OPEN FILE REPORT 97

GEOCHEMICAL SERVICE REPORT

HYDROCARBON SOURCE ROCK EVALUATION STUDY

ORGANIC GEOCHEMICAL ANALYSES OF DRY WELL CUTTINGS

HUMBLE OIL & REFINING CO. NO. 1 N.M. STATE BA WELL

SEC. 25-32S-16W, HIDALGO COUNTY, NEW MEXICO

GeoChem Laboratories, Inc.

Prepared

for

New Mexico Bureau of Mines & Minerals Resources

Socorro, New Mexico

[redacted]
November, 1977

1143-C BRITTMORE ROAD, HOUSTON, TEXAS 77043

New Mexico Bureau of Mines & Mineral Resources
Socorro, NM 87801

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Information: 505/835-5420
Publications: 505/835-5410
After hours: 505/835-5011

December 11, 1978

MEMO

TO: Frank E. Kottlowski, Director

FROM: Sam Thompson III

SUBJECT: Open-file Reports OF 96 and OF 97

As we discussed, the following two reports from Geo Chem Laboratories, Inc. are to be placed in the Bureau's open file:

OF 96: Hydrocarbon source-rock evaluation study, KCM No. 1 Cochise State A well, Hidalgo County, New Mexico, by P.J. Cernock, Geo Chem Laboratories, Inc., 1976, 4 p. (text), 2 figs., 5 tables (11 p.), 1 appendix (4 p.).

OF 97: Hydrocarbon source-rock evaluation study, Humble Oil & Refining Co. No. 1 State BA well, Hidalgo County, New Mexico, by P.J. Cernock, Geo Chem Laboratories, Inc. 1977, 10 p. (text), 3 figs. (sep.), 8 tables (15 p.), 1 appendix (1 p.); supplement of 2 p. (text), 3 tables (3 p.).

cc: Paul J. Cernock
Robert W. Kelley

GeoChem Laboratories, Inc.

GEOCHEMICAL ANALYSES
SOURCE ROCK EVALUATION
CRUDE OIL—SOURCE ROCK CORRELATION
CRUDE OIL CHARACTERIZATION
GEOCHEMICAL PROSPECTING

1143-C BRITTMORE ROAD • HOUSTON, TEXAS 77043 • 713/467-7011

July 3, 1978

Dr. Sam Thompson III
New Mexico Bureau of Mines &
Mineral Resources
Socorro, New Mexico 87801

Re: GeoChem Job No. 1050
Humble Oil & Refining Co.
No. 1 N.M. State BA Well

Dear Sam:

Please find enclosed the results of the organic geochemical analyses carried out on seven (7) cuttings samples which were collected from the Humble Oil & Refining Co. No. 1 N.M. State BA Well located in Sec. 25-32S-16W, Hidalgo County, New Mexico. These samples have been identified by the GeoChem Sample Nos. 1050-001 through -007.

The organic geochemical analyses performed on the cuttings samples comprised hand picking of uncaved lithologies and general lithological description by a geologist, total organic carbon analyses and kerogen isolation, slide preparation and visual assessment. These data are presented in the attached Tables I, II and III.

It should be pointed out that the analyses performed on these seven (7) samples represent additional analyses to complement the hydrocarbon source rock evaluation study which was performed in November, 1977 on the Humble Oil & Refining Co. No. 1 N.M. State BA Well. This report was sent to you in November of 1977. Please compare these data enclosed herein with data presented in the previously submitted report.

The samples analyzed herein may be defined as having fair organic carbon contents for shales. The sample 1050-001 contains fair to good organic carbon contents for a limestone sample. The kerogen analyses show that most samples contain predominant amounts of degraded herbaceous type kerogen with secondary amounts of woody type of

material being present. Maturations have been defined as a Stage 2 to 2+, thus suggesting that these sediments have undergone a moderately mature thermal history. In comparing these data with data from the earlier report (identified by GeoChem Job No. 1001), we see that there is a slight discrepancy in the thermal maturity and visual kerogen maturation. Visual kerogen data for the 1001 report defined thermal maturations ranging from 2+ to 3- for samples above and below these samples described for the 1050 report. Thus, we appear to have a difference of 2 to 2+ (for samples 1050) compared to a Stage 2+ to 3- for samples from Job No. 1001. The visual kerogen type appears very similar, inasmuch as the samples from Job 1001 contained predominant or secondary amounts of woody and/or degraded herbaceous type kerogens. I requested Ms. Ann Reaugh, GeoChem's palynologist, to look at slides from both sets of samples. She stated that the samples examined in this study most probably are more correct on a maturation basis. The samples examined from Job No. 1001 contained greater amounts of reworked material which were more difficult to interpret as reworked material or in-place material. To sum it up, Sam, we feel that this shallower section has a thermal maturation ranging from 2 to 2+, or possibly 2+ to 3-. In either case, we would still remain within the oil generating window. However, with the type of kerogen being present being degraded herbaceous and woody, I would certainly interpret this section as being gas-prone, rather than oil-prone.

If you have any questions concerning the enclosed data, please feel free to give me a call and discuss it on the telephone. Enclosed also find an invoice No. 01538 for the Job No. 1050 analyses. I hope that all has gone well for you in the field and that you have an opportunity to incorporate field data into your regional studies.

Yours very truly,

Paul J. Cernock

Paul J. Cernock
Vice President & Chief Geologist
GEOCHEM LABORATORIES, INC.

PJC/bh
Enclosures

Table I

Picked Samples

Summary of Organic Carbon Analyses and Lithologic Description

GeoChem Sample Number	Well Depth Interval (feet)	Percent Organic Carbon	Lithology
1050-001	460 - 470	0.44; 0.37R	Limestone, argillaceous, gray.
1050-002	4160 - 4170	0.43	Shale, silty, dark gray.
1050-003	4170 - 4180	0.56	Shale, silty, dark gray.
1050-004	4180 - 4190	0.68	Shale, silty, dark gray.
1050-005	4190 - 4200	0.72	Shale, silty, dark gray.
1050-006	4200 - 4210	0.83	Shale, silty, dark gray.
1050-007	4210 - 4220	0.90	Shale, silty, dark gray.

Table II

Summary of Organic Carbon and Visual Kerogen Analysis

GeoChem Sample Number	Well Depth Interval (feet)	Organic Carbon (% of Rock)	Visual Kerogen	
			Type	Alteration (1-5 Scale)
1050-001	460 - 470	0.44; 0.37R	H*;-;W(C)	2 to 2+
1050-002	4160 - 4170	0.43	H*-W;-;C	2 to 2+
1050-003	4170 - 4180	0.56	H*;W;C	2 to 2+
1050-004	4180 - 4190	0.68	H*;W;C	2 to 2+
1050-005	4190 - 4200	0.72	H*;U;C	2 to 2+
1050-006	4200 - 4210	0.83	H*-W;-;C	2 to 2+
1050-007	4210 - 4220	0.90	W;H*;C	2 to 2+

R = Repeat Sample

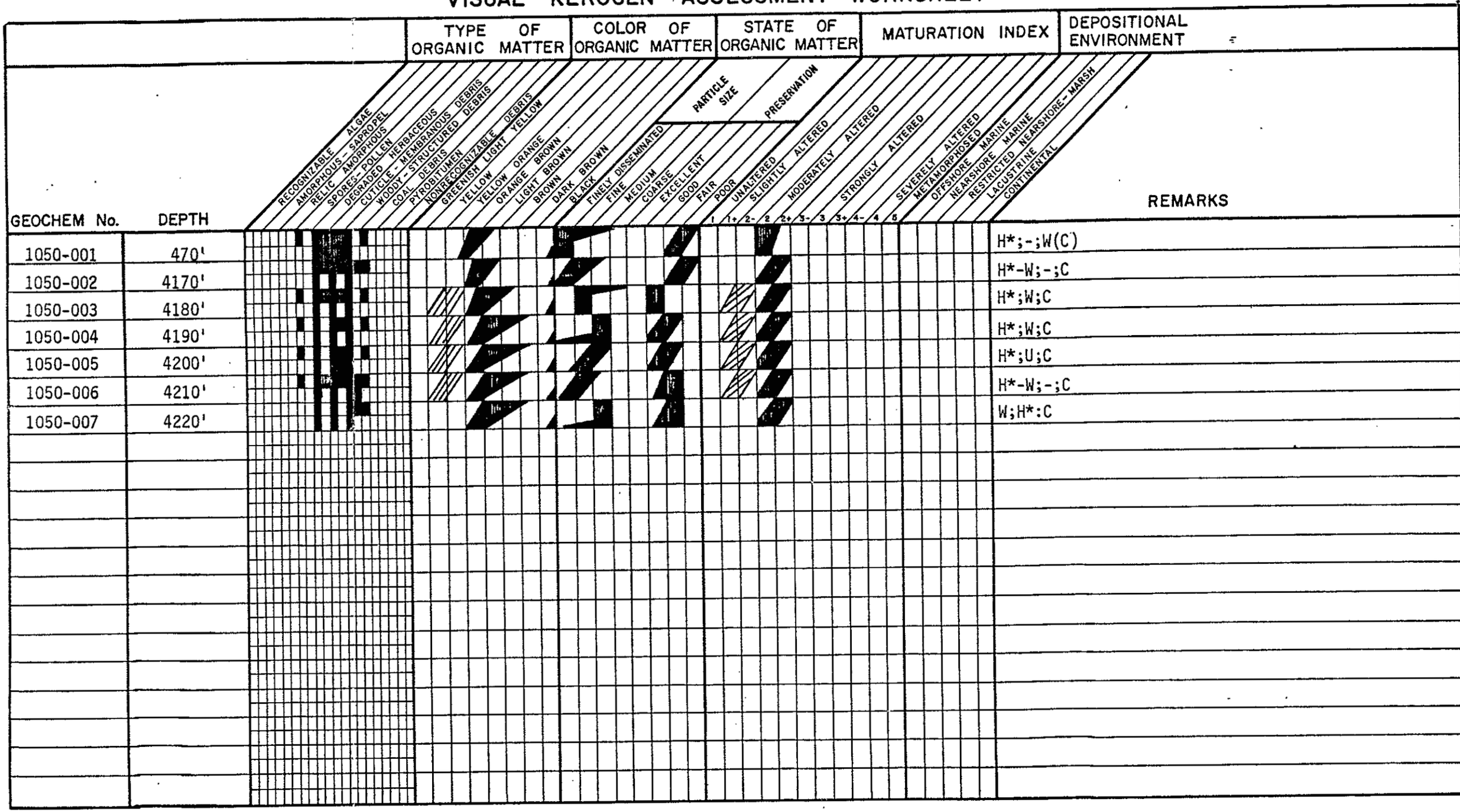
Kerogen Key

Predominant; Secondary; Trace
60 - 100%; 20 - 40%; 1 - 20%

Al = Algal
Am = Amorphous-Sapropel
H = Herbaceous-Spore/Cuticle
H* = Degraded Herbaceous
W = Woody
C = Coaly
U = Unidentified Material

TABLE III

VISUAL KEROGEN ASSESSMENT WORKSHEET



GEOCHEM No.	DEPTH	REMARKS
1050-001	470'	H*;-;W(C)
1050-002	4170'	H*-W;-;C
1050-003	4180'	H*;W;C
1050-004	4190'	H*;W;C
1050-005	4200'	H*;U;C
1050-006	4210'	H*-W;-;C
1050-007	4220'	W;H*:C

HYDROCARBON SOURCE ROCK EVALUATION STUDY

ORGANIC GEOCHEMICAL ANALYSES OF DRY WELL CUTTINGS

HUMBLE OIL & REFINING CO. NO. 1 N.M. STATE BA WELL

SEC. 25-32S-16W, HIDALGO COUNTY, NEW MEXICO

SUMMARY

Organic geochemical analyses run on a suite of dried cuttings, collected from the Humble Oil & Refining Company No. 1 N.M. State BA Well, over the interval from 460± feet to 14,510± feet, indicate the following:

- Zone A (460± feet to 7,350± feet) contains rocks which have a mature, very poor oil, condensate, "wet" and/or "dry" gas source character.

