable for petroleum generation. The kerogen composition is reported as % alginite (algal and amorphous debris), % exinite (herbaceous plant debris and palynomorphs), % woody plant debris, and % coaly fragments. The ability of the various kerogen types to yield oil decreases in the following order: alginite - exinite - woody - coaly. The color (Thermal Alteration Index) of the spore and pollen grains present is also used as an indicator of thermal maturation level.

For visual kerogen analysis, standard palynological techniques are used to separate the kerogen from the rock matrix. The isolated organic matter (kerogen) is mounted on a glass slide and examined under a high-powered Leitz microscope.

VITRINITE REFLECTANCE

Vitrinite reflectance provides a method for determining the thermal alteration history of a sediment. Vitrinite particles, originating from wood, are found dispersed throughout most sedimentary rock samples which are younger than Silurian. Since vitrinite reflectance increases regularly with increased thermal alteration, a reflectance measurement can be used to determine the degree of thermal maturation of that sediment.

Kerogen is prepared for vitrinite reflectance by imbedding the isolated kerogen in a bioplastic plug. The hardened plug is polished and the reflectance of the individual vitrinite particles are measured under a microscope. A histogram of reflectance values for each sample is reported.

ELEMENTAL ANALYSIS OF KEROGEN (H/C)

Chemical analysis of kerogen is used to characterize the type of organic matter present in a sediment in terms of its oil or gas generating potential. Kerogens with a high hydrogen content or high H/C ratio tend to generate oil. To measure the elemental composition, isolated kerogen is combusted in a Perkin-Elmer Elemental Analyzer. This method provides a direct, calibrated measurement for characterizing the kerogen type present in a sediment. The results are reported as % hydrogen, % carbon, % nitrogen and H/C ratio.

FIGURE 1

GEOCHEMICAL SUMMARY PROFILE

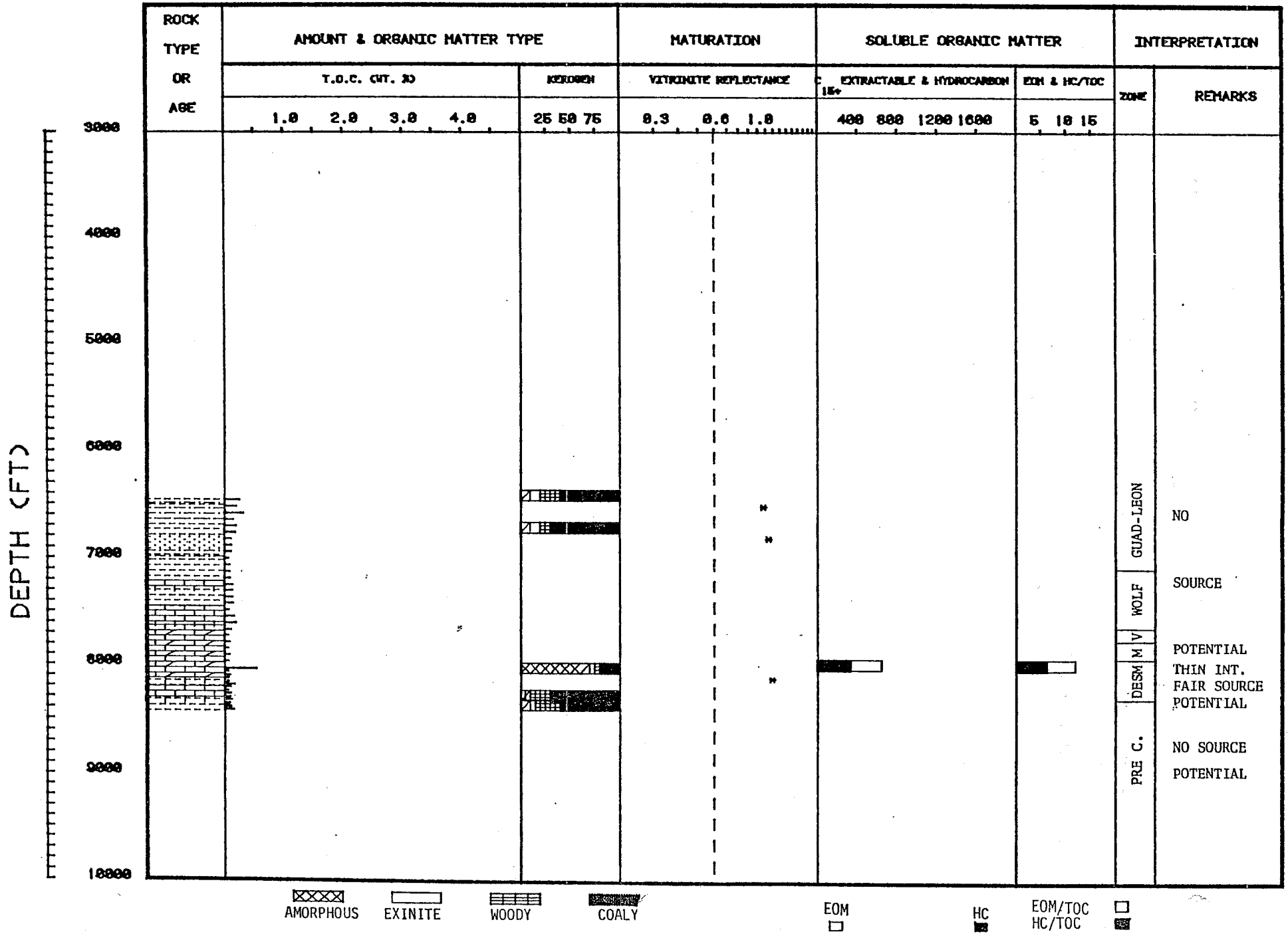


FIGURE 2

TOTAL ORGANIC CARBON CHARACTERIZATION

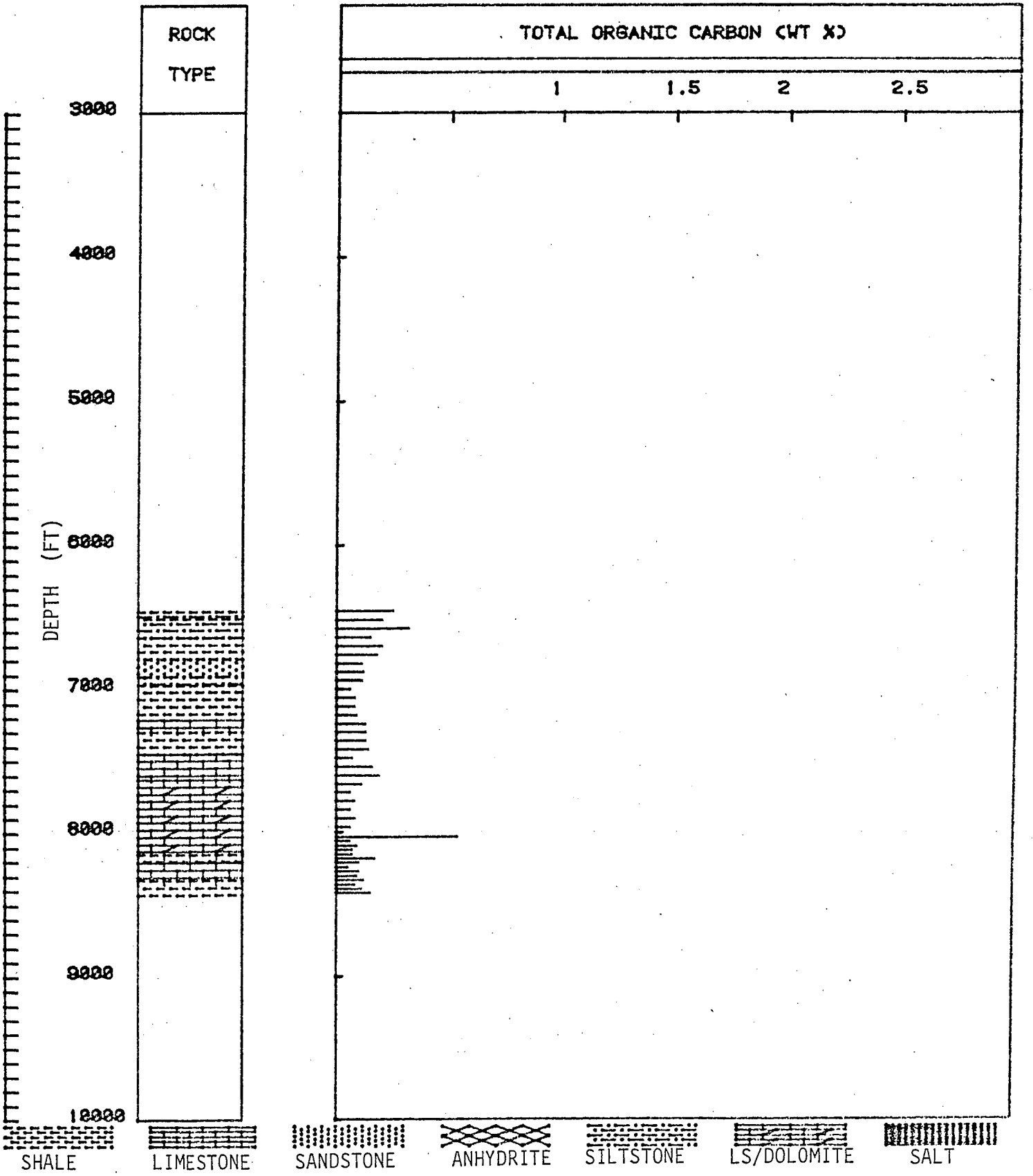


FIGURE 3

SOLUBLE ORGANIC MATTER CHARACTERIZATION

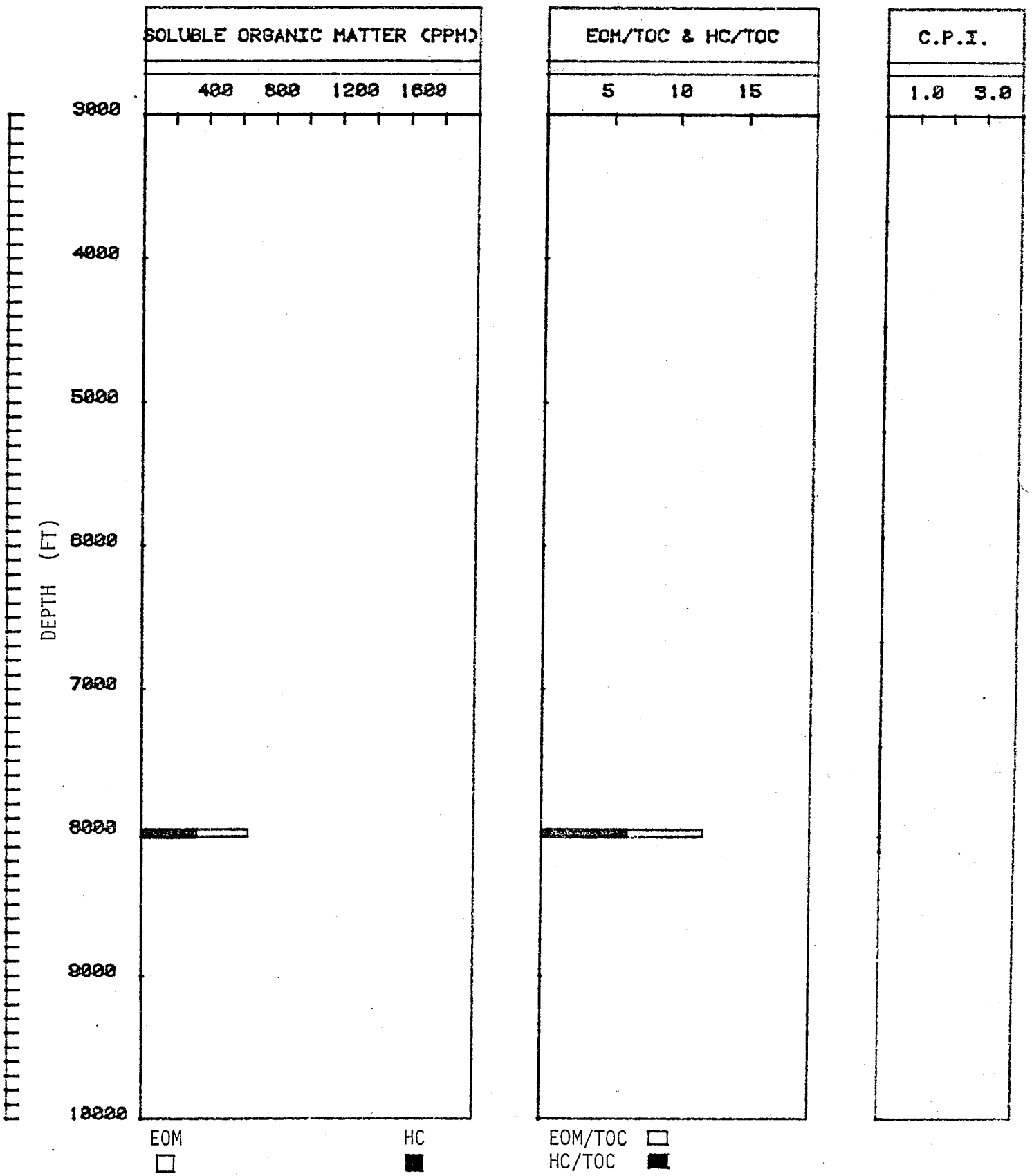


Table II

Results of C_{15+} Extractable Organic Matter (EOM) Analysis

Depth (ft)	Sample Type	TOC (wt %)	EOM (ppm)	HC (ppm)	Composition of C_{15+} Extractable Organic Matter (Normalized Percent) F-1	F-2	F-3	CPI
8030-8060	ctgs	0.54	649	340	31.6	20.8	47.6	- -

TOC = Total Organic Carbon; EOM = Extractable Organic Matter (C_{15+}); HC = C_{15+} Hydrocarbons (saturates + aromatics); CPI = Carbon Preference Index (C_{24}-C_{34} carbon number range); F-1 = saturates; F-2 = aromatics; F-3 = asphaltics

Table III

Geochemical Ratios

Depth (ft)	$\frac{EOM}{TOC} \times 100$	$\frac{HC}{TOC} \times 100$	$\frac{HC}{EOM} \times 100$
8030-8060	12.0	6.3	52.4

TOC = Total Organic Carbon (ppm); EOM = C_{15+} Extractable Organic Matter (ppm); HC = C_{15+} Hydrocarbons (ppm)

Table IV

VISUAL KEROGEN OBSERVATIONS

DATE APRIL 30, 1981

WELL TRAVIS

S.B.E.
JOB NO. 80212

X = >80%
/ = SECONDARY
* = ± 5-20%
T = TRACE

DENVER BASIN STUDY

TRAVIS

DEPTH	THERMAL ALTERATION INDEX									COLOR							KEROGEN TYPE						SPORINITE FLUORESCENCE COLOR							PRES				REMARKS
	1 UNALTERED	1+	2 SLIGHT ALTERATION	2+	3 MODERATE ALTERATION	3+	4 STRONG ALTERATION	4+	5 SEVERE ALTERATION	GREENISH LIGHT YELLOW	YELLOW	YELLOW - ORANGE	ORANGE - BROWN	LIGHT - BROWN	BROWN	DARK - BROWN	BLACK	ALGAL DEBRIS	AMORPHOUS DEBRIS	FINELY DISPERSED O.M.	HERB PLANT DEBRIS	WOODY PLANT DEBRIS	COALY FRAGMENTS	PALYNOMORPHS	GREEN	GREENISH YELLOW	YELLOW	PALLOW YELLOW	ORANGE	BROWN	BLACK	GOOD	FAIR	POOR	VERY POOR RECOVERY	BARREN OR O.M.	
6460 - 6490				/	X							X						*			/	X	*					T				X				ABUNDANT PENN. FLORA
6760 - 6790				/	X							X						*			*	X	*					T				X				ABUNDANT PENN. FLORA
8030 - 8060				/	X							X						X			*	*	T					T				X				
8330 - 8360				/	X	/						X						T			*	X	T					T				X				
8420 - 8440				/	X	/						X						*	T	*	*	X	T					T				X				

DEMSHUR AFTER BURGESS (77)