- Zone B (7,350± feet to 10,150± feet) contains rocks which have a very mature, very poor oil, condensate and associated "wet" gas source character, and a fair to good "dry" thermally derived methane gas source character.

- Zone C (10,150± feet to 14,510± feet) contains rocks which have a very mature to severely altered, very poor oil, condensate and associated "wet" gas source character. This zone contains two intervals (10,900± feet to 11,200± feet and 12,500± feet to 12,900± feet) which have a fair "dry" thermally derived methane gas source character.

In order of priority, exploration plays in the local area of the Humble Oil & Refining Company No. 1 N.M. State BA Well are interpreted as follows (providing that reservoir traps are available):

1. Permo-Pennsylvanian Horquilla Limestone Formation (Zone A)

   This section should be prospective for moderate to good quantities of "dry" thermally derived methane gas. This gas is most probably being generated from dark gray shale intervals found within the Permo-Pennsylvanian Horquilla Limestone Formation from 7,350± feet to 10,150± feet.

2. Devonian Percha Shale within Zone C (Subunit c_2: 12,500± feet to 12,900± feet)

This section should be prospective for fair quantities of "dry" thermally derived methane gas.

3. Mississippian Paradise Formation within Zone C (Subunit c_1: 10,900± feet to 11,200± feet)

This section should be prospective for fair quantities of "dry" thermally derived methane gas.

Paul J. Cernock

Paul J. Cernock
GEOCHEM LABORATORIES, INC.

INTRODUCTION

This report summarizes the results of a source rock evaluation study carried out on a suite of dry paleo cuttings collected over the gross well interval 460± feet to 14,510± feet from the Humble Oil & Refining Company No. 1 N.M. State BA Well in Sec. 25-32S-16W, Hidalgo County, New Mexico.

The purpose of this study has been to:

- investigate the richness, type (oil, condensate or gas), and state of thermal maturity of the hydrocarbon source rocks, and their stratigraphic distribution within the sedimentary sequence penetrated by the Humble Oil & Refining Company No. 1 N.M. State BA Well.

- characterize geochemical zones within the stratigraphic section of this well as a basis for any subsequent crude oil - parent rock correlations which may be required in the future.

- define the exploration significance of this study with respect to future drilling in the local area of the Humble Oil & Refining Company No. 1 N.M. State BA Well.

Analytical

On arrival at GeoChem's Houston laboratory, the Humble Oil & Refining Company No. 1 N.M. State BA Well was assigned the GeoChem Job No. 1001-. Small samples (5± grams) were hand-picked by a geologist at intervals of approximately 150± feet throughout this well. Dr. Sam Thompson, III, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico, provided a list of sample locations with various priority ratings for this well. Utilizing Dr. Thompson's priority listing, and the 150± foot sample interval guide, a total of seventy-six (76) small samples were hand-picked throughout the well interval from 460± feet to 14,510± feet. Each of these seventy-six (76) samples was identified by the suffix -001 through -076 in order of increasing depth.

Each of the seventy-six (76) samples was analyzed for total organic carbon content. On the basis of these results, plus the geological zonation and lithology of the samples, various single or composited samples were selected for more detailed geochemical analyses.

The following lists the number and type of geochemical analyses carried out on the dried well cuttings which were collected from the Humble Oil & Refining Company No. 1 N.M. State BA Well:

Type of Analysis	Humble Oil & Refining Co. No. 1 N.M. State BA Well
Organic carbon analyses	87
Kerogen isolation, slide preparation and visual assessment	18
C_{15+} soxhlet extraction w/deasphaltening	11
C_{15+} quantitative liquid chromatographic separation	1
C_{15+} qualitative liquid chromatographic separation	10
C_{15+} paraffin-naphthene (P-N) analysis	11
Vitrinite reflectance	1

A brief description of the standard analytical procedures used by GeoChem in this study is presented in Appendix A.

All the analytical data obtained in this study, whether used in the ultimate interpretation or not, is documented in the appropriate Tables I through VIII of this report. The organic carbon values from the screen analysis are presented in Table I and in Figure 1, the gross lithologic description and organic carbon values are presented in Table II and Figure 1, the kerogen organic matter type and alteration data are presented in Tables III and VI and in Figure 1, the C_{15+} extraction, deasphaltening and liquid chromatographic separation data are presented in Table IV-A, -B and -C, the C_{15+} paraffin-naphthene (P-N) compositional data are presented in Table V-A and -B and the vitrinite reflectance data are presented in Table VII and in Figure 2. The gas chromatographic traces, showing the molecular distribution of the C_{15+} paraffin-naphthene (P-N) hydrocarbons, are presented in Figure 2. The summary of the various geochemical parameters which identify three (3) major organic zones in the Humble Oil & Refining Company No. 1 N.M. State BA Well are outlined in Table VIII.

General Information

Two (2) copies of this report have been forwarded to Dr. Sam Thompson, III, New Mexico Bureau of Mines and Minerals Resources, Socorro, New Mexico, who authorized and coordinated this study. GeoChem has worked closely with Dr. Thompson in performing a source rock evaluation study on the No. 1 N.M. State BA Well. The program was designed to provide the most geochemical information, with the least

amount of cost. In providing this report to [redacted] Thompson, GeoChem has also made another copy of the report for GeoChem's files in Houston, Texas. This report copy will be utilized for reference purposes in discussions with authorized New Mexico Bureau of Mines and Minerals Resources personnel on specific details of this study.

All remaining used and unused, picked and unpicked cuttings samples, C_{15+} hydrocarbon and nonhydrocarbon chromat fractions and etc. will be returned to [redacted] Thompson, New Mexico Bureau of Mines and Minerals Resources, Socorro, New Mexico, under separate cover in the very near future.

The data, interpretations, sample materials and all other matters pertaining to this well study have been treated in a highly confidential manner and are considered proprietary to the New Mexico Bureau of Mines and Minerals Resources.

RESULTS AND INTERPRETATIONS

A. Geological Zonation

The sedimentary sequence penetrated by the Humble Oil & Refining Company No. 1 N.M. State BA Well in Hidalgo County, New Mexico has been divided into a number of discrete geological formations or groups. Specific formations which were provided to GeoChem in an excerpt from Zeller (1965) include the following:

Formation	Depth
Quaternary gravels, etc.	Surface
Lower Cretaceous U-Bar Formation	230'
Lower Cretaceous Hell-to-Finish Formation	648'
Permian Concha Limestone	995'
Permian Scherrer Formation	1,522'
Permian Epitaph Dolomite	1,532'
Permian Colina Limestone	4,450'
Permian Earp Formation	5,258'
Permo-Pennsylvanian Horquilla Limestone (Tentative correlations based on fusulinid identifications by Garner L. Wilde are: top Wolfcampian at 6,625', top? Virgilian at 8,755', top? Missourian at 8,935', top Desmoinesian at 9,425', top Derryan at 9,910', top Morrowan? at 10,800'.)	6,265'
Mississippian Paradise Formation	10,995'
Mississippian Escabrosa Limestone	11,425'
Devonian Percha Shale	12,500'
Ordovician Montoya Dolomite; Cutter Member	12,830'
Ordovician Montoya Dolomite; Aleman Member	12,985'
Ordovician Montoya Dolomite; Upham Member	13,097'
Ordovician Montoya Dolomite; Cable Canyon Member	13,155'
Ordovician El Paso Formation	13,214'
~~Mississippian Escabrosa Limestone (below reverse fault)~~	~~14,120'~~
Total depth in ~~Escabrosa~~ El Paso (probable)	14,585'

Corr. by ST 77.12.1

B. Geochemical Zonation

The stratigraphic section, penetrated by the Humble Oil & Refining Company No. 1 N.M. State BA Well over the interval from 460± feet to 14,585± feet T.D., can

be subdivided into three (3) major organic zones based primarily on the organic carbon contents, organic matter (kerogen) type and predominance, and the content and composition of the C_{15+} solvent extractable bitumen and C_{15+} total hydrocarbon of the fine-grained sediments. The deepest most zone (Zone C from 10,150± feet to 14,510± feet) contains two minor subunits which have significantly different organic character than the major Zone C section overall. The geochemical zonation and subunitization, both of which are independent of the formation tops, are as follows:

Zone A	460± feet to 7,350± feet
Zone B	7,350± feet to 10,150± feet
Zone C	10,150± feet to 14,510± feet
Subunit c_1.....	10,900± feet to 11,200± feet
Subunit c_2.....	12,500± feet to 12,900± feet

C. Thermal Maturity and Hydrocarbon Source Character of Sediments

1. Zone A (460± feet to 7,350± feet)

The Lower Cretaceous, Permian Concha through Earp Formations and Permo-Pennsylvanian Horquilla sediments within Zone A have a mature, very poor oil, condensate, "wet" and/or "dry" gas source character. The Zone A section, overall, has not generated any significant quantities of hydrocarbons in-place. The section is considered to be non-prospective for any producible quantities of liquid and/or gaseous type hydrocarbons in the local area of the Humble Oil & Refining Company No. 1 N.M. State BA Well.

The mature character of these sediments is based on the mature Maturation Index of Stage 2+ to 3- for the kerogen isolated from most of the samples from 2,410± feet to 4,900± feet. The Maturation Stage then jumps to a very mature Stage 3 to 3+ below 6,660± feet. This jump in Maturation Indices from 2+ to 3- to a 3 to 3+ indicates a possible unconformity or fault.

The very poor oil, condensate, "wet" and/or "dry" gas source character assigned to the Zone A rocks is based on the low organic carbon contents and the type of kerogens predominating in the samples. The very poor liquid and/or gaseous source character assigned to the Zone A sediments is based primarily on the very poor organic carbon contents of the sediments ranging from 0.01% to 0.40%, mean 0.13% (see Tables I, II, III and VIII; Figure 1). It is interpreted that the entire Zone A section

represents non-source rocks. Possibly minor amounts of dry methane gas may be associated with some of the shale stringers contained in the Colian section.

2. Zone B (7,350+ feet to 10,150+ feet)

The Permo-Pennsylvanian Horquilla Limestone Formation within Zone B has a very mature, very poor oil, condensate and associated "wet" gas source character, and a fair to good "dry" thermally derived methane gas source character. This section overall has minimal, if any, amounts of liquid hydrocarbons present within the sediments. Due to the organic matter kerogen type contained in these sediments, and their advanced thermal maturity, the Zone B sediments are considered to be beyond the oil generating window. That is, these sediments are interpreted to have been subjected to temperatures such that only thermally derived methane gas would be present and available for accumulation in adjacent reservoir traps.

The very mature character of these sediments is based on the very mature Maturation Indices of Stages 3 to 3+ for the kerogen isolated from most of the samples from 7,500+ feet to 10,100+ feet (Tables III, VI and VIII; Figure 1), the very mature range of vitrinite reflectance values [(o/o R_o) from 1.76 to 2.36, mean 2.10; Tables VII and VIII; Figure 3] and by the overall mature nature of the C_{15+} paraffin-naphthene (P-N) hydrocarbon fraction (see typical gas chromatographs of Zone B samples in Figure 2).

The very poor oil and condensate source character assigned to these sediments, as well as to the overlying Zone A and underlying Zone C sediments, is attributed primarily to the very poor C_{15+} solvent extractable bitumen contents and very poor C_{15+} total hydrocarbon contents of these samples (see Tables IV-B and VIII). The encouraging factor on the Zone B sediments is the fact that the interbedded shales (dark gray shales) scattered throughout Zone B section do contain good quantities of total organic carbon content. The organic carbon content values of the Zone B samples range from 0.07% to 1.36%, with a mean of 0.58% (see Tables I, II, III and VIII; Figure 1). These fair to good organic carbon contents, in association with predominant amounts of gas-prone woody type kerogens identify the Zone B section as being a fair to good "dry" thermally derived methane gas source. It is interpreted that this section may contain numerous thin zones of dark gray shales which are good "dry" methane gas sources. Any available reservoir traps in juxtaposition to these shales in the local area of the Humble No. 1 State BA Well, should be prospective for fair to good quantities of dry methane gas.

3. Zone C (10,150± feet to 14,510± feet)

The Mississippian, Devonian and Ordovician rocks within Zone C have a very mature to severely altered, very poor oil, condensate and associated "wet" gas source character. It should be noted that this zone does contain two intervals (10,900± feet to 11,200± feet and 12,500± feet to 12,900± feet) which have a fair "dry" thermally derived methane gas source character. These two intervals actually represent the Paradise Formation (shale) and the Percha Shale. It is interpreted that these two shale intervals represent fair "dry" thermally derived methane gas sources. Any available reservoir traps in juxtaposition to these shale sections in the local area of the No. 1 State BA Well, should be prospective for fair quantities of "dry" methane gas provided that reservoir traps are available.

The very mature to severely altered character of these sediments is based primarily on the very mature to severely altered Maturation Indices ranging from a Stage 3+ to 4- to a Stage 4- to 4 in most of the samples analyzed from 11,150± feet to 14,440± feet.

The very poor oil, condensate and associated "wet" gas source character assigned to these sediments is based primarily on the very poor total C_{15+} solvent extractable bitumen contents and very poor C_{15+} total hydrocarbon contents contained in these sediment samples (see Tables IV-A and VIII). The fair "dry" thermally derived methane gas source character assigned to the two minor intervals within Zone C is based primarily on fair amounts of organic carbon content for these samples and the presence of the gas-prone coaly type kerogen contained in these samples (see Tables III, VI and VIII; Figure 1).

D. Exploration Significance of This Source Rock Evaluation Study

Examination of the richness, type (oil, condensate or gas) and state of thermal maturity of the hydrocarbon source rocks penetrated by the Humble Oil & Refining Company No. 1 N.M. State BA Well shows that the stratigraphic interval from 460± feet to 14,510± feet, contains zones which have no prospectiveness for indigenously generated liquid hydrocarbons. One major organic facies zone and minor subunits within another zone are considered to be fair to good sources for "dry" thermally derived methane gas. In order of priority, exploration plays are interpreted as follows:

Locally:

1. Zone B (7,350+ feet to 10,150+ feet)

   The medium dark gray shales interbedded with argillaceous, micritic limestones within the Horquilla Limestone Formation have a very mature, very poor oil, condensate and associated "wet" gas source character, and a fair to good "dry" thermally derived methane gas source character. This section is considered to have sourced moderate quantities of "dry" methane gas to available reservoir traps in the local area of this well. It is emphasized that the Zone B section in-place has been thermally advanced beyond the oil-generating window. Thus, no liquid hydrocarbon potential exists within this section.

2. Subunit c_1 and c_2 within Zone C (10,900+ feet to 11,200+ feet and 12,500+ feet to 12,900+ feet)

   The Paradise Shale and Percha Shales within Subunits c_1 and c_2 have a very mature to severely altered, very poor oil, condensate and associated "wet" gas source character. However, these two subunits do have a fair "dry" thermally derived methane gas source character. These sediments are interpreted to have sourced fair quantities of "dry" methane gas to available reservoir traps in the local area of the Humble Oil & Refining Company No. 1 N.M. State BA Well. Again, it is emphasized that these sediments are also beyond the oil-generating window, in-place. Thus, no liquid and/or wet gas hydrocarbon potential exists for Zone C section.

In summation, this source rock evaluation study defines the local area around the Humble Oil & Refining Company No. 1 N.M. State BA Well as being prospective primarily for "dry" methane gas. Liquid hydrocarbon prospectiveness is minimal, if any! If the explorationist is concerned strictly with oil and condensate type plays, he should concentrate on encountering section penetrated by this well in an laterally updip position, and thus, thermally less mature and within the oil-generating window. Likewise, the explorationist may concentrate his efforts in encountering section with a completely different type of organic matter kerogen type -- that is, amorphous-sapropel oil-prone kerogen types. The reader should realize that the Zone B section, and the underlying Subunits c_1 and c_2, may be prospective for fair to good quantities of "dry" methane gas.

TABLE I

Picked Samples
Summary of Organic Carbon Analyses and Lithologic Description

GeoChem Sample Number	Well Depth*	Percent Organic Carbon	Lithology
1001-001	460- 470	0.31	Medium dark gray, very argillaceous and calcareous dolomite.
1001-002	740- 750	0.05	Grayish red silty shale.
1001-003	1510- 1520	0.01	Light brown limestone.
1001-004	1560- 1570	0.03	Dolomite.
1001-005	1680- 1690	0.02; 0.02R	Dolomite.
1001-006	1810- 1820	0.02	Dolomite.
1001-007	2010- 2020	0.03	Dolomite.
1001-008	2210- 2220	0.04	Dolomite.
1001-009	2400- 2410	0.18	Dolomite.
1001-010	2500- 2510	0.05; 0.07R	Dolomite.
1001-011	2750- 2760	0.09	Dolomite.
1001-012	2940- 2950	0.18	Dolomite.
1001-013	3030- 3040	0.22	Dolomite.
1001-014	3280- 3290	0.17	Dolomite.
1001-015	4350- 4360	0.36; 0.35R	Dolomite.
1001-016	4450- 4460	0.14	Limestone.
1001-017	4550- 4560	0.23	Limestone.
1001-018	4750- 4760	0.16	Limestone.
1001-019	4890- 4900	0.23	Limestone.
1001-020	5050- 5060	0.15; 0.16R	Limestone.
1001-021	5200- 5210	0.13	Limestone.
1001-022	5290- 5300	0.04	Grayish red silty shale.
1001-023	5640- 5650	0.05	Limestone.
1001-024	5920- 5930	0.05	Siltstone.
1001-025	6350- 6360	0.09; 0.08R	Limestone.
1001-026	6550- 6560	0.11	Medium dark gray, silty shale.
1001-027	6650- 6660	0.12	Medium dark gray, limy shale.
1001-028	6850- 6860	0.12	Limestone.
1001-029	7100- 7110	0.12	Medium dark gray, very calcareous shale.
1001-030	7260- 7270	0.11; 0.06R	Medium dark gray, calcareous shale.
1001-031	7400- 7410	0.10	Limestone.
1001-032	7470- 7480	1.09	Dark gray shale.
1001-033	7660- 7670	0.07	Medium dark gray, silty shale.
1001-034	7920- 7930	0.24	Medium dark gray, silty shale.
1001-035	7940- 7950	0.85; 0.80R	Dark gray shale.
1001-036	8070- 8080	0.08	Limestone.
1001-037	8240- 8250	0.26	Medium dark gray shale.
1001-038	8390- 8400	0.39	Medium dark gray shale.
1001-039	8590- 8600	0.34	Medium dark gray shale.
1001-040	8790- 8800	1.36; 1.32R	Dark gray shale.

* In feet

TABLE I (continued)

Picked Samples
Summary of Organic Carbon Analyses and Lithologic Description

GeoChem Sample Number	Well Depth*	Percent Organic Carbon	Lithology
1001-041	8840- 8850	0.66	Dark gray shale.
1001-042	8970- 8980	0.59	Dark gray shale.
1001-043	9080- 9090	0.97; 0.98R	Dark gray shale.
1001-044	9290- 9300	0.89	Dark gray shale.
1001-045	9470- 9480	0.11	Limestone.
1001-046	9570- 9580	0.22	Limestone.
1001-047	9850- 9860	0.50	Grayish black shale.
1001-048	9960- 9970	0.69	Dark gray shale.
1001-049	10050-10060	1.10	Grayish black shale.
1001-050	10180-10190	0.18; 0.17R	Limestone.
1001-051	10460-10470	0.10	Limestone.
1001-052	10820-10830	0.06	Limestone.
1001-053	10990-11000	0.29	Medium dark gray shale.
1001-054	11100-11110	0.54	Medium dark gray shale.
1001-055	11350-11360	0.16; 0.14R	Limestone.
1001-056	11490-11500	0.08	Limestone.
1001-057	11690-11700	0.02	Limestone.
1001-058	11900-11910	0.13	Limestone.
1001-059	12090-12100	0.12	Limestone.
1001-060	12300-12310	0.02; 0.04R	Limestone.
1001-061	12400-12410	0.09	Limestone.
1001-062	12600-12610	0.30	Dark gray shale grading into micrite.
1001-063	12700-12710	0.27	Dark gray shale grading into micrite.
1001-064	12800-12810	0.88	Dark gray shale.
1001-065	12900-12910	0.05; 0.11R	Dolomite.
1001-066	13000-13010	0.12	Dolomite.
1001-067	13140-13150	0.08	Dolomite.
1001-068	13300-13310	0.10	Limestone.
1001-069	13450-13460	0.10	Limestone.
1001-070	13600-13610	0.08; 0.08R	Limestone.
1001-071	13750-13760	0.09	Limestone.
1001-072	13900-13910	0.09	Limestone.
1001-073	14050-14060	0.10	Limestone.
1001-074	14200-14210	0.05	Limestone.
1001-075	14400-14410	0.22; 0.17R	Limestone, very argillaceous.
1001-076	14500-14510	0.13	Limestone.