FIGURE 4

KEROGEN TYPE

THERMAL MATURITY

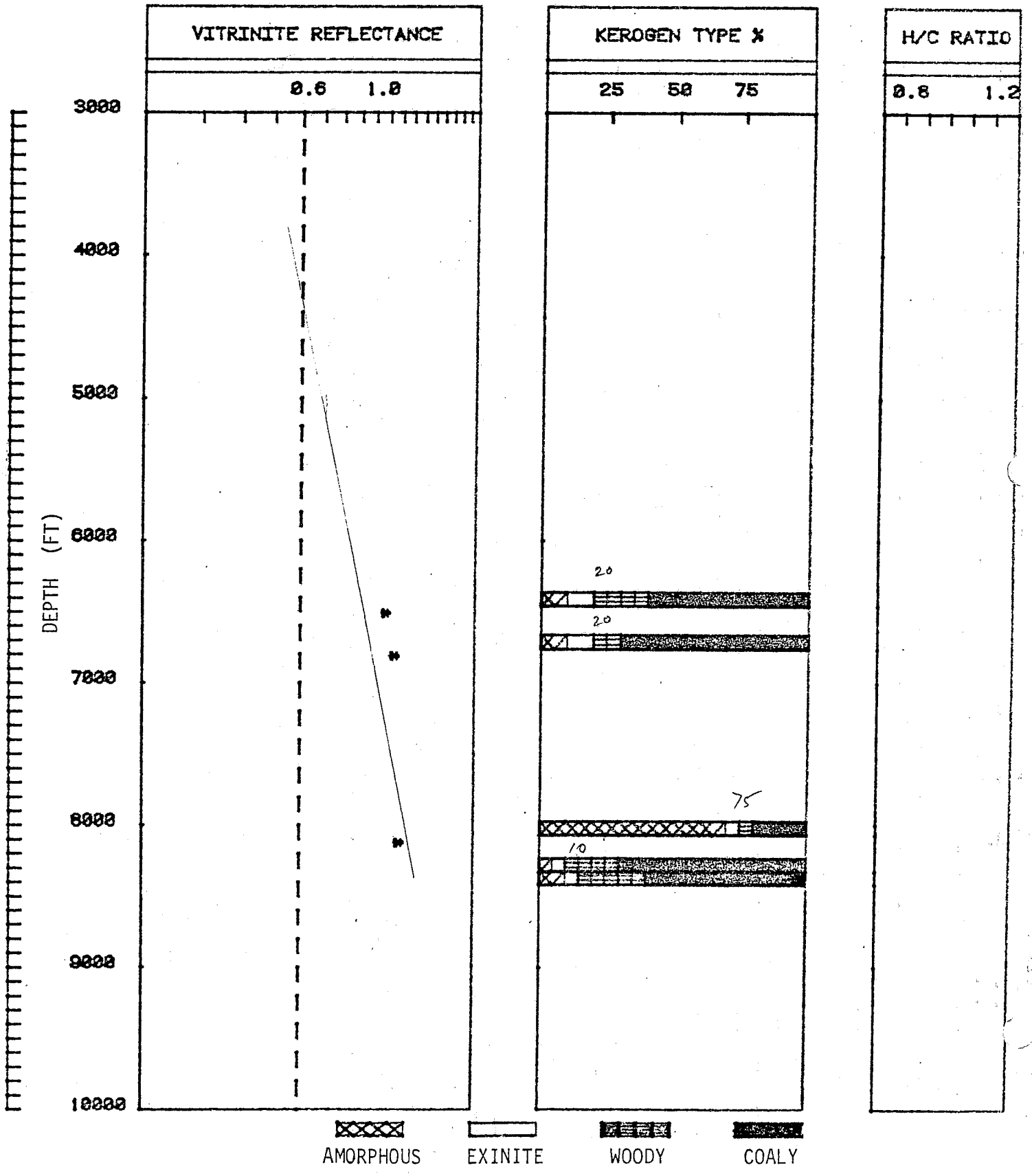
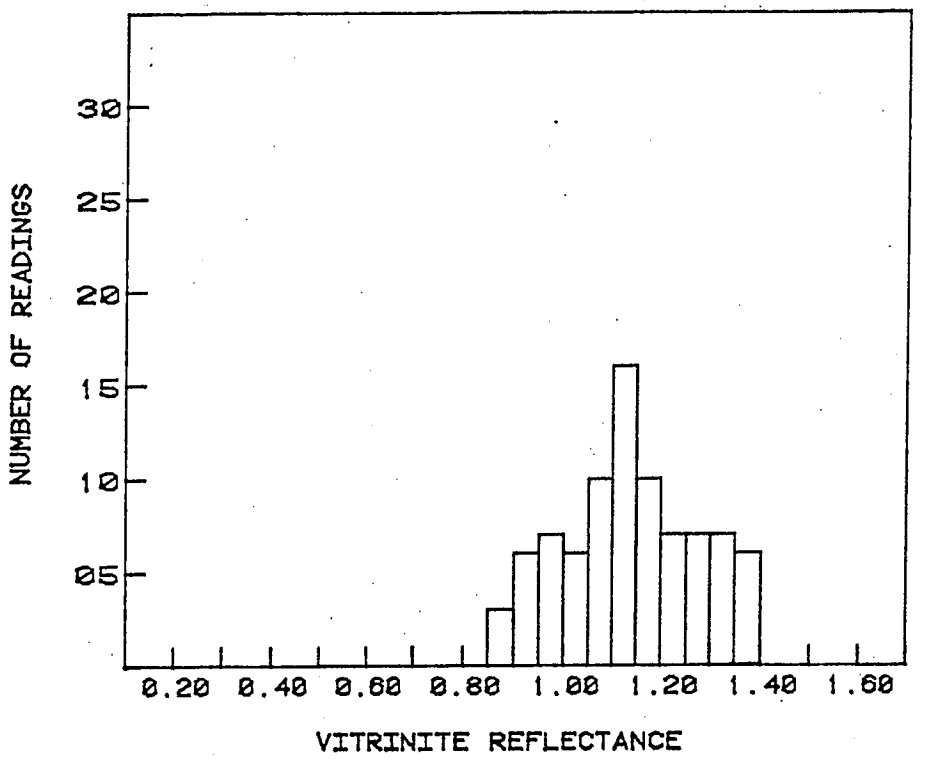


Table V

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

TRAVIS #18

DEPTH:6460-6490 FEET

MEAN REF.:1.13%

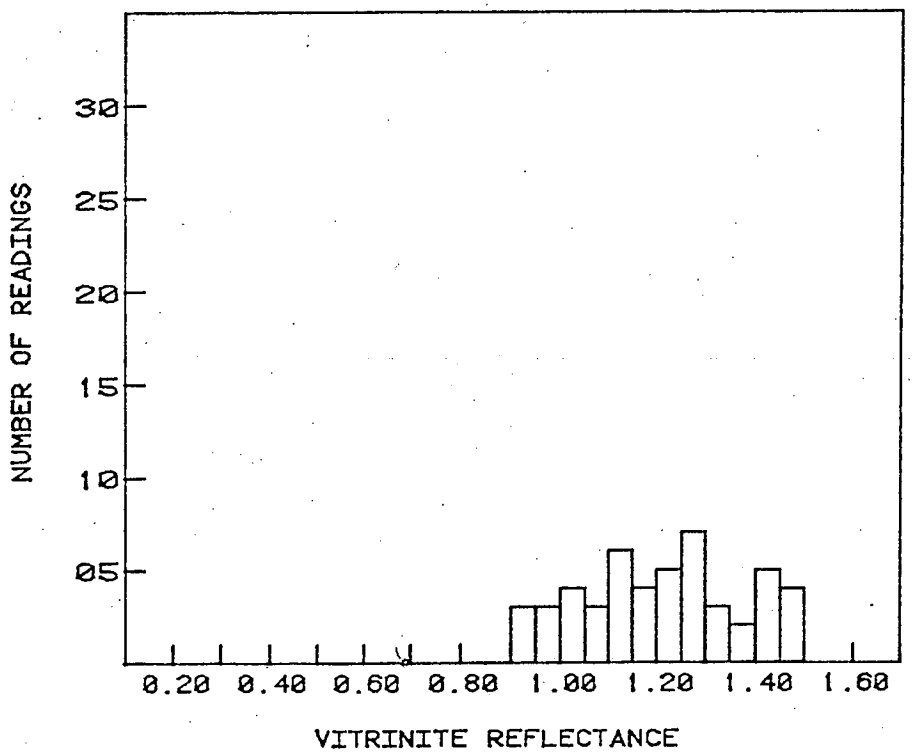
MAX. REF.:1.39%

MIN. REF.:0.86%

READINGS:83

SAMPLE:CUTTINGS

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

TRAVIS #18

DEPTH:6760-6790 FEET

MEAN REF.:1.20%

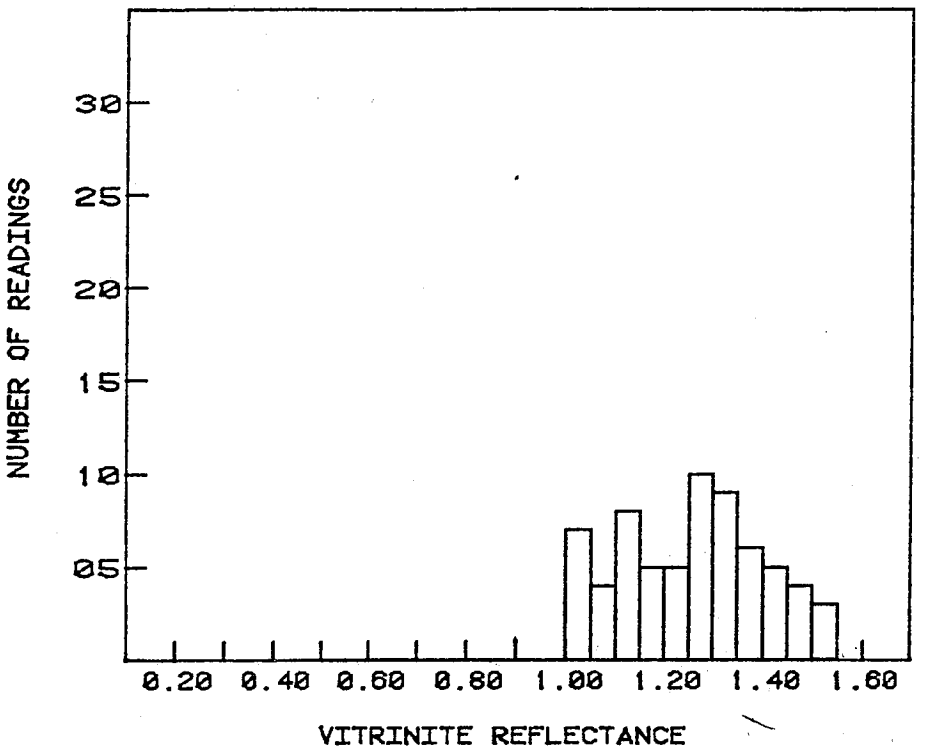
MAX. REF.:1.49%

MIN. REF.:0.90%

READINGS:49

SAMPLE:CUTTINGS

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

TRAVIS #18

DEPTH: 8020-8060 FEET

MEAN REF.: 1.25%

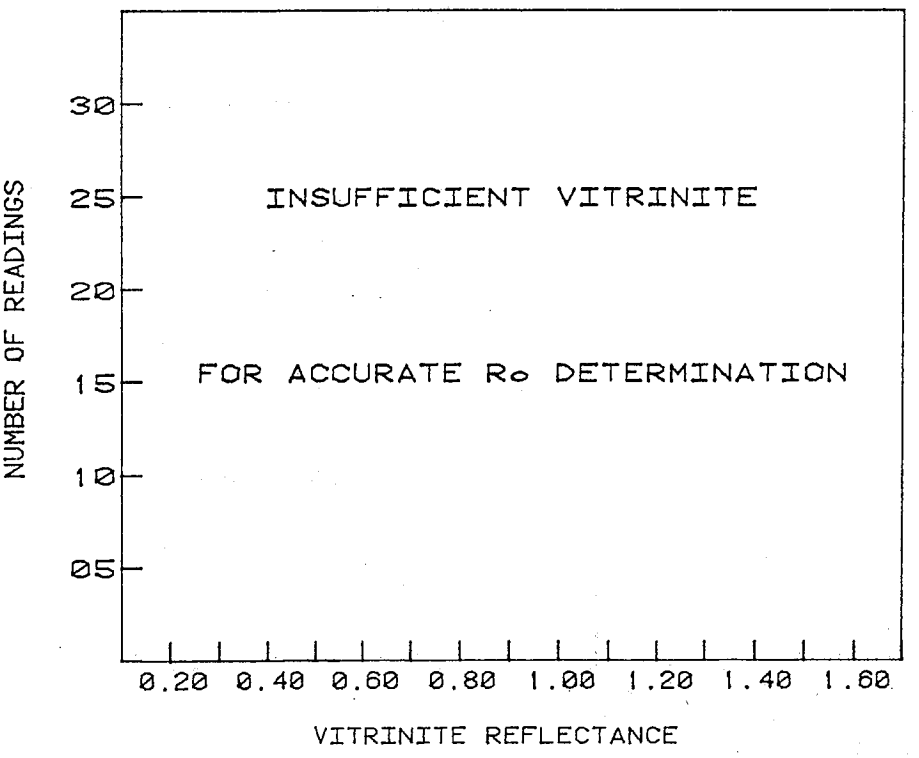
MAX. REF.: 1.54%

MIN. REF.: 1.01%

READINGS: 66

SAMPLE: CUTTINGS

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

TRAVIS #18

DEPTH: 8330-8360 FEET

MEAN REF.: ----%

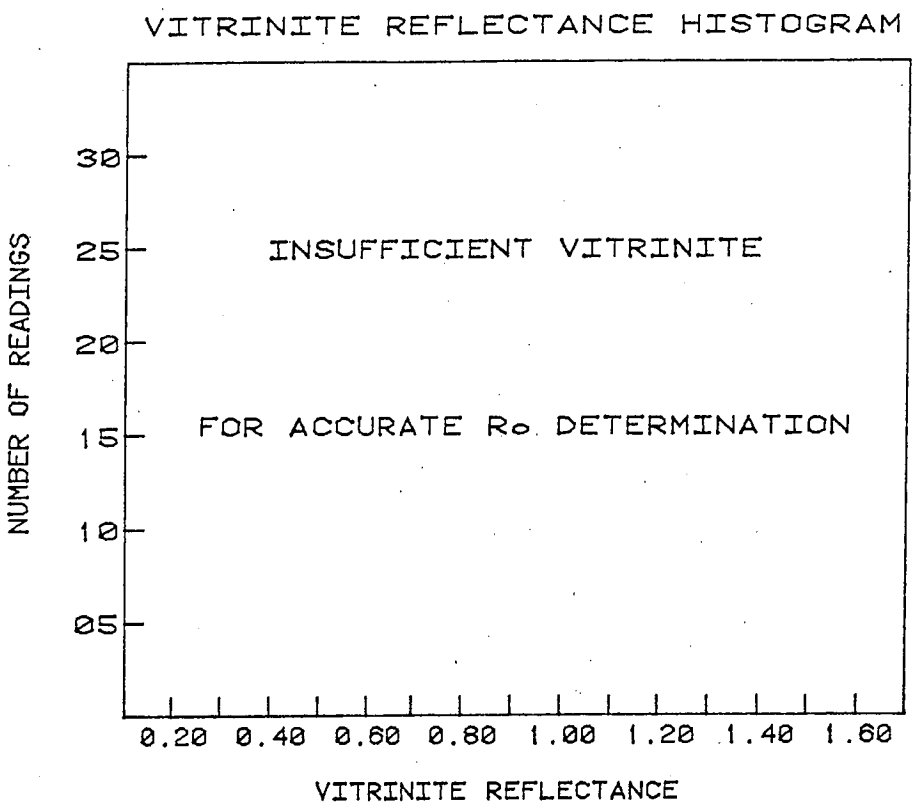
MAX. REF.: ----%

MIN. REF.: ----%

READINGS: 0

SAMPLE: CUTTINGS

Table V (cont.)



DENVER BASIN STUDY

TRAVIS #18

DEPTH: 8420-8440 FEET

MEAN REF.: ----%

MAX. REF.: ----%

MIN. REF.: ----%

READINGS: 0

SAMPLE: CUTTINGS

FIGURE 5

Travis #18

C_{10+} Saturated Hydrocarbon Fraction

8030-8060 feet

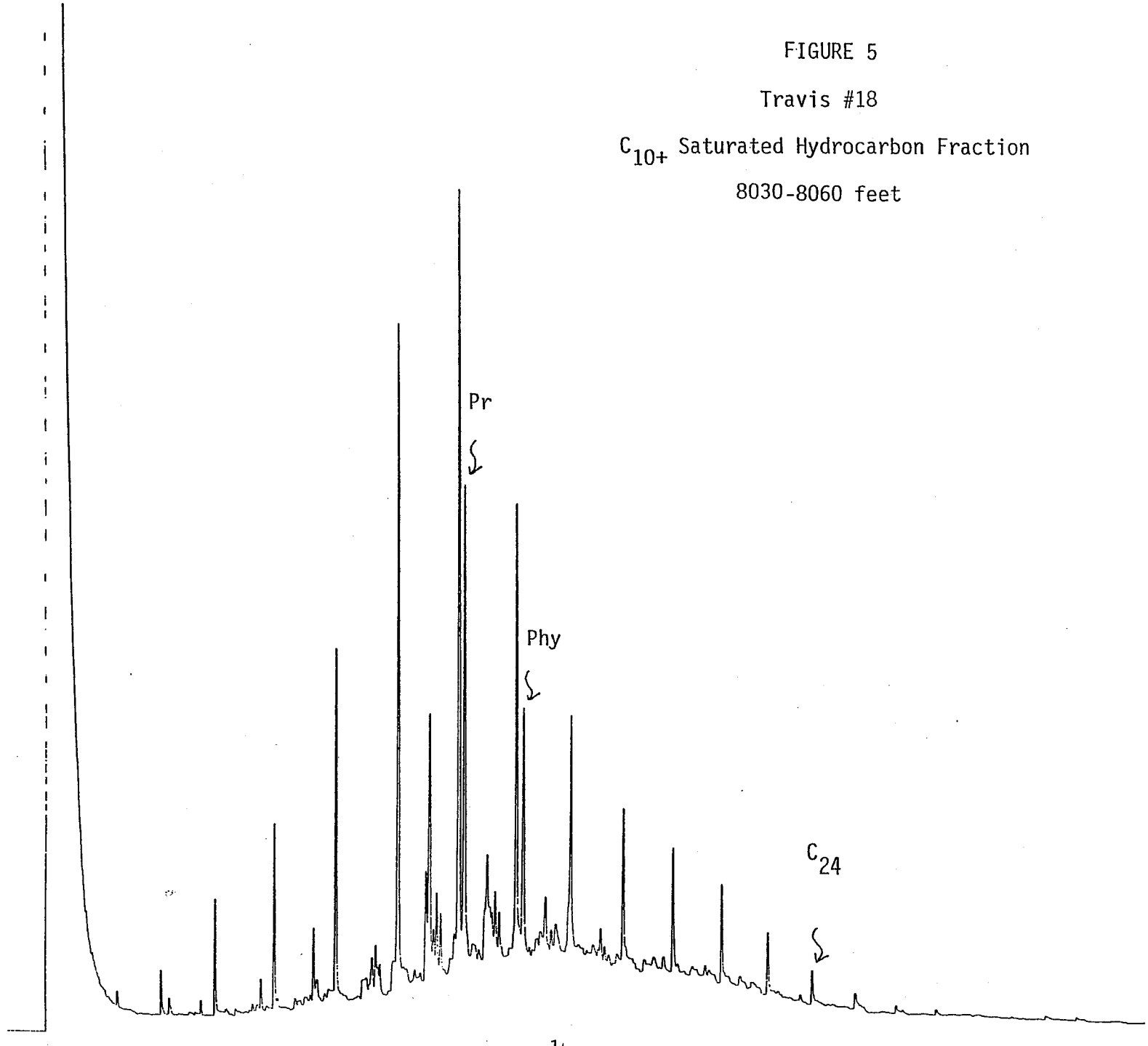


Table I

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
6460-6490	ctgs	75% sh; gy, occ gn-gy, n calc, sub fss-fss 25% sltst; rd, n calc, blky Tr-anhy; wh, suc	0.25
6520-6550	ctgs	65% sltst; rd, n calc, blky 30% sh; gy, occ gn-gy, n calc, sub fss-fss 5% anhy; wh, suc	0.20
6580-6610	ctgs	95% sltst; rd, n calc, blky 5% sh; gy, occ gn-gy, n calc, sub fss-fss Tr-anhy; wh, suc	0.32
6640-6670	ctgs	Clyst; rd, n calc, blky, v sft Tr-sh; gy, occ gn-gy, n calc, sub fss-fss; anhy; wh, suc	0.15
6700-6730	ctgs	95% clyst/sltst; rd, n calc, blky 5% sh; gy, occ gn-gy, n calc, sub fss-fss Tr-anhy; wh, suc	0.20
6760-6790	ctgs	50% sh; gy, occ dk gy, n calc, blky-sub fss 50% clyst/sltst; rd, n calc, blky Tr-anhy; wh, suc	0.18/0.18
6820-6850	ctgs	60% ss/sd; wh trans, m gr, mod srtd 40% clyst/sltst; rd, n calc, blky Tr-anhy; wh, suc; sh; gy, occ dk gy, n calc, blky-sub fss	0.11
6940-6970	ctgs	60% ss/sd; wh trans, m gr, mod srtd 40% clyst/sltst; rd, n calc, blky Tr-anhy; wh, suc; sh; gy, occ dk gy, n calc, blky-sub fss	0.09

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
6880-6910	ctgs	60% ss/sd; wh trans, m gr, mod srtd 40% clyst/sltst; rd, n calc, blky Tr-anhy; wh, suc; sh; gy, occ dk gy, n calc, blky-sub fss	0.12
6940-6970	ctgs	90% sltst; rd, n calc, blky 10% anhy; wh, suc	0.11
7000-7030	ctgs	75% sh; lt rd, orng, sl calc, blky, anhy 25% anhy; wh, suc, gran in pt, occ xln	0.06
7060-7090	ctgs	95% sh; lt rd, orng, sl calc, blky, anhy 5% anhy; wh, suc, gran in pt, occ xln Tr-sh; gy, n calc, blky	0.08
7120-7150	ctgs	95% sh; lt rd, orng, sl calc, blky, anhy 5% anhy; wh, suc, gran in pt, occ xln	0.08
7180-7215	ctgs	95% sh; lt rd, orng, sl calc, blky, anhy 5% anhy; wh, suc, gran in pt, occ xln	0.09/0.08
7240-7265	ctgs	60% ls; wh, chky, sft 30% sh; lt rd, orng, sl calc, blky, anhy 5% anhy; wh, suc, gran in pt, occ xln 5% dol; lt gy, xln, suc	0.13
7300-7330	ctgs	90% sh; rd, sl calc, blky, anhy 5% sh; gy, n calc, blky-sub fss 5% anhy Tr-ls; wh, chky, sft; dol; lt gy, xln, suc	0.13
7360-7390	ctgs	70% sh; rd, sl calc, blky, anhy 25% ls; wh, chky, sft 5% anhy; wh, suc, gran in pt, occ xln Tr-sh; gy; n calc, blky-sub fss; dol; lt gy, xln, suc	0.13

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
7900-7930	ctgs	Ls/dol; off wh, lt gy, occ crm, xln-chky, occ suc Tr-sh; rd, orng, sl calc, blky	0.08
7960-7990	ctgs	75% ls/dol; off wh, lt gy, occ crm, xln-chky, occ suc 25% sd; trans, mlky, sub rnd	0.06
8030-8060	ctgs	50% ls/dol; dk gy-blk, xln, occ cht 45% Ls/dol; off wh, lt gy, occ crm, xln-chky, occ suc 5% sh/sltst; blk, carb, dol in pt	0.54
8060-8090	ctgs	90% ls/dol; off wh-wh, lt pk, occ dk gy, xln, occ chky 10% sh/sltst; lt rd, orng, sl calc, blky	0.06
8090-8120	ctgs	80% ls/dol; off wh-wh, lt pk, occ dk gy, xln, occ chky 20% sh/sltst; lt rd, orng, sl calc, blky	0.09/0.08
8120-8150	ctgs	50% ls/dol; off wh-wh, lt pk, occ dk gy, xln, occ chky 50% sd; trans, clr, sub rnd	0.07
8150-8180	ctgs	50% ls/dol; off wh-wh, lt pk, occ dk gy, xln, occ chky 50% sd; trans, clr, sub rnd	0.07
8180-8210	ctgs	40% sh; rd, orng, sl calc, blky, v sft 30% ls/dol; off wh-wh, lt pk, occ dk gy, xln, occ chky 20% sd; trans, clr, sub rnd 10% ss; dk rd-lt pk, m gr	0.17

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
7420-7450	ctgs	70% sh; rd, orng, sl calc, blky, anhy 25% anhy; wh, chky in pt, occ xln, suc 5% sh; gy, n calc, blky, sub fss Tr-ls; dk gy, f xln	0.14
7480-7510	ctgs	Ls; crm, occ lt gy, mst chky, occ dol, xln in pt Tr-sh, rd, orng, sl calc, blky, anhy	0.07
7540-7570	ctgs	50% sh; lt gy, calc, blky, sft 40% Ls; crm, occ lt gy, mst chky, occ dol, xln in pt 10% sh; rd, orng, sl calc, blky, anhy	0.16
7600-7630	ctgs	85% ls; crm, dk gy, chky in pt, xln in pt 15% sh; rd, orng, sl calc, blky, anhy Tr-dol; lt brn, xln	0.19
7660-7690	ctgs	95% ls/dol; off wh, lt gy, occ crm, xln-chky, occ suc 5% sh; rd, orng, sl calc, blky, anhy	0.11/0.10
7720-7750	ctgs	Ls/dol; off wh, lt gy, occ crm, xln-chky, occ suc Tr-sh; rd, orng, sl calc, blky, anhy	0.06
7780-7810	ctgs	Ls/dol; off wh, lt gy, occ crm, xln-chky, occ suc, vug in pt Tr-sh; rd, orng, sl calc, blky, anhy	0.08
7840-7870	ctgs	Ls/dol; off wh, lt gy, occ crm, xln-chky, occ suc, vug in pt Tr-sh; rd, orng, sl calc, blky, anhy	0.06

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
8210-8240	ctgs	80% ls/dol; off wh-wh 15% sh; rd, orng, sl calc, blky, v sft 5% ss; dk rd-lt pk, m gr	0.10
8240-8270	ctgs	95% ls; off wh-lt gy, xln 5% sh; rd, orng, sl calc, blky, v sft Tr-sh; gy, gn-gy, dk rd-brn	0.05
8270-8300	ctgs	50% ls; off wh-lt gy, xln 50% sh; gy, rd-brn, occ gn, n calc, sub fss-blky Tr-sh; rd, n calc, blky, v sft	0.10
8300-8330	ctgs	50% ls; off wh-lt gy, xln 50% sh; gy, rd-brn, occ gn, n calc, sub fss-blky	0.09
8330-8360	ctgs	80% sh; rd-brn, gy, occ gn, rd, n calc, sub fis 20% ls; wh-lt gy, occ rd, xln	0.12/0.11
8360-8390	ctgs	50% sh; rd-brn, gy, occ gn, rd, n calc, sub fis 30% ls; wh-lt gy, occ rd, xln 20% sh; lt rd, orng, n calc, blky, v sft Tr-ss; wh, rd, m gr, w srtd, cht, off wh	0.08
8390-8420	ctgs	45% sh; rd-brn, gy, occ gn, n calc, sb 40% sh; lt rd, orng, n calc, blky, v sft 10% sd/ss; wh, rd, occ trans, m gr, w srtd 5% cht; buff, lt pk Tr-Crin	0.11
8420-8440	ctgs	50% sh; lt rd, orng, n calc, blky, v sft 30% sh; gy, rd, brn, gy, gn, n calc, sub fss 20% gran; feld, bio, xln	0.15

* TOC = Total Organic Carbon

FILE - DG FILE

DUPLICATE

BIOSTUDY #962

OIL/SOURCE-ROCK STUDY
NORTHERN DENVER BASIN - PALEOZOIC
REPORT NO. 5
CONOCO/PERKINS #1
23-25N-57W, SIOUX CO., NEBRASKA

5

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I. SUMMARY

The Paleozoic sedimentary section from 6610 to 8700 feet in the Conoco Perkins #1 well, 23-25N-57W, Sioux County, Nebraska, was analyzed for hydrocarbon source potential. Seventy-seven (77) cuttings samples, composed of shales, carbonates, siltstones and anhydrites, were analyzed. Lithologic tops provided by Conoco were used to divide the Permian and Pennsylvanian sections into time stratigraphic units.

Guadalupian/Leonardian rocks (6605-7360 feet) from 6610 to 6940 feet have good organic richness. These shales are dominated by marginally-mature woody and coaly kerogen and would be minor sources for petroleum hydrocarbons at optimum thermal maturity. Wolfcampian (7360-7860 feet) rocks are organic-lean have no hydrocarbon source potential. Virgilian/Missourian (7860-7995 feet) and Desmoinesian (7995-8250 feet) carbonate sequences contain thin intervals with fair organic richness. These intervals require deeper burial to reach optimum thermal maturity. Atokan/Morrowan (8250-8480 feet), Mississippian (8480-8560 feet) and Precambrian (8560-8700 feet) intervals are organic-lean and do not have the potential to generate commercial quantities of hydrocarbons.

Migrated hydrocarbons are suggested in the Virgilian/Missourian at 7920-7950 feet and in the Desmoinesian at 8025 feet and 8076 feet.

II. INTRODUCTION

Core Laboratories', Inc. geochemical study will determine the regional hydrocarbon source potential of the Permian and Pennsylvanian sections in the northern Denver basin. In addition, nine Permian and Pennsylvanian oils will be characterized to determine oil to oil and oil to source correlations. Fourteen (14) individual preliminary well reports and a crude oil correlation study will form the basis for our regional interpretation. These geochemical data from individual reports will be integrated into a geologic framework for the final report.

The Conoco Perkins #1 is located in Sioux County, Nebraska (23-25N-57W). Permian through Precambrian rocks were penetrated from 6605 to 8700 feet and a total of seventy-seven (77) samples were analyzed for organic richness, kerogen type and thermal maturity. Analytical techniques include measurement of total organic carbon, soxhlet extraction, liquid chromatographic separation of the extract on a silica gel column, and high resolution gas chromatography of the C_{10+} saturated hydrocarbon fraction performed on a glass capillary column. In addition, the insoluble organic matter (kerogen) was studied by transmitted and fluorescent light microscopy, vitrinite reflectance and elemental analysis.

Our report is organized in three parts: 1) Interpretation, 2) Graphical Displays and 3) Analytical Data. The Interpretation contains the written text of the report. This includes our conclusions stated in a Summary which precedes this Introduction. Following this Introduction is a more detailed Discussion of Results which provides an evaluation of the hydrocarbon source potential of the sedimentary section penetrated by the Conoco Perkins #1 well. This is followed by the description of our standard Analytical Procedures. The second part of the report contains Graphical Displays of the geochemical data. Figure 1 shows a graphical summary of the geochemical data. Figure 2 shows lithology and total organic carbon content. The soluble organic matter is characterized in Figure 3. Figure 4 shows kerogen type and thermal maturity levels. The third section of the report contains the Analytical Data. Table I gives lithologic descriptions and total organic carbon content. Table II lists

concentrations and compositions of the extractable organic matter. Significant geochemical ratios are listed in Table III. Tables IV and V contain data on kerogen observations and vitrinite reflectance measurements, respectively. Table VI shows elemental hydrogen to carbon ratios for the kerogen. Table VII lists normalized n-paraffin distributions for the C_{15+} saturated hydrocarbons and Table VIII lists the normalized isoprenoid distributions. Figures 5 through 12 are gas chromatograms of the C_{10+} saturated hydrocarbon distributions.

III. DISCUSSION OF RESULTS

Guadalupian/Leonardian 6605-7360 feet

Guadalupian/Leonardian cuttings samples from 6610 to 6940 feet contain an average of 1.03% total organic carbon and have good organic richness. Intervals from 7140 to 7350 feet consist primarily of red siltstones that lack sufficient organic matter for favorable hydrocarbon source potential.

Guadalupian/Leonardian shales are dominated by hydrogen-deficient gas-prone woody and coaly kerogen. This organic material is marginally mature based on a thermal alteration index of 2+ and a 0.86% maximum mean vitrinite reflectance measurement. Elemental hydrogen to carbon ratios for the kerogen average 0.84 indicating only limited potential to generate liquid hydrocarbons.

Concentrations of extractable organic matter and total hydrocarbons average 362 ppm and 91 ppm, respectively. These levels probably reflect the dominance of gas-prone woody kerogen and they are below those usually associated with favorable oil source rocks. Gas chromatograms of the saturated hydrocarbon fractions have an average carbon preference index of 1.29 and are characteristic of marginally mature sediments. Higher temperatures, associated with deeper burial, are required for rocks between 6610-6940 feet to reach optimum maturity and be considered a minor source of petroleum hydrocarbons.

Wolfcampian 7360-7860 feet

The sixteen (16) Wolfcampian cuttings samples analyzed consist primarily of red siltstones, coarse-grained sandstones and evaporites. These lithologies are organic-lean and do not have the potential to generate commercial quantities of petroleum.

Virgilian/Missourian 7860-7995 feet

In general, Virgilian/Missourian cuttings samples are limestones, dolomites and shales that do not contain sufficient organic richness for favorable hydrocarbon source potential. The limestone intervals at 7920-7950 feet and

7980-8010 feet (top of Desmoinesian section occurs at 7995 feet) contain an average of 0.31% total organic carbon and have fair organic richness for carbonates. These intervals contain predominantly woody kerogen that is in the early phases of gaseous hydrocarbon generation. This is based on a thermal alteration index of 2+ and a 0.84% maximum mean vitrinite reflectance measurement.

The concentration of extractable organic matter for cuttings at 7920-7950 feet is 880 ppm. The extractability (EOM/TOC x 100) for this interval is 31.4 and indicates the presence of non-indigenous hydrocarbons. The saturated hydrocarbon distribution has relatively large quantities of the heavier molecular weight paraffins and even carbon predominance.

Desmoinesian 7995-8250 feet

In general, Desmoinesian cuttings and core samples are composed primarily of organic-lean limestones and dolomite that do not have the potential to generate commercial quantities of hydrocarbons. Only carbonate cores at 8029, 8065, 8069, 8076 and 8194 feet and a cuttings interval at 8196-8320 feet contain fair quantities of organic carbon. These rocks are dominated by a mixture of amorphous and woody kerogen. Desmoinesian intervals at this depth are in the early stages of petroleum generation based on a thermal alteration index of 2+ and a 0.84% maximum mean reflectance measurement. Elemental hydrogen to carbon ratios for the kerogen ranges from 1.02 to 0.68 reflecting the different types of kerogen present with Desmoinesian rocks.

The extractable organic matter concentrations for samples at 8029, 8069, 8194 and 8196-8230 feet are below those required for favorable petroleum source facies. The core samples at 8025 and 8076 contain 2716 ppm and 871 ppm extractable organic matter, respectively. Relatively high extractability ratios suggest the presence of non-indigenous, migrated hydrocarbons. Saturated hydrocarbon distributions contain greater quantities of the isoprenoids pristane and phytane relative to normal C_{17} and normal C_{18}, respectively. The distribution at 8025 feet is associated with a thermally mature petroleum mixture. The chromatogram at 8076 feet has unresolved napthenic and sterane regions which are characteristic of thermally immature sediments.

Atokan/Morrowan 8250-8480 feet

The seven Atokan/Morrowan cuttings samples analyzed contain an average of 0.09% total organic carbon and have no hydrocarbon source potential.

Mississippian 8480-8560 feet

The three Mississippian carbonate intervals analyzed are organic-lean and do not have the potential to generate significant quantities of petroleum.

Precambrian 8560-8700 feet total depth

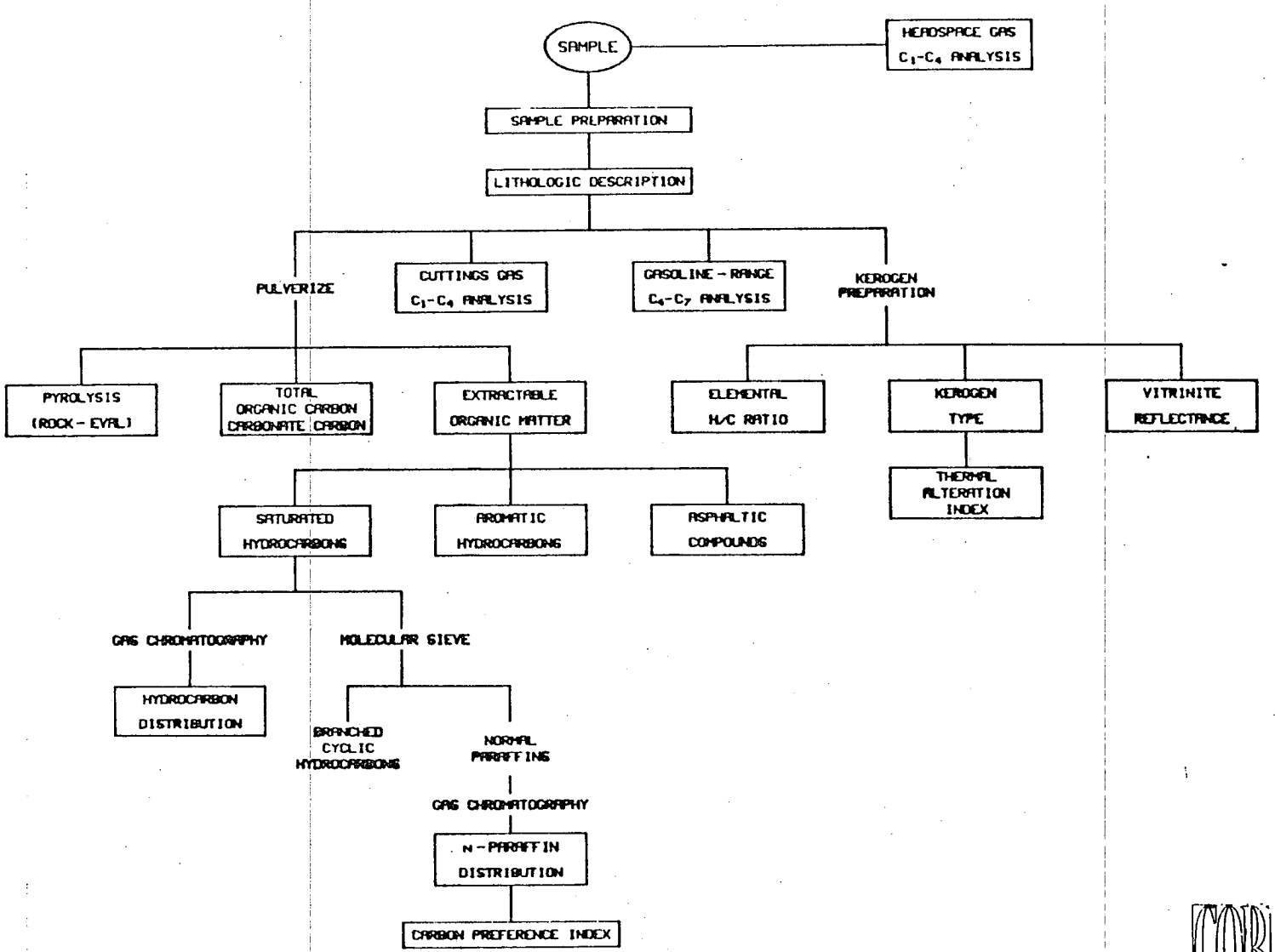
The Precambrian cuttings samples analyzed lack sufficient organic richness for favorable hydrocarbon source potential.