* In feet

Table II

Organic Carbon Analyses and Gross Lithological Description

GeoChem Sample Number	Well Interval	Gross Lithological Description	GSA Color Code	Total Organic Carbon (% of Rock)
1001-015D	4390'			0.40
-A		100% Dolomite, massive-cryptocrystalline, very argillaceous, hard, poor porosity, no show, medium dark gray.	N4	
1001-032D	7500'			0.50
-A		70% Limestone, chalk grading into a very argillaceous micrite, moderately hard to hard, fair to poor porosity, no show, medium light gray to medium dark gray.	N6 to N4	
-B		30% Shale, slightly calcareous, silty, blocky, hard, medium dark gray.	N4	
1001-035D	7980'			1.16
-A		70% Shale, calcareous, silty, blocky to fissile, hard, dark gray.	N3	
-B		30% Limestone, chalk grading into an argillaceous micrite, moderately hard to hard, fair to poor porosity, no show, medium light gray to medium dark gray.	N6 to N4	
1001-038D	8400'			0.49; 0.55R
-A		80% Shale, very calcareous, silty, blocky, hard, medium dark gray.	N4	
-B		20% Limestone, micrite, argillaceous, hard, poor porosity, no show, medium dark gray.	N4	
1001-040D	8800'			0.50
-A		60% Limestone, chalk grading into an argillaceous micrite, moderately hard to hard, fair to poor porosity, no show, light gray to medium gray.	N7 to N5	
-B		40% Shale, calcareous, silty, blocky to fissile, hard, dark gray.	N3	

Table II (continued)

Organic Carbon Analyses and Gross Lithological Description

GeoChem Sample Number	Well Interval	Gross Lithological Description	GSA Color Code	Total Organic Carbon (% of Rock)
1001-043D	9100'			0.53
-A		60% Shale, calcareous, silty, blocky to fissile, hard, dark gray.	N3	
-B		40% Limestone, chalk grading into an argillaceous micrite, moderately hard to hard, fair to poor porosity, no show, light gray to medium gray.	N7 to N5	
1001-049D	10100'			0.79
-A		70% Shale, limy grading into a limestone, slightly silty, blocky to fissile, hard, grayish black.	N2	
-B		30% Limestone, chalk grading into a micrite, moderately hard to hard, fair to poor porosity, no show, white to medium dark gray.	N9 to N4	
1001-054D	11150'			0.29
-A		60% Limestone, chalk grading into micrite and intramicrite, argillaceous, moderately hard to hard, fair to poor porosity, no show, light gray to medium dark gray.	N7 to N4	
-B		40% Shale, limy grading into a limestone, slightly silty, blocky to fissile, hard, grayish black.	N2	
1001-062D	12610'			0.36; 0.35R
-A		50% Shale, noncalcareous, silty, blocky to fissile, hard, dark gray.	N3	
-B		50% Limestone, micrite very argillaceous, hard, poor porosity, no show, dark gray.	N3	

Table II (continued)

Organic Carbon Analyses and Gross Lithological Description

GeoChem Sample Number	Well Interval	Gross Lithological Description	GSA Color Code	Total Organic Carbon (% of Rock)
1001-064D	12820'			0.47
-A		50% Shale, noncalcareous, silty, blocky to fissile, hard, dark gray.	N3	
-B		50% Limestone, micrite very argillaceous, hard, poor porosity, no show, dark gray.	N3	
1001-075D	14440'			0.20
-A		90% Limestone, chalk grading into an argillaceous micrite, moderately hard to hard, fair to poor porosity, no show, light gray to dark gray.	N7 to N3	
-B		10% Shale, limy, silty, blocky, hard, dark gray.	N3	

TABLE III

Summary of Organic Carbon and Visual Kerogen Analysis

GeoChem Sample Number	Well Depth Interval	Organic Carbon (% of Rock)	Visual Kerogen Type	Visual Kerogen Alteration (1-5 Scale)
1001-009D	2400- 2410	0.18	Am-W;H-C;-	2+ to 3-
1001-013D	3030- 3040	0.22	W;H;C	2+ to 3-
1001-015D	4350- 4390	0.40	W;H-C;-	2+ to 3-
1001-017D	4550- 4560	0.23	W;H;C	2+ to 3-
1001-019D	4890- 4900	0.23	H;W;C	2+ to 3-
1001-027D	6650- 6660	0.12	W;C;H	3 to 3+
1001-032D	7450- 7500	0.50	W;H-C;-	3 to 3+
1001-035D	7940- 7980	1.16	H;W;C	3 to 3+
1001-038D	8360- 8400	0.49; 0.55R	W;H;C	3 to 3+
1001-040D	8750- 8800	0.50	W;H;C	3+
1001-043D	9050- 9100	0.53	W;H;C	3+
1001-048D	9960- 9970		W;H;C	3+ to 4-
1001-049D	10050-10100	0.79	W;H-C;-	3+
1001-054D	11100-11150	0.29	C;W;H	3+ to 4-
1001-062D	12600-12640	0.36; 0.35R	C;H;Am-W	3+ to 4-
1001-064D	12760-12820	0.47	C;W;Am-H	3+ to 4-
1001-071D	13750-13760		Am;H-C;-	4- to 4
1001-075D	14400-14440	0.20	W;H;C	4- to 4

R = Repeat Sample

Kerogen Key

Predominant; Secondary; Trace
60-100% 20-40% 1-20%

Al = Algal
Am = Amorphous-Sapropel
H = Herbaceous-Spore/Cuticle
W = Woody
C = Coaly
U = Unidentified Material

Table IV

Summary of C15+ Soxhlet Extraction, Deasphaltening and Liquid Chromatography

A. Weights of Extracts and Chromatographic Fractions

GeoChem Sample Number	Well Interval *	Weight of Rock Extd. (grams)	Total Extract (grams)	Precipitated Asphaltenes (grams)	N-C5 Soluble (grams)	Sulfur (grams)	Paraffins-Naphthenes (grams)	Aromatics (grams)	Eluted NSO'S (grams)	Noneluted NSO'S (grams)
1001-015D	4350- 4390	100.0	0.0059	0.0006	0.0053	N.D.	N.D.	N.D.	N.D.	N.D.
1001-032D	7450- 7500	90.0	0.0080	0.0003	0.0077	N.D.	N.D.	N.D.	N.D.	N.D.
1001-035D	7940- 7980	100.0	0.0099	0.0033	0.0066	N.D.	N.D.	N.D.	N.D.	N.D.
1001-038D	8360- 8400	100.0	0.0086	0.0030	0.0056	N.D.	N.D.	N.D.	N.D.	N.D.
1001-040D	8750- 8800	100.0	0.0066	0.0011	0.0055	N.D.	N.D.	N.D.	N.D.	N.D.
1001-043D	9050- 9100	94.0	0.0162	0.0080	0.0082	N.D.	N.D.	N.D.	N.D.	N.D.
1001-049D	10050-10100	100.0	0.0163	0.0091	0.0072	N.D.	N.D.	N.D.	N.D.	N.D.
1001-054D	11100-11150	100.0	0.0126	0.0075	0.0051	N.D.	N.D.	N.D.	N.D.	N.D.
1001-062D	12600-12640	100.0	0.0106	0.0014	0.0092	N.D.	N.D.	N.D.	N.D.	N.D.
1001-064D	12760-12820	100.0	0.0190	0.0074	0.0116	N.D.	0.0027	0.0023	0.0063	0.0003
1001-075D	14400-14440	100.0	0.0070	0.0015	0.0055	N.D.	N.D.	N.D.	N.D.	N.D.

* In feet.

Table IV (Continued)

B. Concentration of Extracted Materials in Rock

GeoChem Sample Number	Well Interval*	Total Extract (ppm)	Hydrocarbons: Paraffin-Naphthene (ppm)	Hydrocarbons: Aromatic (ppm)	Hydrocarbons: Total (ppm)	Sulfur (ppm)	Nonhydrocarbons: Precipitd. Asphaltene (ppm)	Nonhydrocarbons: Eluted NSO'S (ppm)	Nonhydrocarbons: Noneluted NSO'S (ppm)	Nonhydrocarbons: Total (ppm)
1001-015D	4350- 4390	59	-	-	-	-	6	-	-	-
1001-032D	7450- 7500	89	-	-	-	-	3	-	-	-
1001-035D	7940- 7980	99	-	-	-	-	33	-	-	-
1001-038D	8360- 8400	86	-	-	-	-	30	-	-	-
1001-040D	8750- 8800	66	-	-	-	-	11	-	-	-
1001-043D	9050- 9100	172	-	-	-	-	85	-	-	-
1001-049D	10050-10100	163	-	-	-	-	91	-	-	-
1001-054D	11100-11150	126	-	-	-	-	75	-	-	-
1001-062D	12600-12640	106	-	-	-	-	14	-	-	-
1001-064D	12760-12820	190	27	23	50	-	74	63	3	140
1001-075D	14400-14440	70	-	-	-	-	15	-	-	-

* In feet.

ppm values are expressed on a weight/weight basis,

Table IV (Continued)

C. Composition of Extracts

GeoChem Sample Number	Well Interval *	Hydrocarbons: Paraffin-Naphthene %	Hydrocarbons: Aromatic %	Hydrocarbons: PN/Arom	Hydrocarbons: Sulfur %	Nonhydrocarbons: Eluted NSO'S %	Nonhydrocarbons: Noneluted NSO'S %	Nonhydrocarbons: Precipitd. Asphaltene %	Nonhydrocarbons: Asph/NSO	HC'S %	HC/Non HC
1001-015D	4350- 4390	-	-	-	-	-	-	10.2	-	-	-
1001-032D	7450- 7500	-	-	-	-	-	-	3.8	-	-	-
1001-035D	7940- 7980	-	-	-	-	-	-	33.3	-	-	-
1001-038D	8360- 8400	-	-	-	-	-	-	34.9	-	-	-
1001-040D	8750- 8800	-	-	-	-	-	-	16.7	-	-	-
1001-043D	9050- 9100	-	-	-	-	-	-	49.4	-	-	-
1001-049D	10050-10100	-	-	-	-	-	-	55.8	-	-	-
1001-054D	11100-11150	-	-	-	-	-	-	59.5	-	-	-
1001-062D	12600-12640	-	-	-	-	-	-	13.2	-	-	-
1001-064D	12760-12820	14.2	12.1	1.17	-	33.2	1.6	38.9	1.12	26.3	0.36
1001-075D	14400-14440	-	-	-	-	-	-	21.4	-	-	-

* In feet.

Table V-A

Saturate Hydrocarbon Analyses

Summary of Paraffin-Naphthene Distribution

GeoChem Sample Number	Well Interval*	% Paraffin	% Isoprenoid	% Naphthene	C-P Index A	C-P Index B	ip19/ip20
1001-015D	4350- 4390	15.7	1.9	82.4	1.01	1.20	0.61
1001-032D	7450- 7500	21.3	1.9	76.8	1.02	-	0.85
1001-035D	7940- 7980	13.1	3.3	83.5	1.08	-	0.92
1001-038D	8360- 8400	17.3	1.3	81.4	0.95	-	0.73
1001-040D	8750- 8800	18.0	1.5	80.6	1.11	-	0.77
1001-043D	9050- 9100	14.8	1.0	84.2	1.03	-	0.69
1001-049D	10050-10100	13.4	3.1	83.5	0.97	-	1.00
1001-054D	11100-11150	12.1	0.7	87.3	1.04	-	0.42
1001-062D	12600-12640	12.3	2.4	85.3	1.09	-	1.03
1001-064D	12760-12820	12.1	2.2	85.7	1.15	-	0.72
1001-075D	14400-14440	10.8	1.2	88.0	1.30	-	0.44

* In feet.