IV. ANALYTICAL PROGRAM

The following analytical program was used in determining the hydrocarbon source potential of Paleozoic intervals in the Denver basin.

The quantity of total organic carbon is determined by combustion of pre-treated, carbonate-free, pulverized samples in a Leco WR-12 Analyzer. Generally, no further analyses are performed on samples having total organic carbon content values of less than 0.3% for carbonates and 0.5% for fine-grained clastic sediments. Samples with sufficient total organic carbon content are then analyzed for kerogen type, vitrinite reflectance and C_{15+} extractable organic matter content. If the concentration of the extract is less than 200 ppm, no further analyses are performed on the samples. Samples with extractable organic matter concentrations greater than 200 ppm are then characterized by liquid and gas chromatography analyses.

A description of the analytical procedures used by Core Lab's Geochemical Services Department follows this analytical program.



ANALYTICAL SCHEME FOR SOURCE-BED EVALUATION

DESCRIPTION OF ANALYTICAL PROCEDURES

SAMPLE PREPARATION

Cutting samples are thoroughly washed to remove drilling mud, and if necessary are placed in a solvent to float off contaminants, such as coals or drilling additives. The samples are then air-dried and are examined under a binocular microscope to remove any remaining contaminants. A magnet is used to remove any metal which may be present. The outside surface of sidewall and conventional core samples is removed and then the samples are thoroughly washed with water and allowed to air dry.

LITHOLOGICAL DESCRIPTION

A complete lithological description of each sample is made under a binocular microscope. All obvious cave material is removed and the sample submitted for total organic carbon analysis. The description includes an examination for migrated hydrocarbons under ultraviolet light.

TOTAL ORGANIC CARBON ANALYSIS (TOC)

Total organic carbon analysis measures the organic richness of a rock in weight percent organic carbon. Organic richness is the first requirement for an oil or gas source rock. The analysis is also used as a screening technique to determine which samples merit more detailed analysis. The dried rock samples are pulverized and treated with hot and cold hydrochloric acid to remove carbonates (inorganic carbon). After acid treatment, the organic carbon content is determined by combustion of the sample in a Leco WR-12 Carbon Analyzer. Blanks, standards, and duplicates are routinely run to insure highly reliable results.

EXTRACTION OF SOLUBLE ORGANIC MATTER (BITUMEN)

Soluble organic matter in a rock can result from the organic matter deposited with the rock or from the introduction of non-indigenous migrated hydrocarbons. It is important to know how much soluble organic matter is present for evaluating potential oil source rocks. The amount of indigenous soluble organic matter reflects the rock's total organic matter, type of organic matter, and thermal history. To determine

soluble organic matter concentration, powdered rock samples are placed in Soxhlet thimbles and extracted for 24 hours with chloroform. An aliquot of extracted material is then transferred to a pre-weighed container and the chloroform solvent is evaporated under nitrogen at 40°C. The concentration of the stabilized extract (soluble organic matter) residue is reported in parts per million.

LIQUID CHROMATOGRAPHIC SEPARATION

The composition of the soluble organic matter is determined by liquid chromatographic separation into saturated hydrocarbons, aromatic hydrocarbons, and asphaltic compounds. Compositional data is useful in evaluating oil source quality and thermal maturation. An aliquot of the soluble organic matter extract in chloroform is concentrated and iso-octane solvent is added. Concentration and addition of iso-octane is repeated until all chloroform has been removed without complete evaporation to dryness. The extract in iso-octane is then placed on a silica gel column and successively eluted with hexane, benzene, and benzene/methanol to determine % saturates, % aromatics, and % asphaltics.

GAS CHROMATOGRAPHY OF C_{10+} SATURATED HYDROCARBONS

The saturated hydrocarbon fraction from liquid chromatography is analyzed by gas chromatography before it is evaporated to dryness. This allows analysis of hydrocarbons below C_{15}. The distribution of C_{10+} saturated hydrocarbons documents whether petroleum-like hydrocarbons are present in a rock sample. A high resolution glass capillary column is used to separate the hydrocarbons. The temperature-programmed analysis is performed on a Hewlett Packard gas chromatograph equipped with a flame ionization detector. From the distribution of n-paraffins the Carbon Preference Index (CPI) is calculated according to the following equation:

$$C.P.I. = \frac{1}{2}\left[\frac{\sum_{25}^{33}\ \text{Odd-Carbon n-Paraffins}}{\sum_{26}^{34}\ \text{Even-Carbon n-Paraffins}} + \frac{\sum_{25}^{33}\ \text{Odd-Carbon n-Paraffins}}{\sum_{24}^{32}\ \text{Even-Carbon n-Paraffins}}\right]$$

The CPI is used to evaluate thermal maturity. Saturated hydrocarbon distributions are also useful for oil-to-source rock correlations. In addition to a gas chromatogram, the percent composition of n-paraffins, percent composition of isoprenoids, pristane/phytane ratio and Carbon Preference Index are reported from this analysis.

VISUAL KEROGEN ANALYSIS

High-powered microscope examination of kerogen in transmitted light and under ultraviolet light determines thermal maturation state and whether the type of organic matter is favorable for petroleum generation. The kerogen composition is reported as % alginite (algal and amorphous debris), % exinite (herbaceous plant debris and palynomorphs), % woody plant debris, and % coaly fragments. The ability of the various kerogen types to yield oil decreases in the following order: alginite - exinite - woody - coaly. The color (Thermal Alteration Index) of the spore and pollen grains present is also used as an indicator of thermal maturation level.

For visual kerogen analysis, standard palynological techniques are used to separate the kerogen from the rock matrix. The isolated organic matter (kerogen) is mounted on a glass slide and examined under a high-powered Leitz microscope.

VITRINITE REFLECTANCE

Vitrinite reflectance provides a method for determining the thermal alteration history of a sediment. Vitrinite particles, originating from wood, are found dispersed throughout most sedimentary rock samples which are younger than Silurian. Since vitrinite reflectance increases regularly with increased thermal alteration, a reflectance measurement can be used to determine the degree of thermal maturation of that sediment.

Kerogen is prepared for vitrinite reflectance by imbedding the isolated kerogen in a bioplastic plug. The hardened plug is polished and the reflectance of the individual vitrinite particles are measured under a microscope. A histogram of reflectance values for each sample is reported.

ELEMENTAL ANALYSIS OF KEROGEN (H/C)

Chemical analysis of kerogen is used to characterize the type of organic matter present in a sediment in terms of its oil or gas generating potential. Kerogens with a high hydrogen content or high H/C ratio tend to generate oil. To measure the elemental composition, isolated kerogen is combusted in a Perkin-Elmer Elemental Analyzer. This method provides a direct, calibrated measurement for characterizing the kerogen type present in a sediment. The results are reported as % hydrogen, % carbon, % nitrogen and H/C ratio.

FIGURE 1
GEOCHEMICAL SUMMARY PROFILE

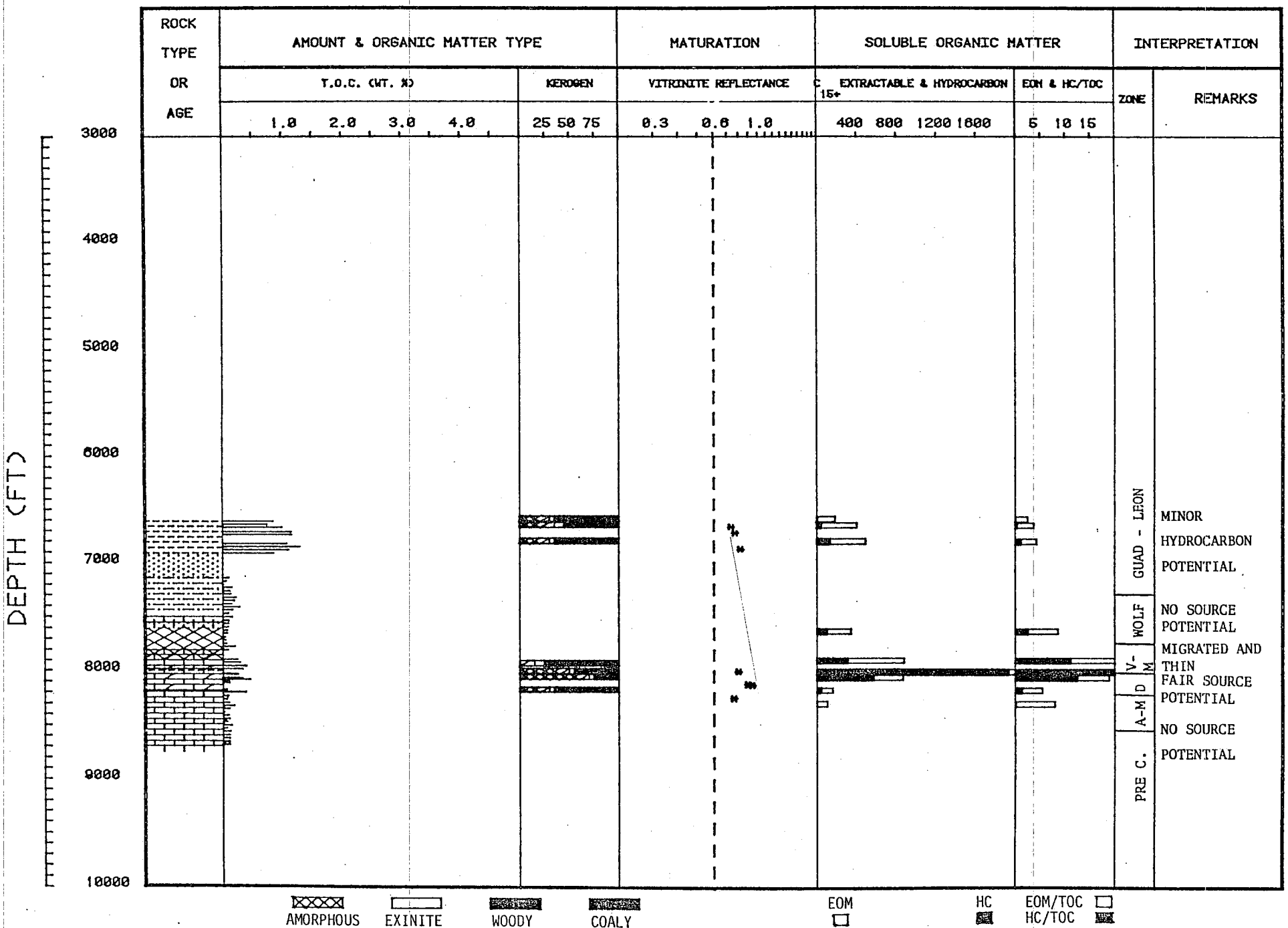


FIGURE 2

TOTAL ORGANIC CARBON CHARACTERIZATION

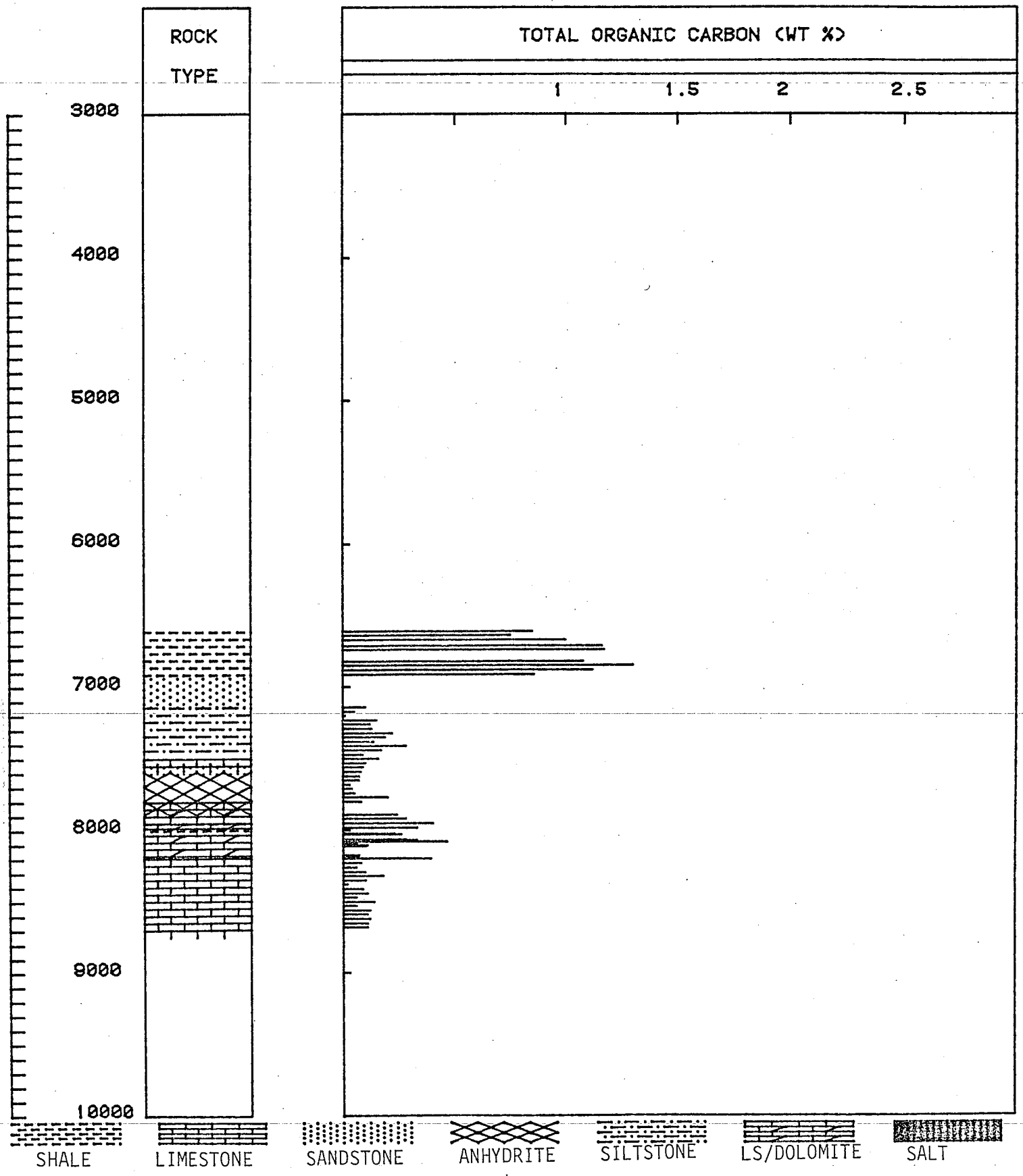


FIGURE 3

SOLUBLE ORGANIC MATTER CHARACTERIZATION

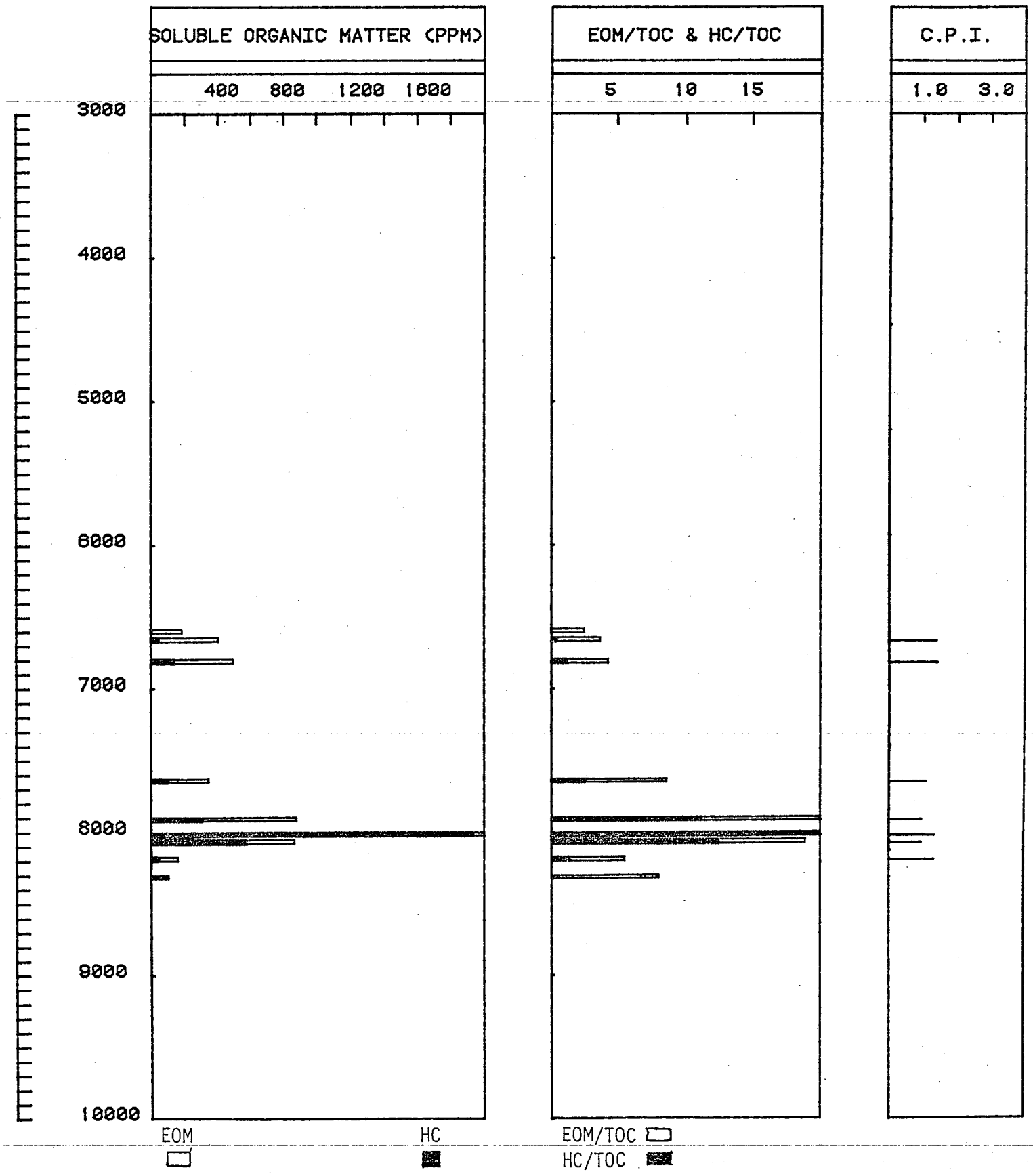
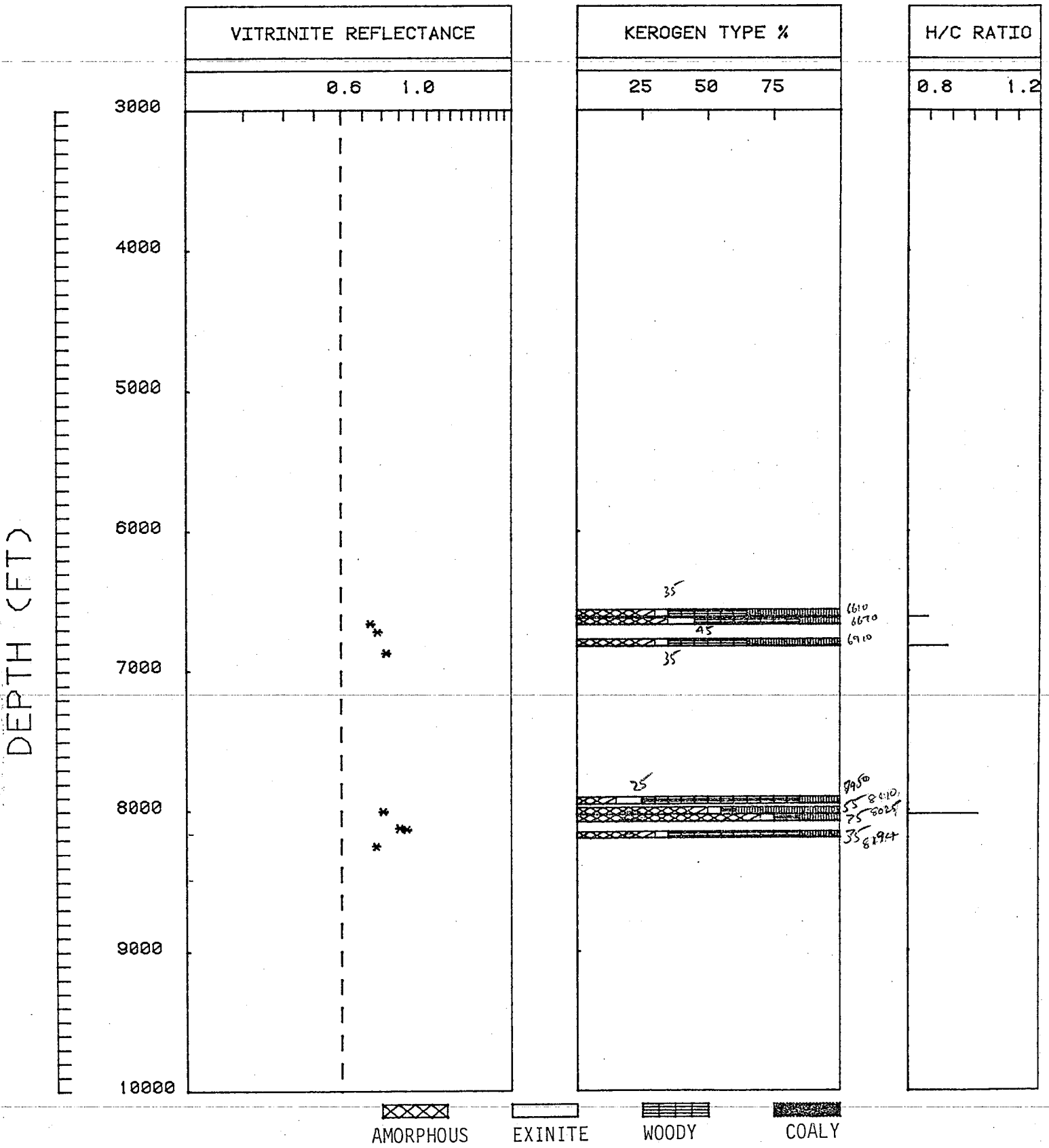


FIGURE 4

KEROGEN TYPE

THERMAL MATURITY



Table

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
6610-6640	ctgs	65% sh; gy-dk gy, occ blk, n calc, sub fis-blky 20% sltst; rd, n calc, blky 10% anhy; wh, gran, occ chky	0.85
6640-6670	ctgs	Sh; gy-dk gy, occ blk, n calc, sub fis-blky Tr-anhy; wh, gran, occ chky; sltst; rd, n calc, blky	0.75
6670-6700	ctgs	Sh; gy-dk gy, occ blk, n calc, sub fis-blky Tr-anhy; wh, gran, occ chky	1.00
6710-6740	ctgs	Sh; gy-dk gy, occ blk, n calc, sub fis-blky Tr-anhy; wh, gran, occ chky	1.16
6740-6770	ctgs	60% Sal (rem) 30% sh; gy-dk gy 10% clyst; off wh, /sal xln, v sft	1.17
6820-6850	ctgs	70% sh; gy-dk gy, brn gy, n calc, sub fss-blky 20% clyst; lt brn, occ gn, n calc, blky 10% sltst; rd, n calc, blky Tr-anhy	1.08
6850-6880	ctgs	90% sh; gy-dk gy, brn gy, n calc, sub fss-blky 5% clyst; lt brn, occ gn, n calc, blky 5% sltst; rd, n calc, blky Tr-anhy	1.30
6880-6910	ctgs	60% sh; gy-dk gy, n calc, sub fss-blky 40% ss; off wh, rd, pk, p srtd, anhy	1.12

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
6910-6940	ctgs	60% ss; off wh, rd, pk, p srtd, anhy 40% sh; gy-dk gy, n calc, sub fss-blky	0.86/0.86
7140-7170	ctgs	Sltst; rd, n calc, anhy, blky Tr-sh; gy-dk gy, n calc, sub fss-blky	0.10
7170-7200	ctgs	Sltst; rd, n calc, anhy, blky Tr-sh; gy-dk gy, n calc, sub fss-blky	0.05
7200-7230	ctgs	Sltst; rd, n calc, anhy, blky Tr-sh; gy-dk gy, n calc, sub fss-blky	0.01
7230-7260	ctgs	Sltst; rd, n calc, anhy, blky Tr-sh; gy-dk gy, n calc, sub fss-blky	0.15/0.16
7260-7290	ctgs	Sltst; rd, n calc, anhy, blky Tr-sh; gy-dk gy, n calc, sub fss-blky	0.12
7290-7320	ctgs	Sltst; rd, n calc, anhy, blky Tr-sh; gy-dk gy, n calc, sub fss-blky	0.13
7320-7350	ctgs	Sltst; rd, n calc, anhy, blky Tr-sh; gy-dk gy, n calc, sub fss-blky	0.22/0.22 7/12/83
7350-7370	ctgs	90% sltst; rd, n calc, anhy, blky 5% sh; gy-dk gy, n calc, sub fss-blky 5% anhy	0.19
7380-7410	ctgs	Sltst; rd, n calc, anhy, blky Tr-anhy; xln, clr, wh, gran, occ chky; sh; dk gy-blk, n calc, sub fss-blky	0.14
7410-7440	ctgs	90% sltst/ss; rd, n calc, anhy, blky 10% anhy; wh, chky, xln	0.28

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
7440-7470	ctgs	80% sltst/ss; rd, n calc, anhy, blky 10% ss; wh, clr, pk, w-rnd, w srtd 10% dol; off wh, lt pk, brn, xln, suc Tr-sh; gy-dk gy, n calc, sub fss-blky	0.17
7470-7500	ctgs	Sltst/ss; rd, n calc, anhy, blky Tr-anhy; xln, clr, wh, gran, occ chky	0.09
7500-7530	ctgs	80% ls; off wh-lt brn, occ dk brn, mic xln-xln 20% sltst/ss; rd, n calc, anhy, blky Tr-sh; gy-dk gy, n calc, sub fss-blky	0.16
7530-7560	ctgs	40% ss; off wh-lt gy, f gr, w srtd 30% ls; off wh-lt brn, occ dk brn, mic xln-xln 20% anhy; wh, chky, occ gran 10% sltst/ss; rd, n calc, anhy, blky	0.10
7560-7590	ctgs	45% ss; off wh-lt gy, f gr, w srtd 40% ls; off wh-lt brn, occ dk brn, mic xln-xln 10% sltst; rd, n calc, anhy, blky 5% anhy; wh, chky, occ gran	0.09/0.10
7590-7620	ctgs	45% anhy; wh, chky 30% ls; gy-lt brn, xln, occ dol 15% sltst/ss; rd, n calc, blky 10% ss; off wh, f-m gr, w srtd	0.08
7620-7650	ctgs	50% anhy; wh, chky 30% sltst/ss; rd, n calc, blky 10% ls; gy-lt brn, xln, occ dol 10% ss; off wh-lt brn, f-m gr, w srtd	0.07

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
7650-7680	ctgs	50% anhy; wh, chky 30% sltst/ss; rd, n calc, blky 10% ls; gy-lt brn, xln, occ dol 10% ss; off wh-lt brn, f-m gr, w srtd	0.07
7680-7710	ctgs	75% anhy; wh, chky 25% dol; lt brn, xln, suc Tr-sltst/ss; rd, n calc, blky	0.03
7710-7740	ctgs	75% anhy; wh, chky 25% dol; lt brn, xln, suc Tr-sltst/ss; rd, n calc, blky	0.04/0.03
7740-7770	ctgs	75% anhy; wh, chky 25% dol; lt brn, xln, suc Tr-sltst/ss; rd, n calc, blky	0.05
7770-7800	ctgs	50% anhy; wh, chky 50% dol; lt gy, xln, occ anhy Tr-ss; off wh, f gr, w srtd; sltst; rd	0.20
7800-7830	ctgs	75% dol; lt gy, xln, occ anhy 25% anhy; wh, chky Tr-ss; off wh, f gr, w srtd; sltst; rd	0.08
7890-7920	ctgs	70% dol; lt gy-gy brn, f xln, frag in pt, styol 20% anhy; wh, chky 10% sh; gy, occ dk rd brn, n calc, sub fss-blky Tr-sltst; rd, n calc, blky, anhy	0.24
7920-7950	ctgs	75% ls/dol; lt gy-gy brn, occ blk, xln, occ yel fluor 20% sh; gy, occ dk rd brn, n calc, sub fss-blky 5% anhy; wh, chky	0.28

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
7950-7980	ctgs	50% sh; dk gy-blk, occ brn, n calc, fss 35% ls; lt brn-gy brn, f xln 10% sltst/sh; rd, n calc, blky 5% anhy; wh, chky	0.40
7980-8010	ctgs	70% ls/dol; gy-lt brn, xln, occ suc 20% sh; dk gy-blk, occ brn, n calc, fss 10% sltst; orng, n calc, blky Tr-anhy	0.33
8021.5	core	Dol; gy brn, f xln-xln, anhy, occ/blk org(?) lay	0.10
8025	core	Dol; brn, f xln-xln	0.23
8028.5	core	Dol; gy brn, f xln-xln, /blk org(?) lay	0.06/0.07
8029	core	Dol; gy brn, f xln-xln/blk org(?) lay, anhy in pt Note: TOC value reflects chip of 50% anhy/blk org(?) lay	0.26
8065	core	Ls/dol; gy brn, f xln	0.28
8066	core	Ls; gy brn, f xln-xln	0.07
8068	core	Ls; gy brn, f xln-xln	- -
8069	core	Dol; dk gy, f xln-mic xln, mica	0.33
8076	core	50% dol; gy brn, f xln-mic xln, lay/ 50% cht; blk, dol in pt	0.46

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
8077	core	Dol; brn, f xln-mic xln, /occ vn of c xln, dol, hd	0.20/0.21
8078	core	Dol; brn, f xln-mic xln/anhy	0.04
8079	core	Dol; brn f xln-mic xln	- -
8080	core	Ls; gy brn, f xln	0.05
8081	core	Ls; gy brn, f xln	0.04
8089.6	core	Ls/dol; lt brn, f xln-mic xln, arg in pt, slty, pos oil(?) stn in pt	0.06
8106	core	Ls/dol; lt brn, f xln-mic xln, arg in pt, slty, anhy, pos oil(?) stn in pt	0.11
8107	core	Ls/dol; lt brn, f xln-mic xln, arg in pt, slty, anhy, pos oil(?) stn, abnt pyr assoc	0.05
8108	core	Ls/dol; lt gy, f xln, arg, anhy, poss oil(?) stn	0.10
8109	core	Ls/dol; lt gy, f xln, arg	0.07
8140	core	Anhy; wh, xln	- -
8172	core	Ls; lt gy brn, xln	0.03
8173	core	Ls; lt gy brn, xln/lam of dk brn mat	0.07

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
8193	core	Ls; lt gy brn, xln/lam of dk brn mat	0.07
8194	core	Ls; lt gy brn/lam of dk brn mat, wxy lus; assoc/abnt pyr & blue gy cht, conc frac	0.39
8195	core	Ls; dk brn, f xln, ool in pt	0.04
8196-8230	ctgs	40% sh; dk gy-blk, occ rd brn, n calc, sub fss-fss 40% ls; off wh-gy brn, xln 20% sltst; orng, n calc, blky Tr-anhy; wh, chky occ gran; cht; blue gy	0.29/0.29
8230-8260	ctgs	70% ls; lt brn-gy, xln 20% ss; off wh, f gr, w srtd 10% sltst; orng, n calc, blky Tr-sh; dk gy-blk, n calc, sub fss-fss; cht; off wh, gy, bl	0.08
8260-8290	ctgs	40% sltst/sh; orng, n calc, blky 30% ls; lt brn-gy, xln 30% ss; off wh, f gr, w srtd Tr-sh; dk gy-blk, n calc, sub fss-fss; cht; off wh, gy, bl	0.06
8290-8320	ctgs	70% ls; gy-lt brn, occ off wh, xln, dol in pt 20% sltst/sh; orng, n calc, blky 5% anhy; wh, chky 5% sh; dk gy-blk, n calc, sub fss-fss Tr-cht; off wh, gy, bl	0.10
8320-8350	ctgs	85% ls; gy-lt brn, occ off wh, xln, dol in pt 10% sltst/ss; orng, n calc, blky 5% sh; dk gy-blk, n calc, sub fss-fss Tr-cht; off wh, gy, bl	0.18

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
8350-8380	ctgs	90% ls; wh-lt gy brn, crypt xln, v hd 10% sltst/ss; orng, n calc, blky Tr-cht; off wh, gy, bl	0.10
8380-8410	ctgs	Ls; wh-lt gy brn, crypt xln, v hd Tr-cht; off wh, gy, bl	0.02
8410-8440	ctgs	Ls; wh-lt gy brn, crypt xl, v hd Tr-cht; sltst; orng; sh; dk gy	0.09
8440-8470	ctgs	Ls; wh-lt gy brn, crypt xl, v hd Tr-cht; sltst; orng; sh; dk gy	0.11/0.12
8470-8500	ctgs	Ls; wh-lt gy brn, crypt xl, v hd Tr-cht; sltst; orng; sh; dk gy	0.06
8500-8530	ctgs	Ls; wh, chky, occ lt gy Tr-sltst; orng; sh; gy; anhy	0.14
8530-8560	ctgs	Ls; wh, chky, occ lt gy Tr-sltst; orng; sh; gy; anhy	0.06
8560-8590	ctgs	Ls; off wh-lt gy brn, xln-crypt xln, occ chky Tr-ss; wh-lt brn, f gr, w srtd, anhy; sltst	0.12
8590-8610	ctgs	Ls; off wh-lt gy brn, xln-crypt xln, occ chky Tr-sh; gy, n calc, fss; sltst	0.11
8620-8650	ctgs	Ls; off wh-lt gy brn, xln-crypt xln, occ chky Tr-sh; gy, n calc, fss; sltst	0.12

* TOC = Total Organic Carbon

Table I (cont.)

Total Organic Carbon Results and Gross Lithologic Descriptions

Depth (ft)	Sample Type	Gross Lithologic Description	TOC* (wt %)
8650-8680	ctgs	Ls; off wh-lt gy brn, xln-crypt xln, occ chky Tr-sh; gy, n calc, fss; sltst	0.11
8680-8700	ctgs	Ls; off wh-lt gy brn, xln-crypt xln, occ chky Tr-sh; gy, n calc, fss; sltst	0.10/0.11

* TOC = Total Organic Carbon

Table II

Results of C_{15+} Extractable Organic Matter (EOM) Analysis

Depth (ft)	Sample Type	TOC (wt %)	EOM (ppm)	HC (ppm)	Composition of C_{15+} Extractable Organic Matter (Normalized Percent) F-1	F-2	F-3	CPI
6610-6670	ctgs	0.75	185	- -	- -	- -	- -	
6670-6740	ctgs	1.09	406	45	11.6	16.3	72.1	1.3
6820-6910	ctgs	1.16	494	137	19.3	23.3	57.4	1.40
7920-7950	ctgs	0.28	880	313	18.4	24.0	57.6	0.95
7950-8010	ctgs	0.40	345	105	24.1	24.1	51.8	1.07
8025	core	0.23	2716	1933	34.2	46.9	18.9	1.06
8029	core	0.26	433	253	12.6	53.3	34.1	1.33
8069	core	0.33	174	- -	- -	- -	- -	
8076	core	0.46	871	576	30.9	40.9	28.2	0.93
8194	core	0.39	45	- -	- -	- -	- -	
8196-8230	ctgs	0.29	159	39	28.6	16.6	54.8	1.31
8320-8380	ctgs	0.13	104	- -	- -	- -	- -	

TOC = Total Organic Carbon; EOM = Extractable Organic Matter (C_{15+}); HC = C_{15+} Hydrocarbons (saturates + aromatics); CPI = Carbon Preference Index (C_{24}-C_{34} carbon number range); F-1 = saturates; F-2 = aromatics; F-3 = asphaltics

Table III

Geochemical Ratios

Depth (ft)	$\frac{EOM}{TOC} \times 100$	$\frac{HC}{TOC} \times 100$	$\frac{HC}{EOM} \times 100$
6610-6670	2.5	- -	- -
6670-6740	3.7	0.4	11.1
6820-6910	4.3	1.2	27.7
7920-7950	31.4	11.2	35.6
7950-8010	8.6	2.6	30.4
8025	118.1	84.0	71.2
8029	16.7	9.7	58.4
8069	5.3	- -	- -
8076	18.9	12.5	66.1
8194	5.5	- -	- -
8196-8230	5.5	1.4	24.5
8320-8380	8.0	- -	- -

TOC = Total Organic Carbon (ppm); EOM = C_{15+} Extractable Organic Matter (ppm); HC = C_{15+} Hydrocarbons (ppm)

CORE LAB

Table IV

VISUAL KEROGEN OBSERVATIONS

DATE MARCH 24, 1981

WELL PERKINS #1

S.B.E.