Table V-B

Saturate Hydrocarbon Analyses

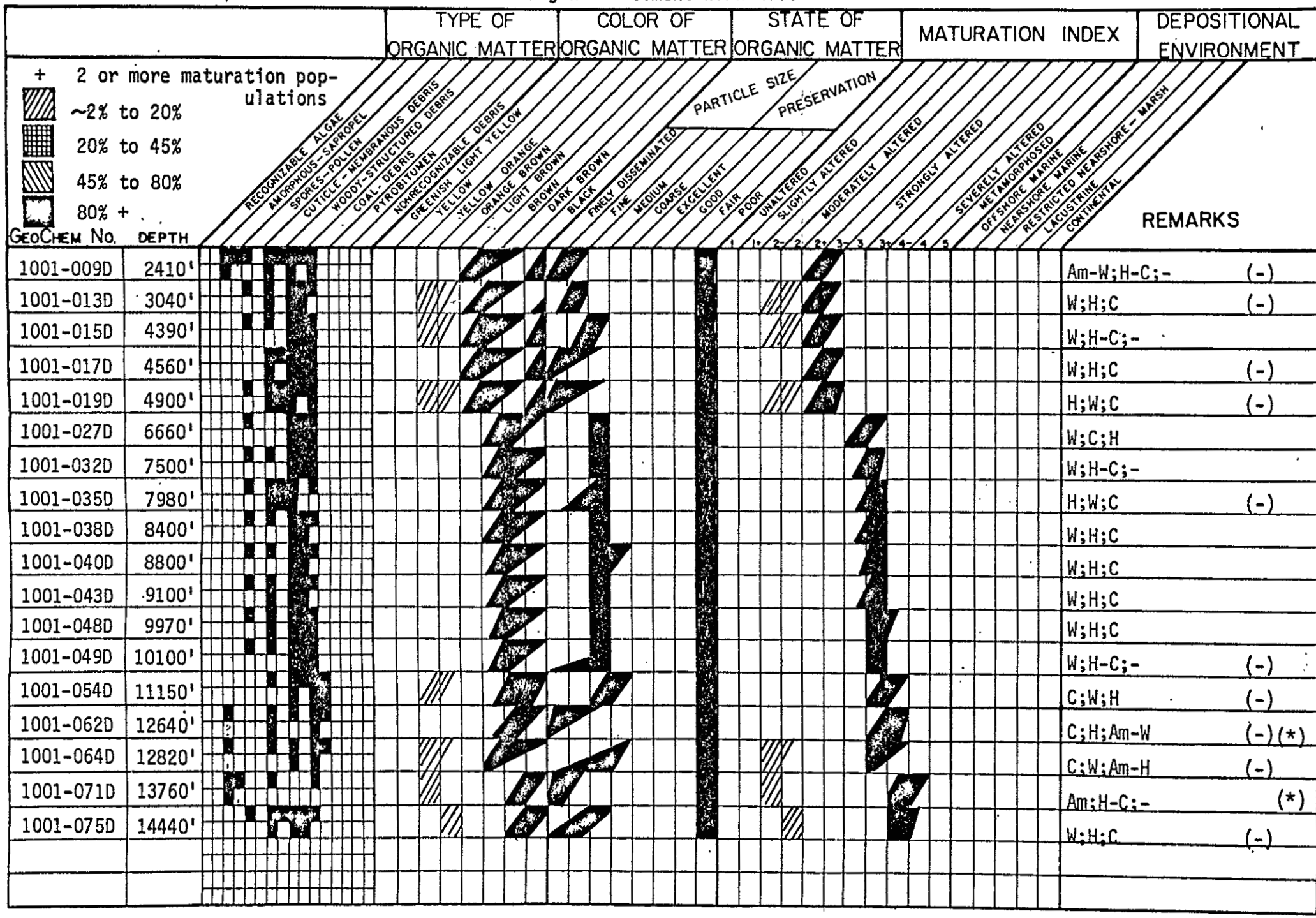
Normalized Paraffin Distribution

GeoChem Sample Number	Well Interval *	% nC15	% nC16	% nC17	% ip19	% nC18	% ip20	% nC19	% nC20	% nC21	% nC22	% nC23	% nC24	% nC25	% nC26	% nC27	% nC28	% nC29	% nC30	% nC31	% nC32	% nC33	% nC34	% nC35
1001-015D	4350- 4390	0.9	1.9	7.2	4.1	12.6	6.7	14.6	11.2	9.2	9.2	7.5	5.5	3.9	2.4	1.4	0.7	0.4	0.3	0.2	0.1	0.0	0.0	0.0
1001-032D	7450- 7500	0.4	1.5	6.3	3.8	9.6	4.4	10.2	8.9	10.3	11.4	10.1	8.6	6.4	3.9	2.2	1.0	0.5	0.2	0.1	0.0	0.0	0.0	0.0
1001-035D	7940- 7980	0.9	3.3	15.4	9.6	18.0	10.5	14.7	8.8	6.5	5.2	3.2	1.7	1.3	0.6	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1001-038D	8360- 8400	0.4	1.4	6.4	3.0	10.0	4.1	11.7	8.6	7.9	10.0	9.1	9.1	7.5	5.2	3.0	1.5	0.7	0.3	0.1	0.0	0.0	0.0	0.0
1001-040D	8750- 8800	0.5	2.5	8.6	3.3	11.7	4.3	12.1	8.7	8.2	8.6	8.5	7.5	7.8	3.7	2.3	1.0	0.5	0.2	0.1	0.0	0.0	0.0	0.0
1001-043D	9050- 9100	0.4	1.1	5.8	2.6	10.1	3.8	12.1	8.8	8.8	10.9	10.6	8.9	7.6	4.4	2.5	1.0	0.5	0.1	0.1	0.0	0.0	0.0	0.0
1001-049D	10050-10100	0.6	3.6	13.9	9.5	16.3	9.5	14.4	8.7	6.4	6.5	4.4	2.8	1.8	0.9	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1001-054D	11100-11150	0.2	0.8	5.2	1.6	11.1	3.7	15.2	11.5	11.0	11.8	10.7	7.5	4.9	2.5	1.3	0.4	0.3	0.1	0.1	0.0	0.0	0.0	0.0
1001-062D	12600-12640	0.5	4.6	15.5	8.3	17.3	8.0	14.8	9.7	7.4	5.8	3.8	1.9	0.8	0.5	0.4	0.2	0.4	0.1	0.1	0.0	0.0	0.0	0.0
1001-064D	12760-12820	0.4	2.9	14.4	6.6	19.0	9.1	16.7	10.9	7.9	5.9	3.5	1.1	0.6	0.3	0.3	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1001-075D	14400-14440	0.5	0.9	7.2	2.9	16.7	6.7	19.9	13.9	11.3	7.0	6.0	2.6	1.4	0.5	0.7	0.7	0.7	0.2	0.2	0.0	0.0	0.0	0.0

* In feet.

Table VI

Visual Kerogen Assessment Worksheet



	GeoChem No.	Depth	Remarks
	1001-009D	2410'	Am-W;H-C;- (-)
+	1001-013D	3040'	W;H;C (-)
+	1001-015D	4390'	W;H-C;-
	1001-017D	4560'	W;H;C (-)
+	1001-019D	4900'	H;W;C (-)
	1001-027D	6660'	W;C;H
	1001-032D	7500'	W;H-C;-
	1001-035D	7980'	H;W;C (-)
	1001-038D	8400'	W;H;C
	1001-040D	8800'	W;H;C
	1001-043D	9100'	W;H;C
	1001-048D	9970'	W;H;C
	1001-049D	10100'	W;H-C;- (-)
+	1001-054D	11150'	C;W;H (-)
	1001-062D	12640'	C;H;Am-W (-)(*)
+	1001-064D	12820'	C;W;Am-H (-)
+	1001-071D	13760'	Am;H-C;- (*)
+	1001-075D	14440'	W;H;C (-)

(-) Degraded herbaceous.

(*) Relic amorphous.

Table VII

Vitrinite Reflectance Summary

GeoChem Sample Number	Depth (feet)	Number of Readings	Minimum Reflectance (% Ro)	Maximum Reflectance (% Ro)	Average Reflectance (% Ro)
1001-49D	10050' - 10060'	21	1.76	2.36	2.10

Table VIII

Summary of Hydrocarbon Source Character

ORGANIC FACIES	WELL DEPTH INTERVAL (FEET)	LITHOLOGY	ORGANIC CARBON (% of rock)	VISUAL KEROGEN TYPE	VISUAL KEROGEN ALTERATION (Considered in place)	VITRINITE REFLECTANCE (% R_o)	C_{15+} EXTRACTION DATA (ppm) TOTAL	P-N	AROM	TOTAL HC's	HYDROCARBON SOURCE CHARACTER	PROSPECTIVENESS
	400±	Medium dark gray agrillaceous dolomites and micritic limestones predominate.	0.01	Woody Predominates							Mature, very poor oil, condensate, "wet" and/or "dry" gas source character.	Non-prospective for any producible quantities of indigenously generated hycarbons.
A	to		to									
			0.40	W;H;C	2+ to 3-	N.D.	59	< 20	< 20	< 40		
	7,350±		0.13 Mean	Secondary Herbaceous								
	7,350±	Medium dark gray shales alternating with argillaceous, micritic limestones predominate.	0.07	Woody Predominates		1.76	66	≈10	≈10	≈20	Very mature, very poor oil, condensate and associated "wet" gas source character, and a fair to good "dry" thermally derived methane gas source character.	Non-prospective for any producible quantities of oil, condensate or "wet" gas.
			to			to	to	to	to	to		
B	to		1.36	W;H;C	3 to 3+	2.36	172	≈30	≈30	≈60		Prospective for fair to good quantities of "dry" methane gas provided that reservoir traps are available.
	10,150±		0.58 Mean	Secondary Herbaceous		2.10 Mean	112 Mean	< 20 Mean	< 20 Mean	< 40 Mean		
	10,150±	Argillaceous, dark gray micritic limestones predominate.	0.02	Coaly Predominates			70	≈ 20	≈20	≈40	Very mature to severely altered, very poor oil, condensate and associated "wet" gas source character. This zone contains two intervals (10,900± to 11,200± feet and 12,500± to 12,900± feet) which have a fair "dry" thermally derived methane gas source character.	Overall, non-prospective for any producible quantities of oil, condensate or "wet" gas.
			to			N.D.	to	to	to	to		
C	to		0.88	C;H-W;Am	3+ to 4		190	≈30	≈30	≈60		Two intervals (10,900± to 11,200± feet and 12,500± to 12,900± feet) are considered prospective for fair quantities of "dry" methane gas provided that reservoir traps are available.
	14,510±		0.19 Mean	Secondary Herbaceous/ Woody			123 Mean	< 25 Mean	< 25 Mean	< 50 Mean		

N.D. = No Data.

Table VIII (Contd.)

GEOTHERMAL DIAGENTIC CRITERIA AND VARIOUS GEOCHEMICAL RICHNESS SCALES UTILIZED FOR TABLE VIII DATA

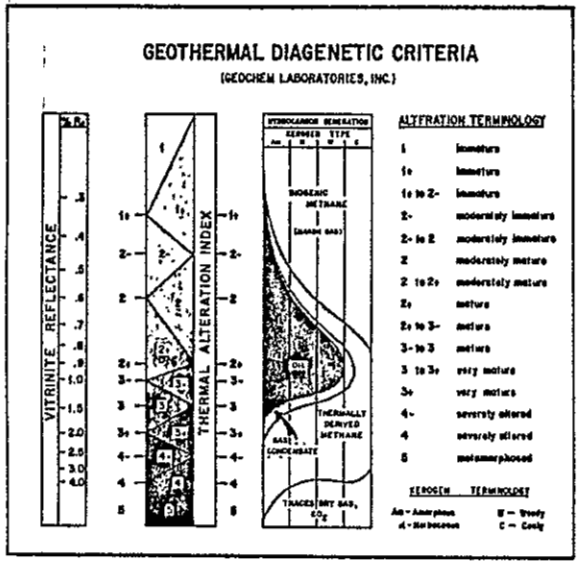
ORGANIC CARBON RICHNESS SCALE

	Carbonates	Clastics
Very poor to poor	0 to 0.25%	0 to 0.5%
Fair to good	0.25 to 0.50%	0.5 to 1.00%
Good to very good	0.50 to 1.0 %	1.0 to 4.0%
Excellent	> 1.00%	> 4.0%

KEROGEN TYPE & PREDOMINANCE KEY

Predominant;	Secondary;	Trace
60-100%	20-40%	1-20%

Al = Algal
Am = Amorphous-Sapropel
H = Herbaceous-Spore/Cuticle
W = Woody
C = Coaly
U = Unidentified Material



C_{15+} TOTAL BITUMEN EXTRACT RICHNESS SCALE

0 - 250 ppm : Very Poor
250 - 500 ppm : Poor
500 - 1000 ppm : Fair
1000 - 2000 ppm : Good
2000 - 4000 ppm : Very good
Greater than 4000 ppm : Excellent

C_{15+} TOTAL HYDROCARBON RICHNESS SCALE

0 - 50 ppm : Very poor
50 - 100 ppm : Poor
100 - 200 ppm : Fair
200 - 400 ppm : Good
400 - 800 ppm : Very good
Greater than 800 ppm : Excellent

APPENDIX A

BRIEF DESCRIPTION OF ORGANIC GEOCHEMICAL ANALYSES PERFORMED IN THIS STUDY

Lithological Description and Picking of Samples

Rock samples of dry paleo cuttings and conventional cores were lithologically described and carefully screened to remove obvious cavings. Representative lithologies were composited for detailed geochemical analysis. Sample identification and lithological descriptions are recorded in Table II.

Organic Carbon

The total organic carbon content of a rock is a measure of its total organic richness. This data is used in conjunction with visual kerogen and C_1-C_4, C_4-C_7 and C_{15+} hydrocarbon content of a rock to indicate its hydrocarbon source quality.

The procedure for determining the total organic carbon content of a rock involves grinding the dried sample to a powder, weighing out a 0.2729 gram sample into a crucible and acidizing with hot and cold hydrochloric acid to remove any carbonate, and performing combustion carbon analysis in a Leco carbon analyzer.

We run several blank crucibles, standards (iron rings of known carbon content) and duplicate rock samples in this analysis for purposes of data quality control.

The organic carbon data is recorded in Tables II and III.

C_{15}- Soxhlet Extraction, Deasphaltening and Chromatographic Separation

The amount and composition of the organic matter which can be solvent-extracted from a rock reflects source quality and source type. C^{13}/C^{12} carbon isotopic, high mass spectrometric and gc analyses of the paraffin-naphthene and aromatic hydrocarbon fractions of the soluble extract gives data which is used in crude oil-parent rock correlations.

This analysis involves grinding of a dry rock sample to a powder and removal of the soluble organic matter by soxhlet extraction using a benzene-methanol solvent. Where the amount of available sample material permits, we like to use at least 100 grams of rock for this analysis.

The extracted bitumen is separated into an asphaltene (Asph) and a pentane soluble fraction by normal pentane precipitation. The pentane soluble components are separated into a saturate hydrocarbon (P-N), aromatic hydrocarbon (AROM) and nitrogen-sulfur-oxygen containing fraction (NSO) by adsorption chromatography on a silica gel-alumina column.

A semi-quantitative micro-chromatographic analysis was performed on some of the samples since they contained an insufficient amount of n-C_5 soluble extract suitable for quantitative liquid chromatography. This enabled GeoChem to run gas-chromatographic analyses of the C_{15+} paraffin-naphthene (P-N) hydrocarbon fraction for all of the samples.

All C_{15+} compositional data is reported in Tables IV-A, B and C.

GC Analysis of C_{15+} Paraffin-Naphthene Hydrocarbons

The content and molecular composition of the heavy C_{15+} paraffin-naphthene hydrocarbons of rocks, as determined by gc analysis, reflects source quality, source type and degree of thermal maturation.

In this analysis we subject a very small fraction of the total amount of the P-N fraction extracted from a rock sample to gc analysis. The gas chromatograph is a Varian Aerograph Model 1400 equipped with a solid rod injection system and a eutectic column.

The chromatographic traces are shown in Figures 2, and the compositional data obtained for the C_{15+} saturate hydrocarbon is reported in Tables V-A and B.

In this study the calculated C. P. I. (carbon preference index) values for the normal paraffin data is defined as the mean of two ratios which are determined by dividing the sum of concentrations of odd-carbon numbered n-paraffins by the sum of even-carbon numbered n-paraffins. The C. P. Indices A and B were obtained by the formulas:

$$\text{C. P. Index A} = \frac{\dfrac{C_{21}+C_{23}+C_{25}+C_{27}}{C_{22}+C_{24}+C_{26}+C_{28}} + \dfrac{C_{21}+C_{23}+C_{25}+C_{27}}{C_{20}+C_{22}+C_{24}+C_{26}}}{2}$$

$$\text{C. P. Index B} = \frac{\dfrac{C_{25}+C_{27}+C_{29}+C_{31}}{C_{26}+C_{28}+C_{30}+C_{32}} + \dfrac{C_{25}+C_{27}+C_{29}+C_{31}}{C_{24}+C_{26}+C_{28}+C_{30}}}{2}$$

These C. P. I. values are recorded in Table V-A.

Visual Kerogen

A visual study of kerogen, the insoluble organic matter in rocks, can indicate the relative abundance, size, and state of preservation of the various recognizable kerogen types and thereby indicate the hydrocarbon source character of a rock. The color of the kerogen can be used to indicate the state of thermal maturity of the sediments (i.e. their time-temperature history). Thermal maturation plays an important role in the generation of hydrocarbons from organic matter and also affects the composition of reservoired hydrocarbons.

Our procedure for visual kerogen slide preparation involves isolation of the organic matter of a rock by removal of the rock material with hydrochloric and hydrofluoric acid treatment and heavy liquid separation. This procedure is comparable to that used by the palynologist except it does not include an oxidation stage. (The oxidation treatment is deleted from our procedure because it removes a great deal of kerogen and blanches any remaining kerogen to an extent whereby it is useless for our kerogen color observations.) The kerogen residue is mounted on a glass slide and is examined visually under a high power microscope. The kerogen assessment is noted in Tables III and VI.

Vitrinite Reflectance (%R_o)

Vitrinite reflectivity (%R_o) is a precise method of determining the state of geochemical maturation of the organic matter in sediments.

The kerogen isolated from the sedimentary rock by a similar process to that described above is embedded in Epoxy and polished. The Vitrinite reflectivity is then measured using a high resolution microscope calibrated against a known standard. The degree of thermal alteration is derived statistically by obtaining approximately 40 measurements on different pieces of vitrinite. Data is presented in Table VII and in histogram format in Figure 3.