JOB NO. 80206

X = > 80 %
/ = SECONDARY
* = ± 5-20 %
T = TRACE

DENVER BASIN STUDY

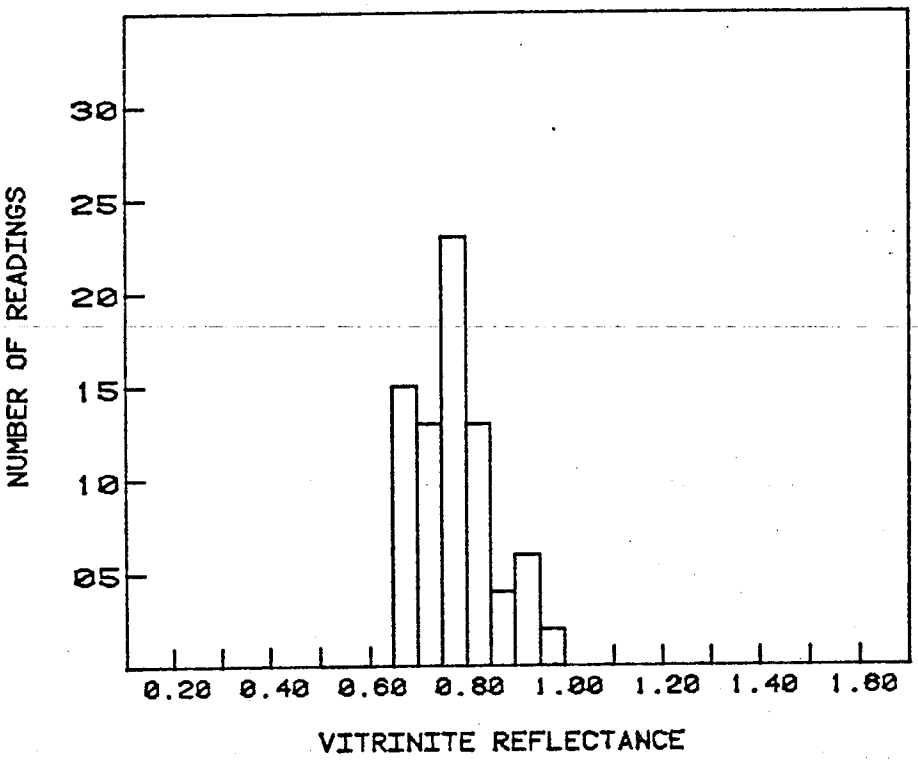
PERKINS #1

DEPTH	THERMAL ALTERATION INDEX						COLOR							KEROGEN TYPE						SPORINITE FLUORESCENCE COLOR						PRES				REMARKS
	1 UNALTERED	1+	2 SLIGHT ALTERATION	2+	3 MODERATE ALTERATION	3+	4 STRONG ALTERATION	4+	5 SEVERE ALTERATION	GREENISH LIGHT YELLOW	YELLOW	YELLOW - ORANGE	ORANGE - BROWN	LIGHT - BROWN	BROWN	DARK - BROWN	BLACK	ALGAL DEBRIS	AMORPHOUS DEBRIS	FINELY DISPERS. O.M.	HERB PLANT DEBRIS	WOODY PLANT DEBRIS	COALY FRAGMENTS	PALYNOMORPHS	GREEN	GREENISH YELLOW	YELLOW	SALLOW YELLOW	ORANGE	BROWN	BLACK	GOOD	FAIR	POOR	VERY POOR RECOVERY	BARREN OF O.M.	
6610 - 6670				X								X						/	T		X	*	T				T					X				
6670 - 6740				X								X						/	T		X	*	*				T					X				
6820 - 6910				X								X						/	T		X	*	T				T					X				
7920 - 7950				X								X						/	T		X	*	*				T					X				
7950 - 8010				X								X						*	T		X	*	T				T					X				
8025				X								X						X	/		T	*	T				T					X				
8029				X								X						/	T		X	*	T				T					X				
8069					X								X					*	T		X	/	T				T					X				
8076					X								X					X	T		*	*	T				T					X				
3194					X								X					*	T		X	*	T				T					X				
3196 - 8230					X								X					/	T		X	*	T				T					X				

DEMSHUR AFTER BURGESS (77)

Table V

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

PERKINS #1

DEPTH: 6610-6670 FEET

MEAN REF.: 0.77%

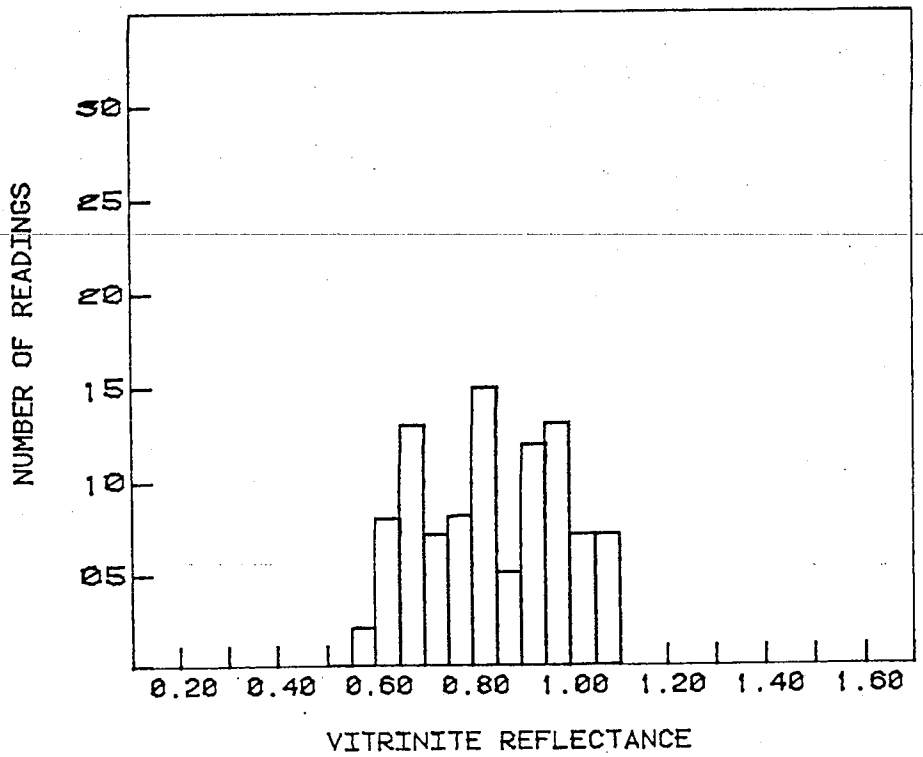
MAX. REF.: 0.95%

MIN. REF.: 0.65%

READINGS: 76

SAMPLE: CUTTINGS

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

PERKINS #1

DEPTH: 6670-6740 FEET

MEAN REF.: 0.81%

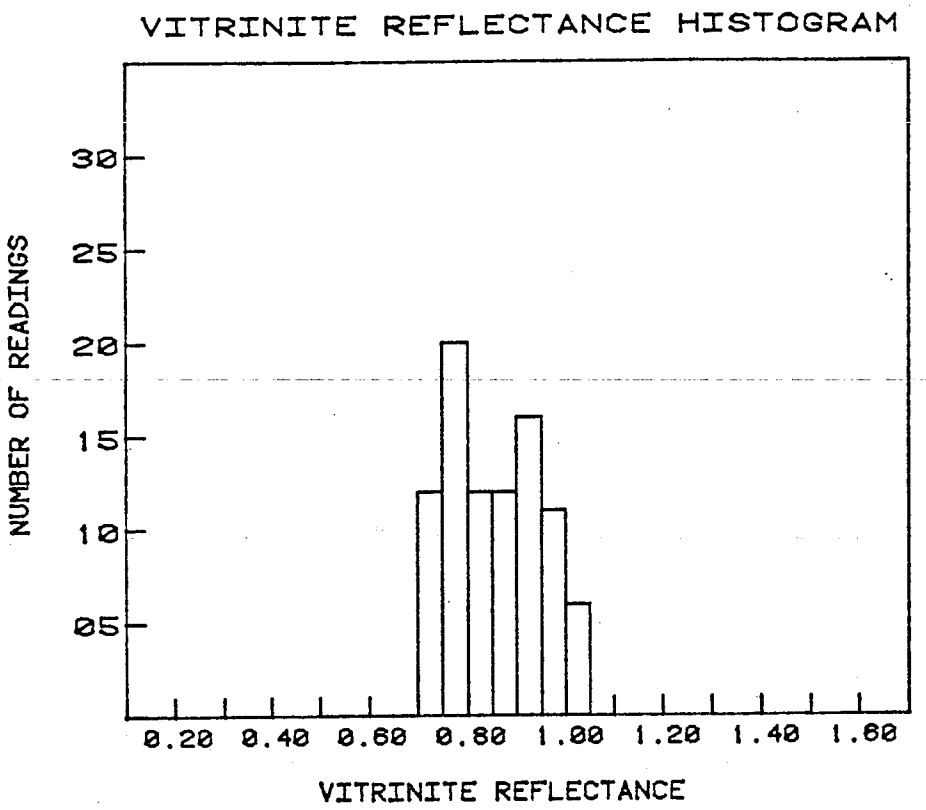
MAX. REF.: 1.09%

MIN. REF.: 0.59%

READINGS: 97

SAMPLE: CUTTINGS

Table V (cont.)



DENVER BASIN STUDY

PERKINS #1

DEPTH: 6820-6910 FEET

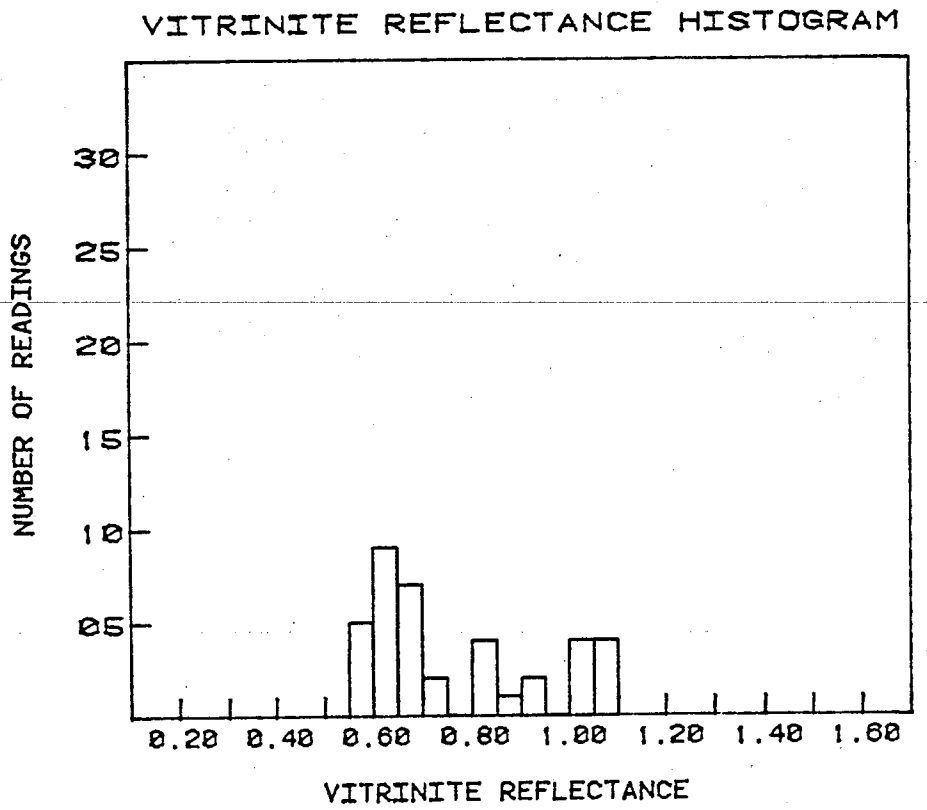
MEAN REF.: 0.86%

MAX. REF.: 1.04%

MIN. REF.: 0.70%

READINGS: 89

SAMPLE: CUTTINGS



DENVER BASIN STUDY

PERKINS #1

DEPTH: 7920-7950 FEET

MEAN REF.: 0.76%

MAX. REF.: 1.09%

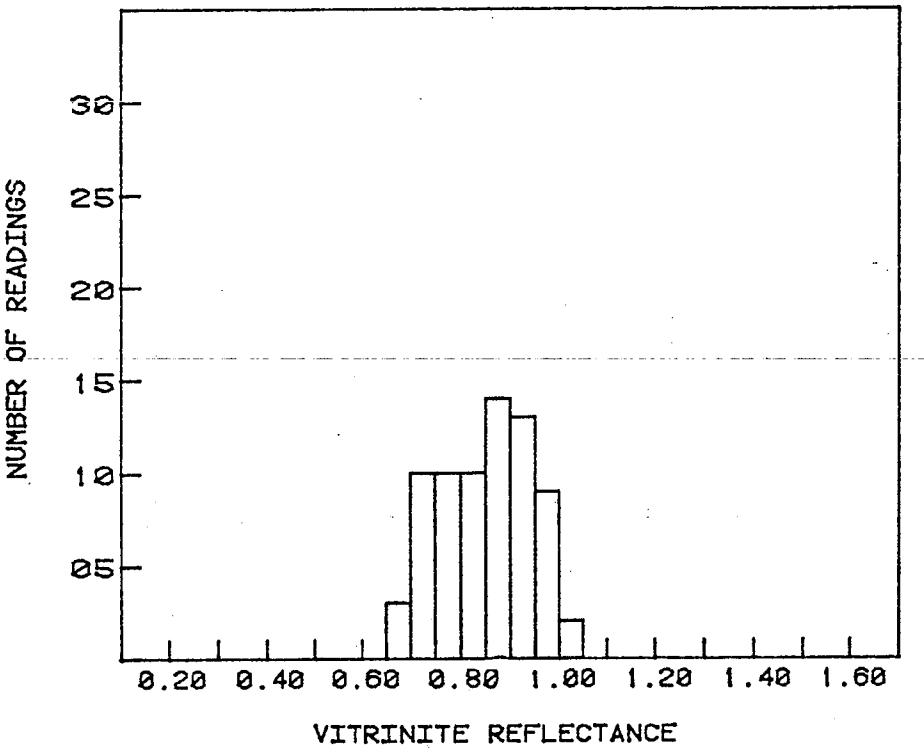
MIN. REF.: 0.55%

READINGS: 38

SAMPLE: CUTTINGS

Table V (cont.)

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

PERKINS #1

DEPTH: 7950-8010 FEET

MEAN REF.: 0.84%

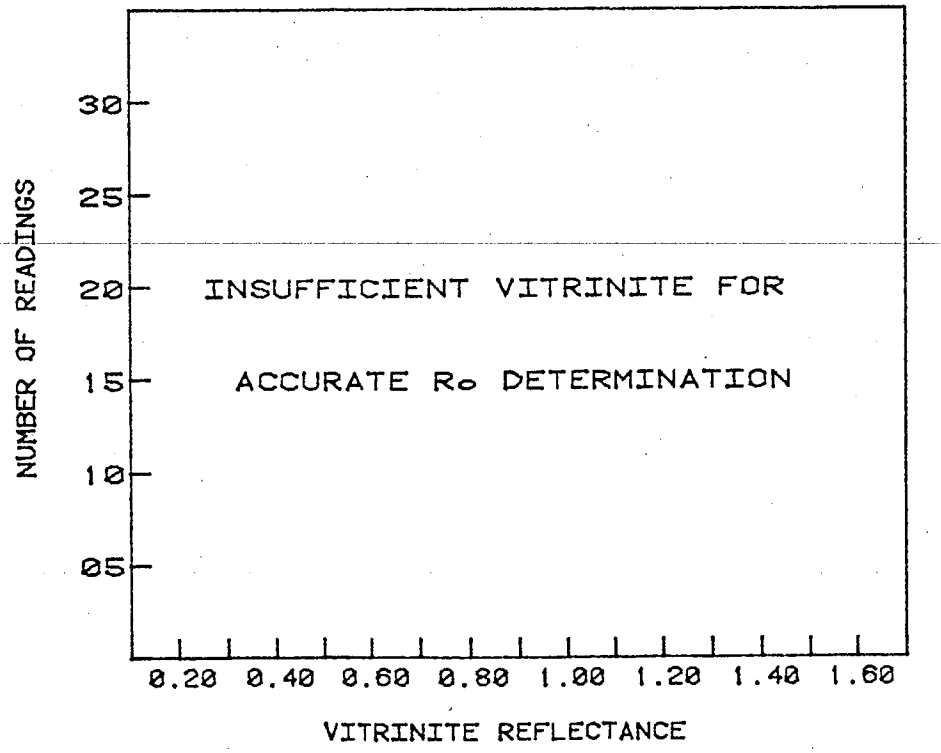
MAX. REF.: 1.01%

MIN. REF.: 0.68%

READINGS: 71

SAMPLE: CUTTINGS

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

PERKINS #1

DEPTH: 8025 FEET

MEAN REF.: ----%

MAX. REF.: ----%

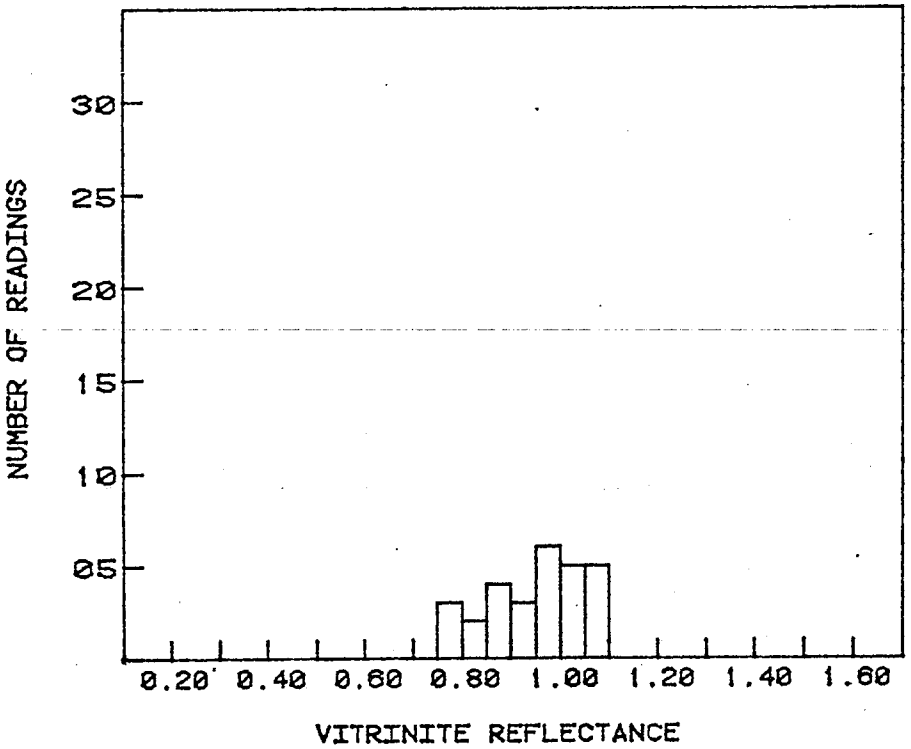
MIN. REF.: ----%

READINGS: 0

SAMPLE: CORE

Table V (cont.)