FIGURE 1

HUMBLE No. 1 STATE BA
HIDALGO COUNTY, NEW MEXICO

SUMMARY OF ORGANIC ANALYSES

SOURCE CHARACTER

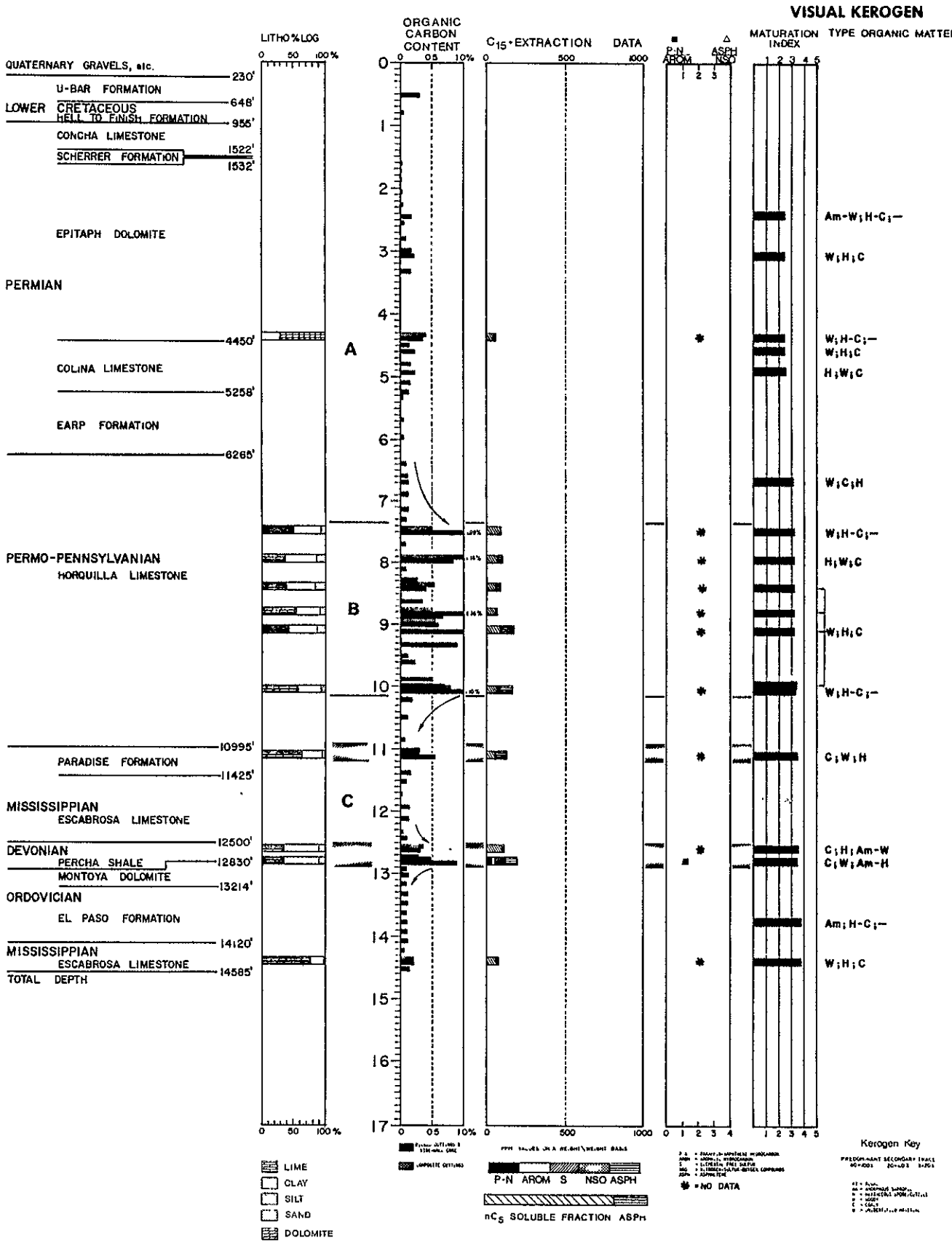


FIGURE 2

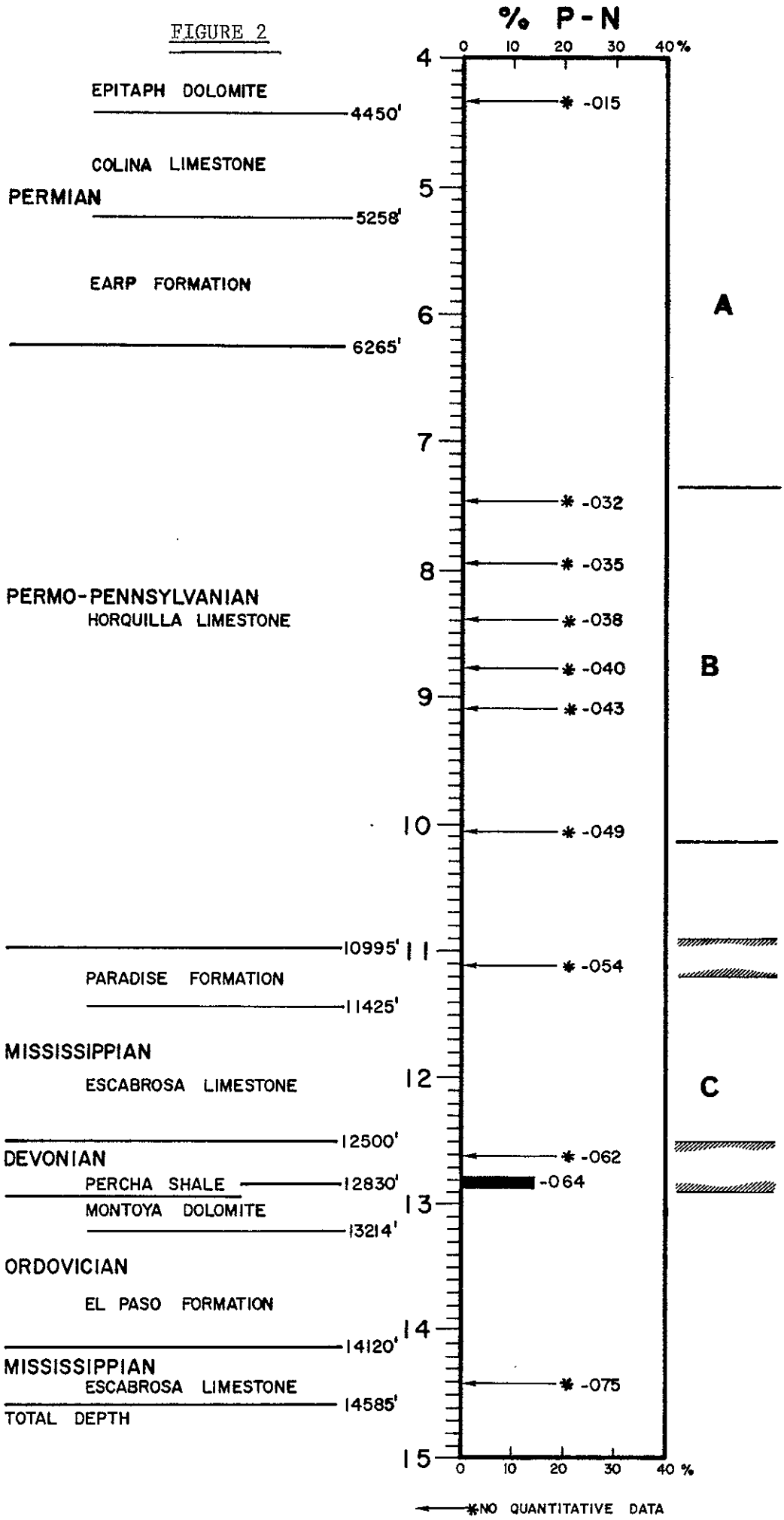

% P-N
0 10 20 30 40%
EPITAPH DOLOMITE
4450'
COLINA LIMESTONE
PERMIAN
5258'
EARP FORMATION
6265'
PERMO-PENNSYLVANIAN
HORQUILLA LIMESTONE
10995'
PARADISE FORMATION
11425'
MISSISSIPPIAN
ESCABROSA LIMESTONE
12500'
DEVONIAN
PERCHA SHALE
12830'
MONTOYA DOLOMITE
13214'
ORDOVICIAN
EL PASO FORMATION
14120'
MISSISSIPPIAN
ESCABROSA LIMESTONE
14585'
TOTAL DEPTH
4
5
6
7
8
9
10
11
12
13
14
15
-015
-032
-035
-038
-040
-043
-049
-054
-062
-064
-075
A
B
C
0 10 20 30 40 %
*NO QUANTITATIVE DATA