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

PERKINS #1

DEPTH: 8069 FEET

MEAN REF.: 0.94%

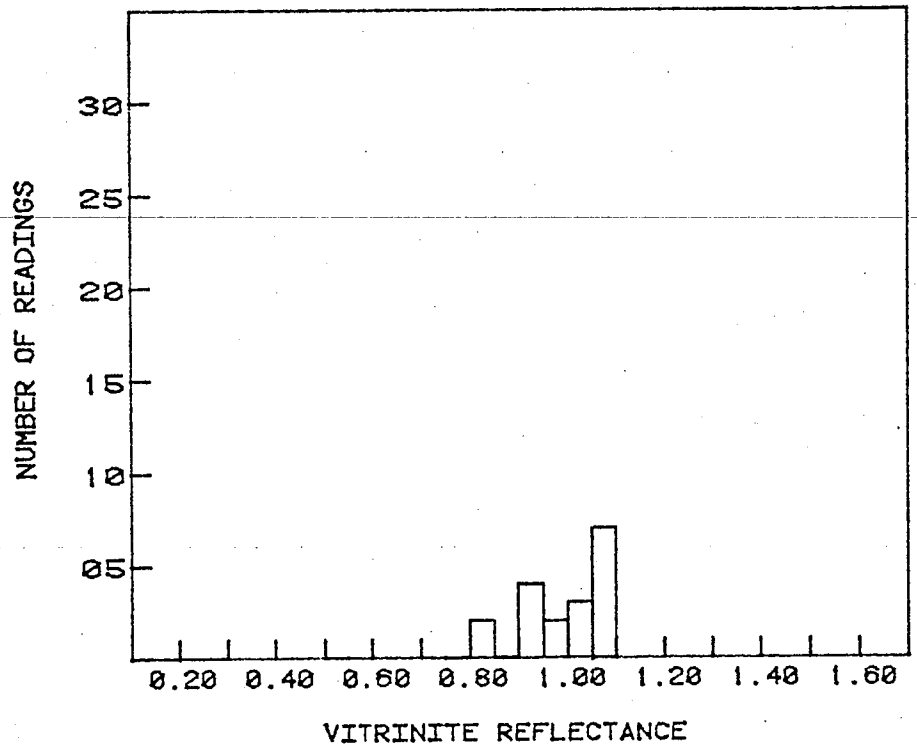
MAX. REF.: 1.08%

MIN. REF.: 0.75%

READINGS: 28

SAMPLE: CORE

VITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

PERKINS #1

DEPTH: 8076 FEET

MEAN REF.: 0.99%

MAX. REF.: 1.09%

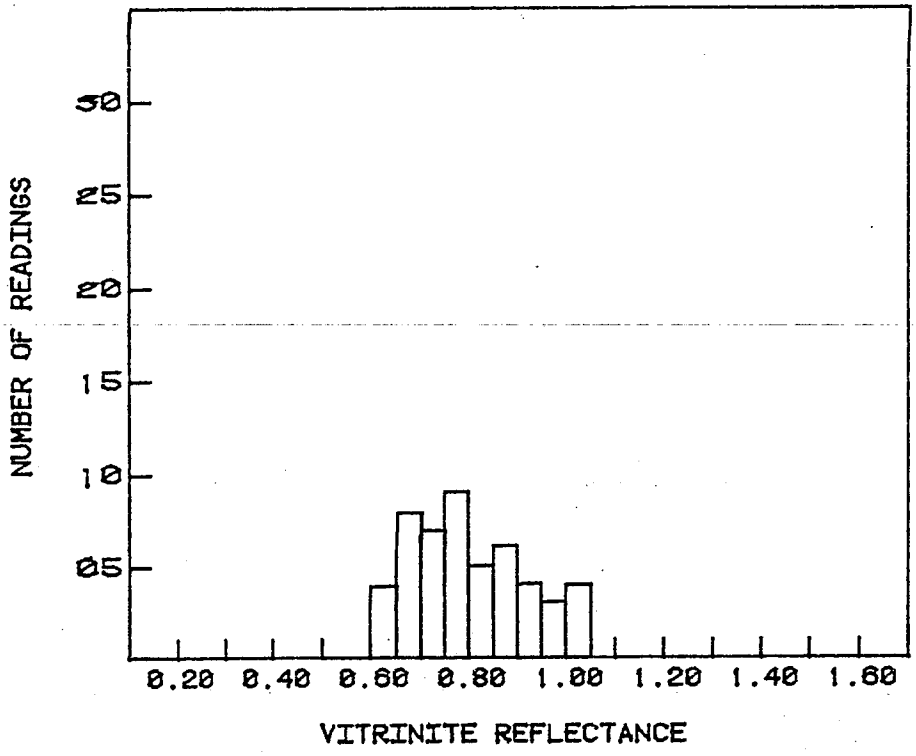
MIN. REF.: 0.80%

READINGS: 18

SAMPLE: CORE

Table V (cont.)

YITRINITE REFLECTANCE HISTOGRAM



DENVER BASIN STUDY

PERKINS #1

DEPTH: 8196-8230 FEET

MEAN REF.:0.80%

MAX. REF.:1.02%

MIN. REF.:0.61%

READINGS:50

SAMPLE:CUTTINGS

Table VI

Elemental Analysis

Depth (ft)	Hydrogen:Carbon Ratio (H/C)	
6610-6670	0.79	
6820-6910	0.88	
8025	.23%TOC 1.02	} amorph dominant in both.
8076	0.68	
8320-8380	0.91	

Table VII

Normalized n-Paraffin Distribution

	6670-6740	6820-6910	7920-7950	7950-8010
C_{15}	12.9	10.8	2.0	7.4
C_{16}	12.0	10.1	2.7	8.5
C_{17}	10.7	9.8	3.7	19.1
Pristane	9.4	7.9	1.1	3.7
C_{18}	7.8	7.3	4.4	8.3
Phytane	4.2	4.0	1.3	3.2
C_{19}	6.5	6.6	5.2	8.3
C_{20}	5.0	5.3	6.1	6.8
C_{21}	4.6	5.3	5.9	5.2
C_{22}	3.9	4.5	6.1	4.7
C_{23}	3.5	4.6	5.9	4.0
C_{24}	2.7	3.5	6.1	3.6
C_{25}	2.7	3.6	6.0	3.6
C_{26}	2.3	3.0	6.2	3.3
C_{27}	2.7	3.3	5.9	3.3
C_{28}	2.1	2.3	6.1	3.0
C_{29}	2.7	2.7	5.5	3.1
C_{30}	1.1	1.3	5.4	2.5
C_{31}	1.6	2.4	4.4	2.6
C_{32}	0.6	0.8	4.5	2.6
C_{33}	0.6	0.6	3.1	2.0
C_{34}	0.3	0.3	2.4	1.2
Pristane/Phytane	2.24	1.98	0.85	1.16
CPI	1.39	1.40	0.95	1.07

Table VII (cont.)

Normalized n-Paraffin Distribution

	8025	8029	8076	8196-8230
C_{15}	3.4	4.3	1.0	8.3
C_{16}	5.4	4.1	1.7	9.6
C_{17}	7.6	5.4	2.5	10.4
Pristane	8.3	1.9	3.9	7.2
C_{18}	8.4	4.2	3.3	8.3
Phytane	9.3	2.1	7.4	4.6
C_{19}	8.4	4.5	5.2	7.7
C_{20}	8.4	5.6	7.3	6.2
C_{21}	7.1	7.3	7.1	4.6
C_{22}	6.2	8.6	7.0	3.9
C_{23}	5.3	7.3	6.6	3.5
C_{24}	4.3	5.4	6.0	2.8
C_{25}	3.6	9.2	5.8	3.1
C_{26}	2.9	3.9	5.6	2.5
C_{27}	2.4	4.8	5.2	2.9
C_{28}	1.9	3.9	4.7	2.5
C_{29}	1.7	3.3	4.4	3.3
C_{30}	1.2	3.7	5.2	1.9
C_{31}	1.0	3.4	3.0	2.9
C_{32}	0.8	2.2	2.5	1.8
C_{33}	0.7	2.5	2.1	1.3
C_{34}	0.6	2.4	2.5	0.7
Pristane/Phytane	0.89	0.90	0.53	1.57
CPI	1.06	1.33	0.93	1.31

Table VIII

Normalized Isoprenoid Distribution

	6670-6740	6820-6910	7920-7950	7950-8010
Ip13	6.9	5.7	3.4	3.8
Ip14	5.8	5.1	3.1	3.8
Ip15	8.7	8.2	6.0	6.5
Ip16	18.0	18.1	7.5	14.9
Ip18	14.5	15.6	17.8	17.6
Pristane	31.8	31.2	28.1	28.6
Phytane	14.3	16.1	34.1	24.8

Table VIII (cont.)

Normalized Isoprenoid Distribution

	8029	8076	8196-8230
Ip13	9.0	2.3	5.6
Ip14	11.2	2.6	1.7
Ip15	10.5	4.1	4.2
Ip16	13.7	6.4	12.9
Ip18	14.9	16.0	16.6
Pristane	19.3	23.6	36.0
Phytane	21.4	45.1	23.0

FIGURE 5

Conoco

C_{10+} Saturated Hydrocarbon Fraction

Perkins #1

6670-6740 feet

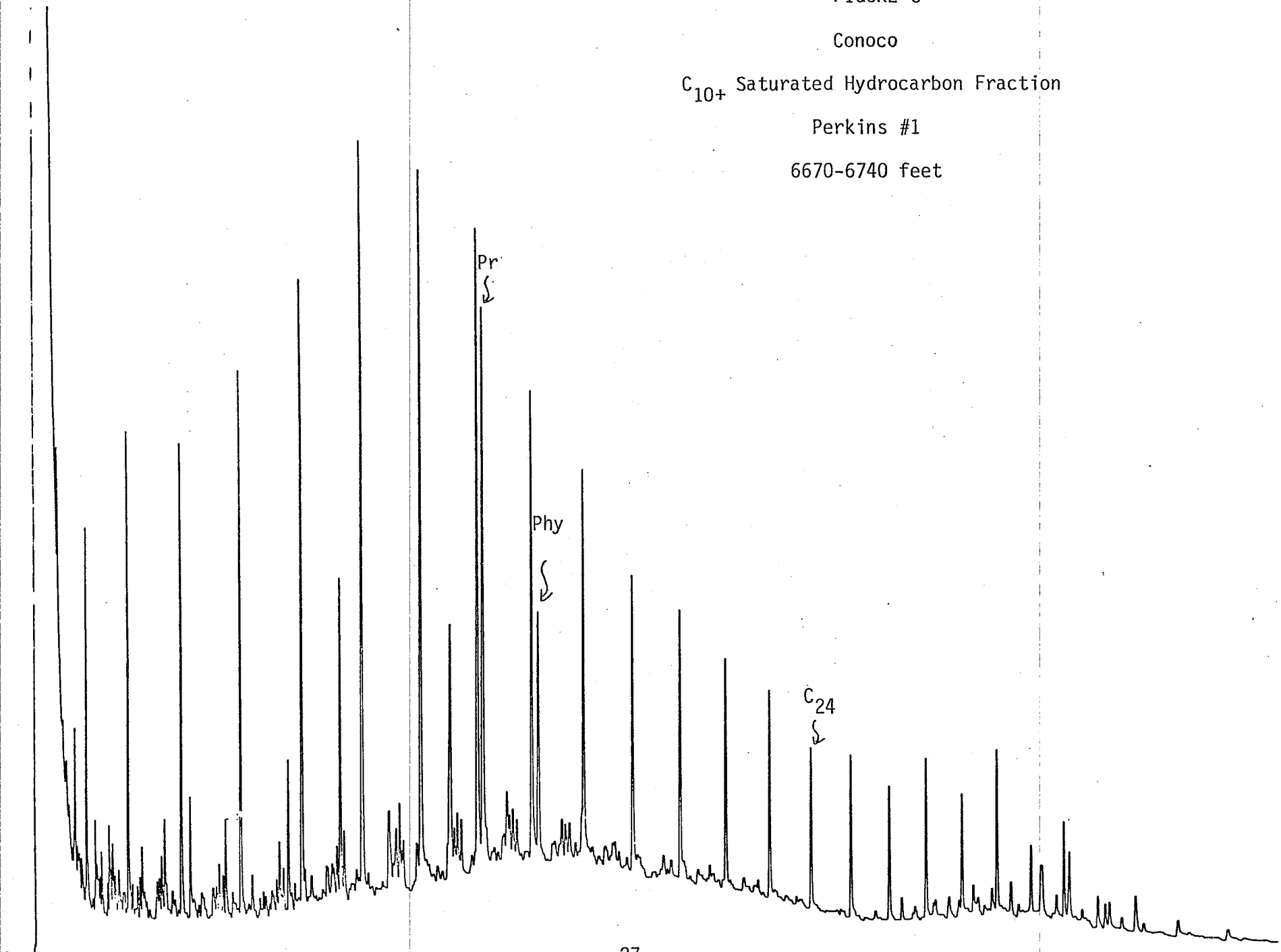


FIGURE 6

Conoco

C_{10+} Saturated Hydrocarbon Fraction

Perkins #1

6820-6910 feet

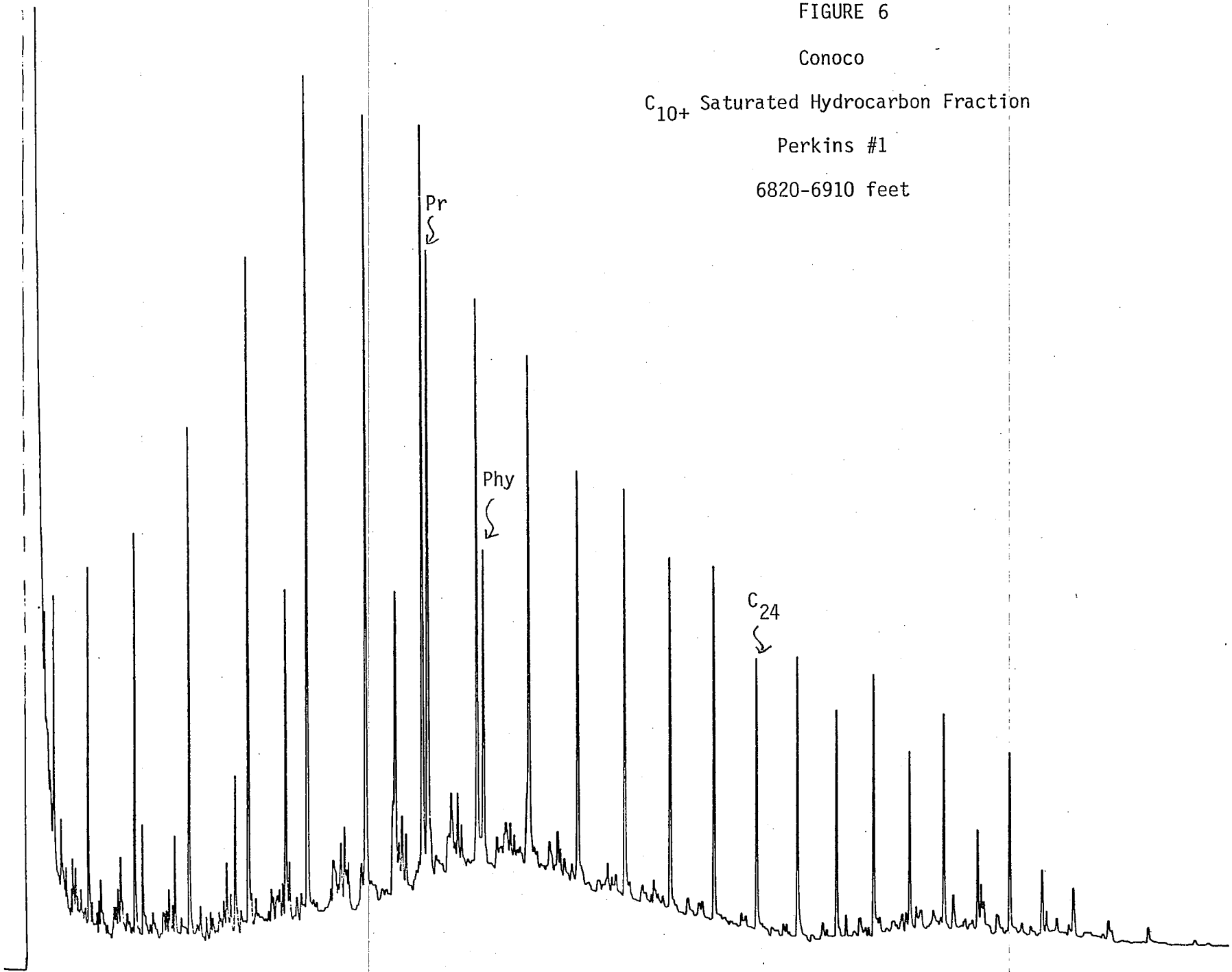


FIGURE 7

Conoco

C_{10+} Saturated Hydrocarbon Fraction

Perkins #1

7920-7950 feet

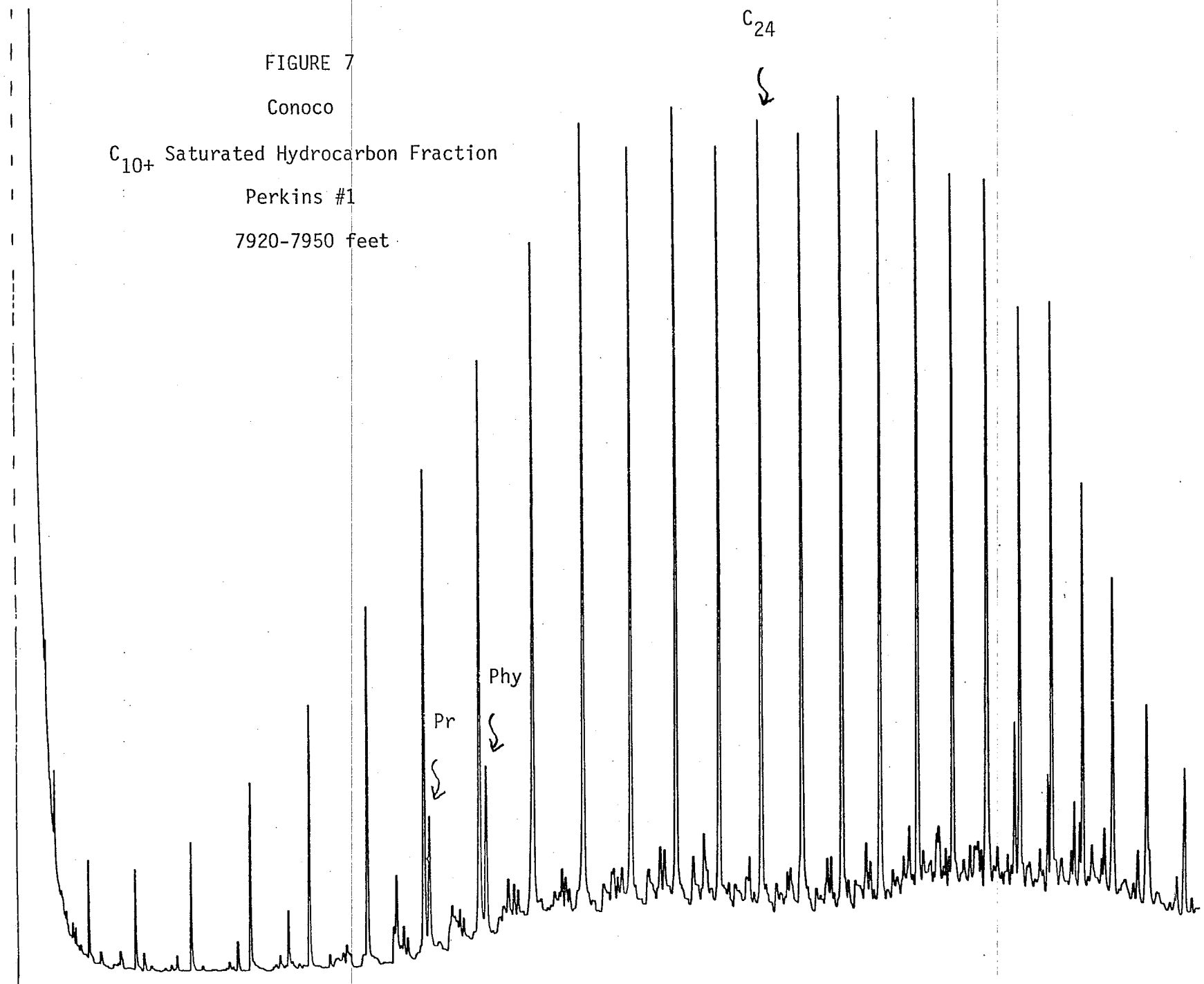


FIGURE 8

Conoco

C_{10+} Saturated Hydrocarbon Fraction

Perkins #1

7950-8010 feet

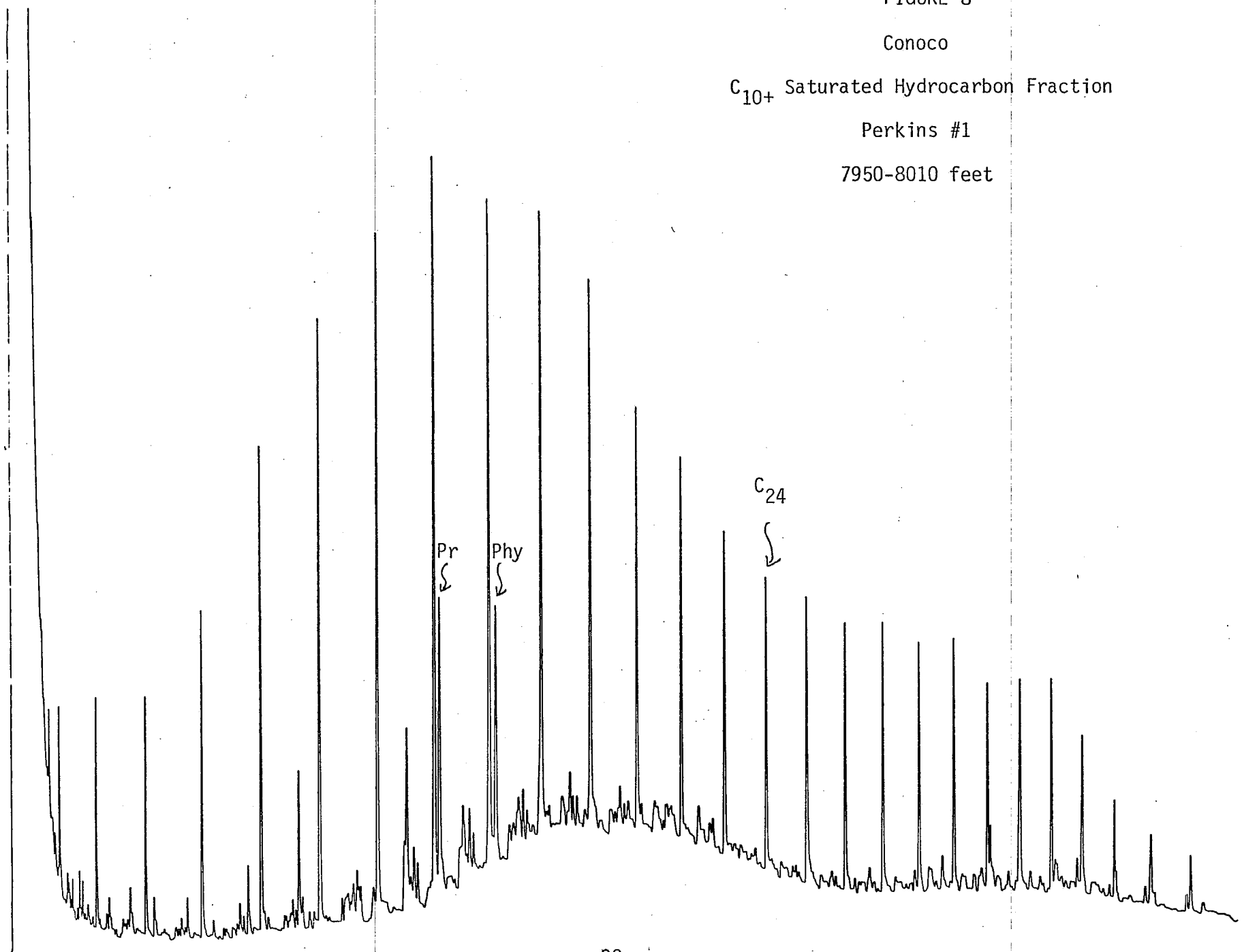


FIGURE 9

Conoco

C_{10+} Saturated Hydrocarbon Fraction

Perkins #1

8025 feet

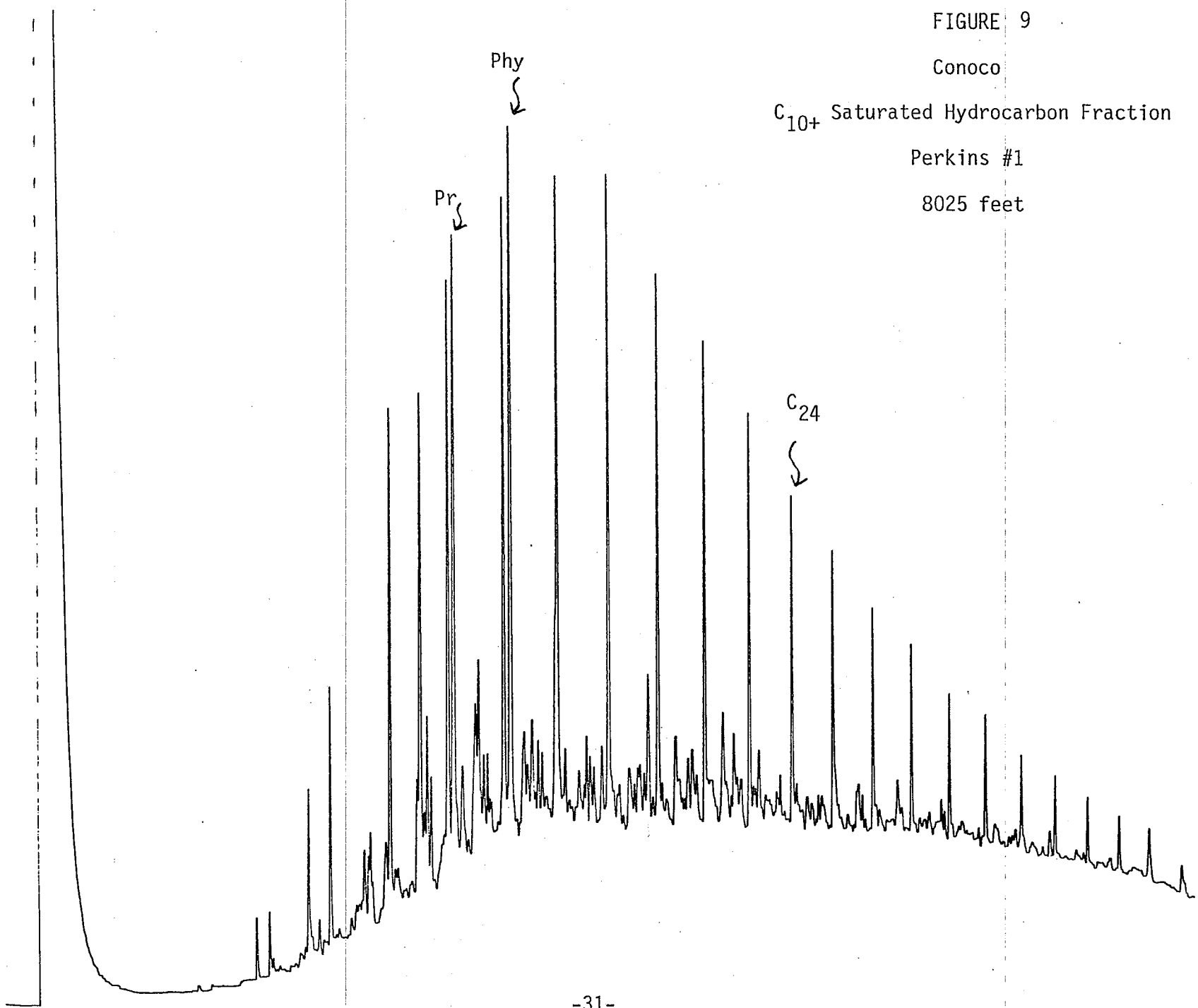


FIGURE 10

Conoco

C_{10+} Saturated Hydrocarbon Fraction

Perkins #1

8029 feet

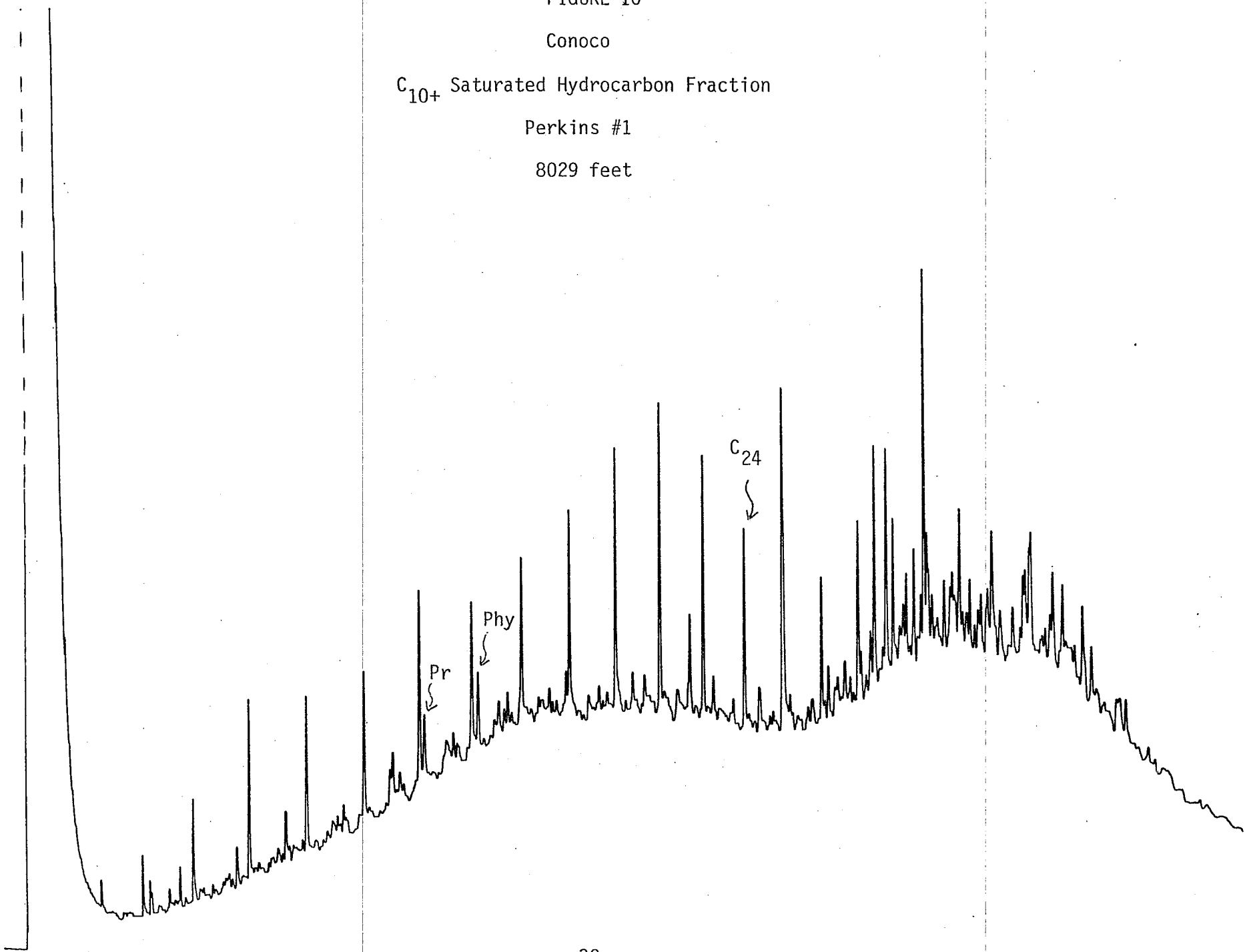


FIGURE 11

Conoco

C_{10+} Saturated Hydrocarbon Fraction

Perkins #1

8076 feet

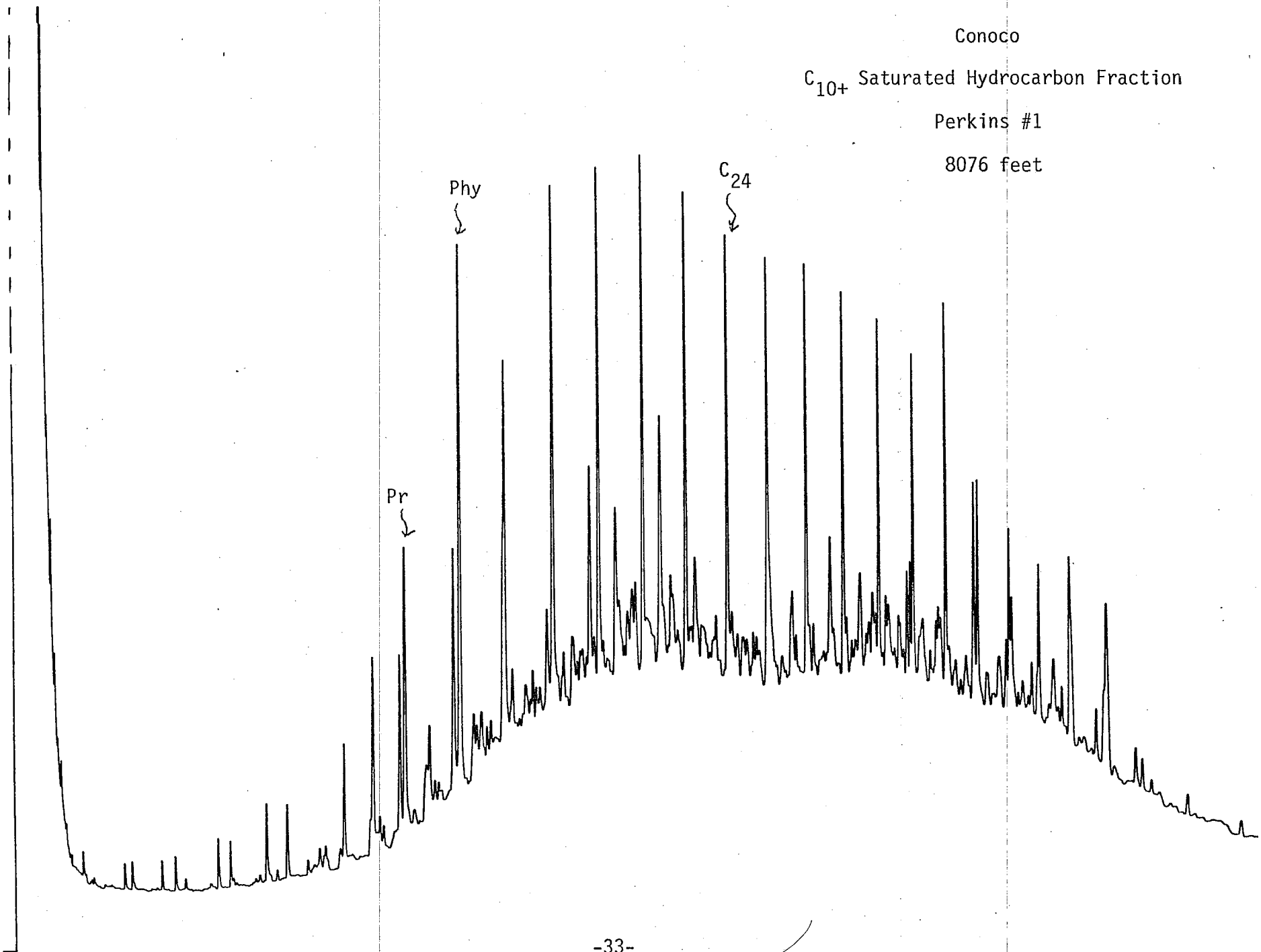


FIGURE 12

Conoco

C_{10+} Saturated Hydrocarbon Fraction

Perkins #1

8196-8230 feet