FIG. 2 - B

1001-015

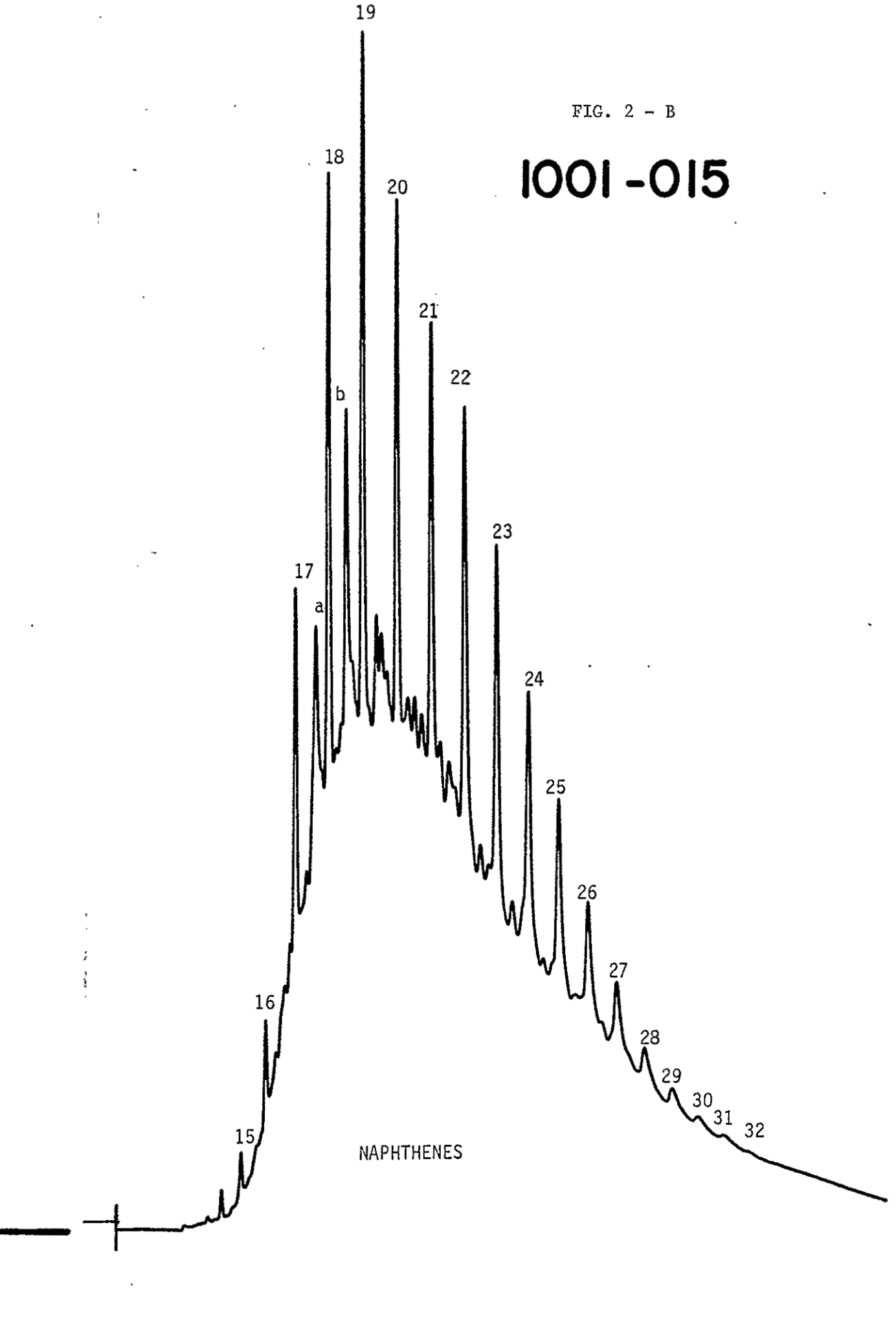


FIG. 2 C

-032

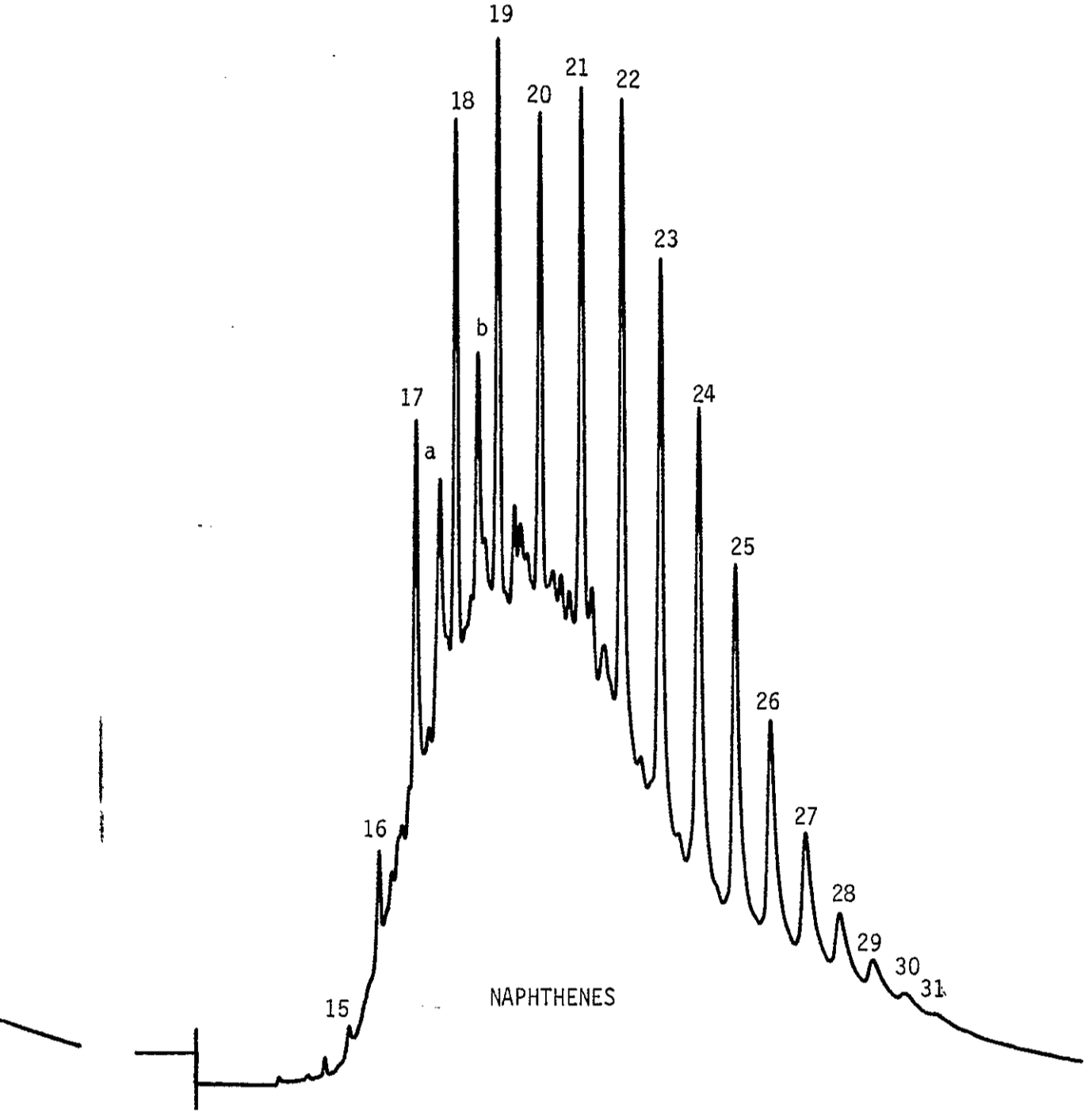


FIG 2 D

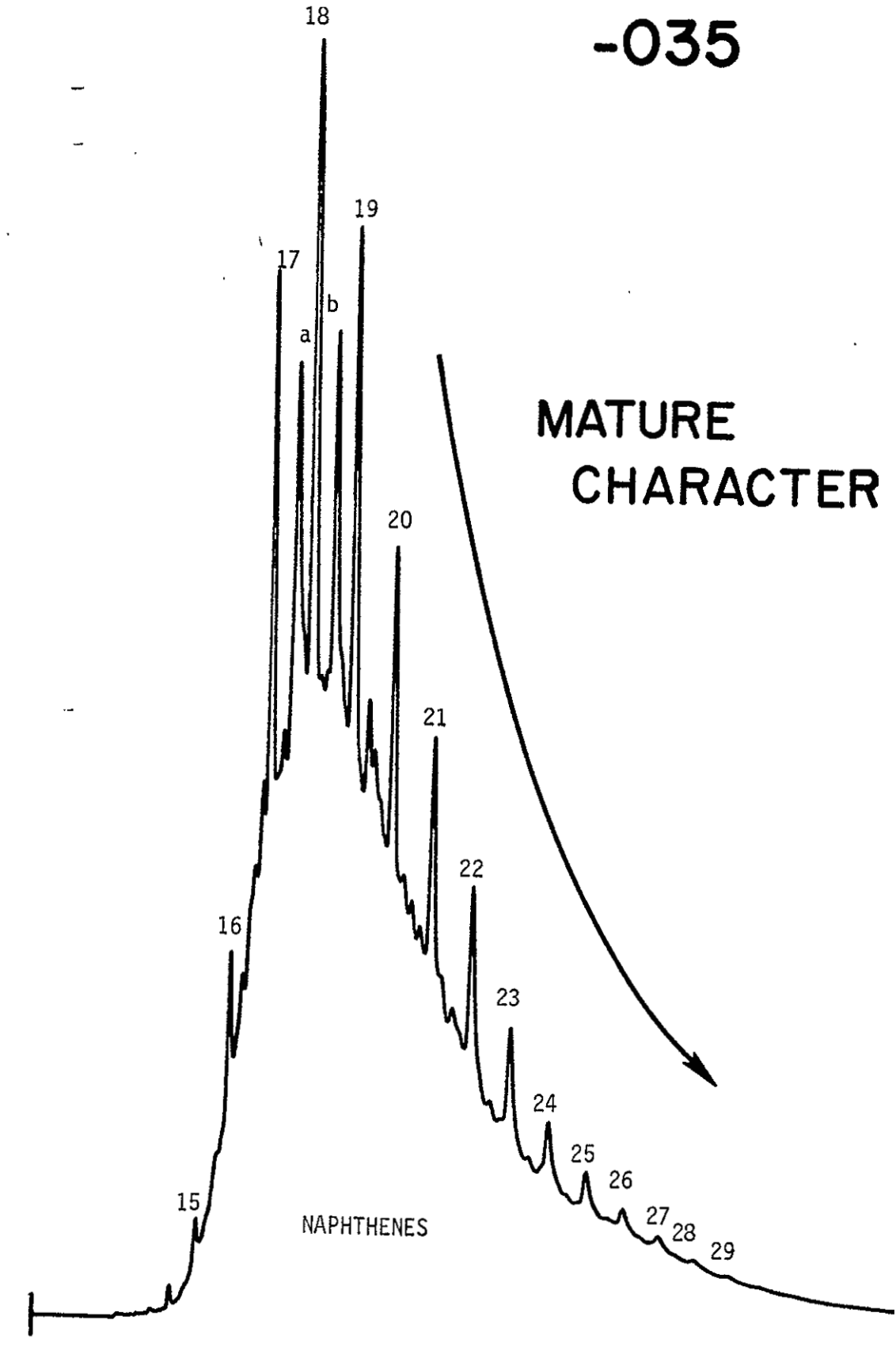

-035
18
19
17
a
b
MATURE
CHARACTER
20
21
22
16
23
24
25
26
27
28
29
15
NAPHTHENES

FIG 2 E

-038

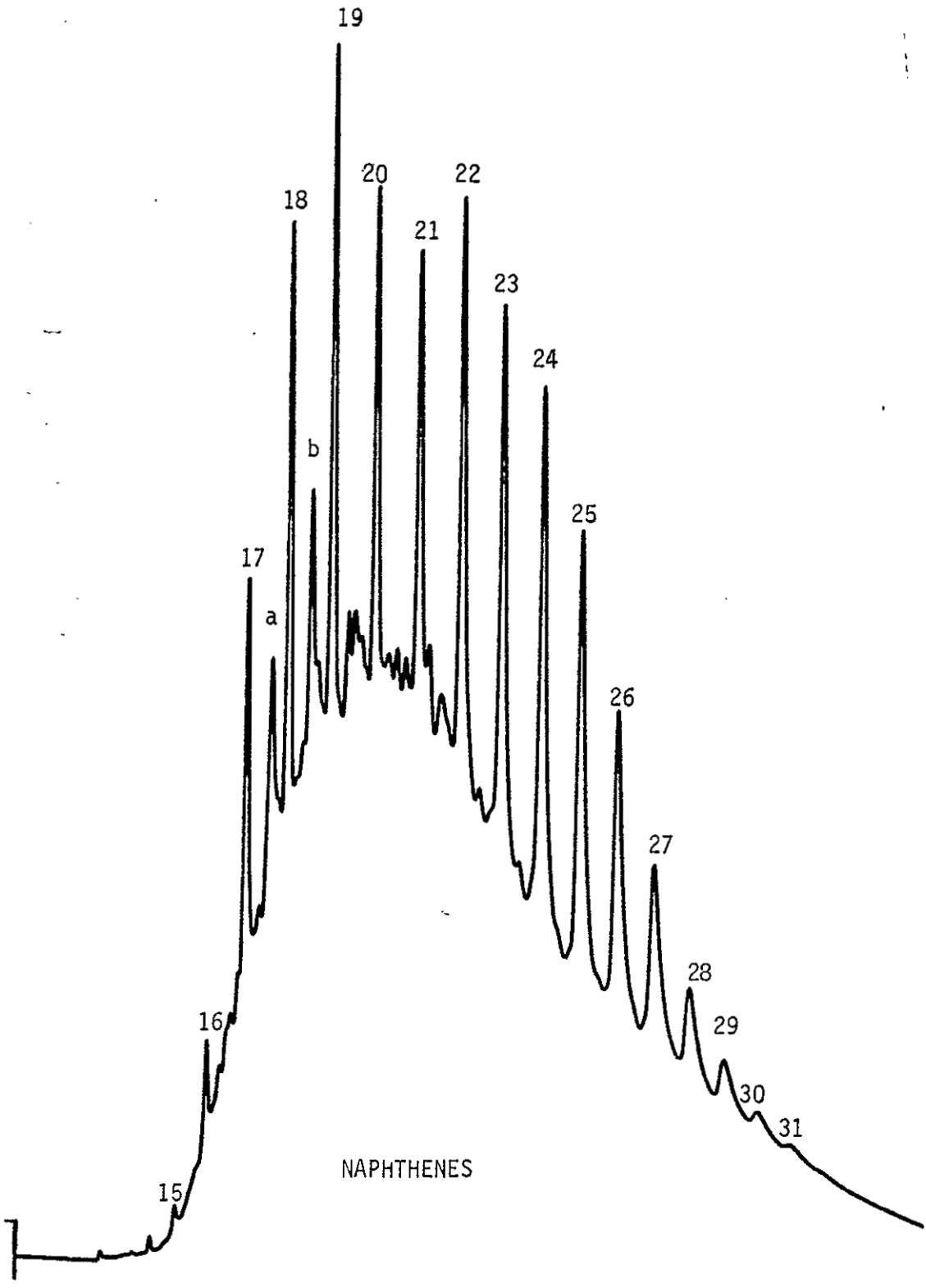


FIG. 2 F

-040

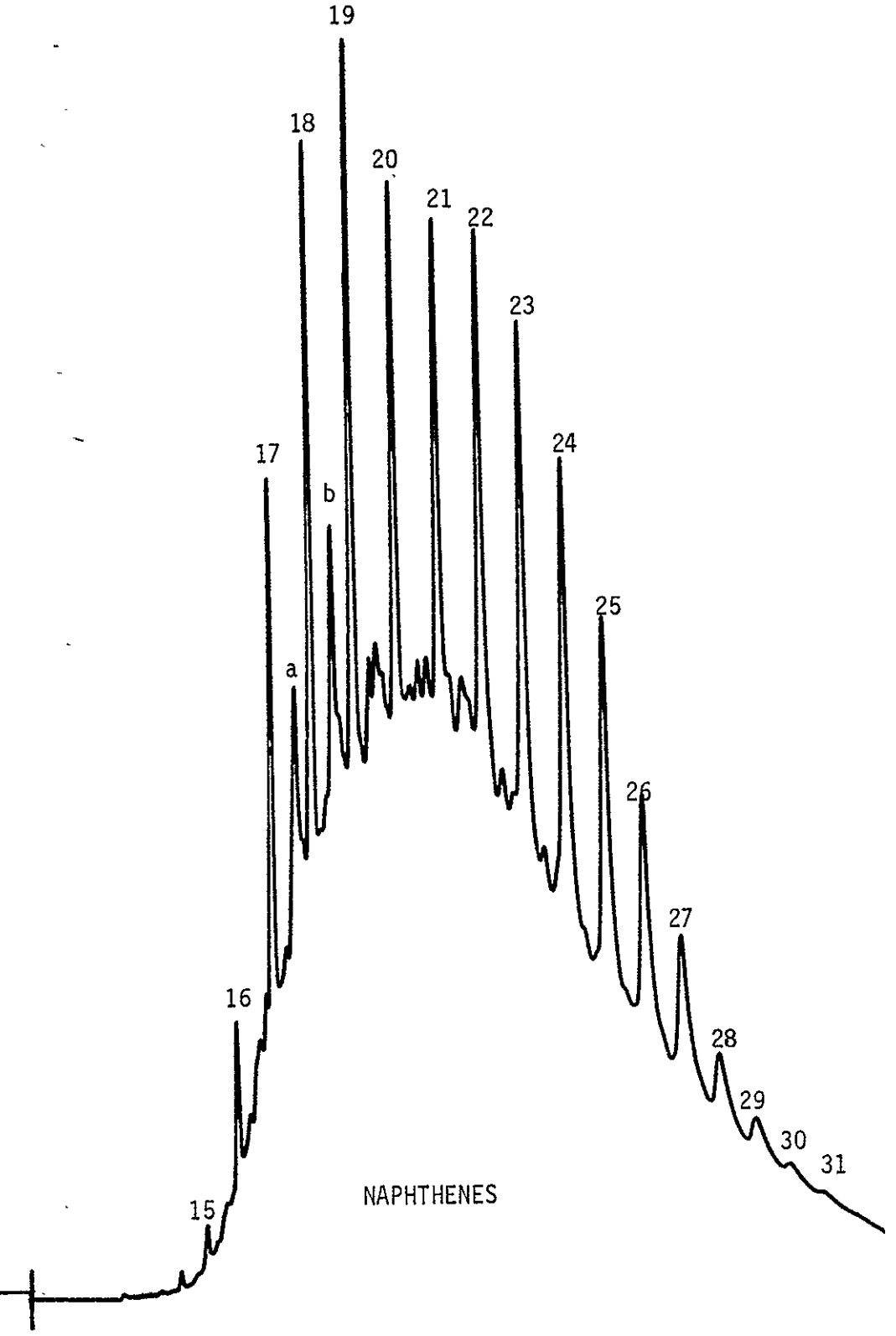
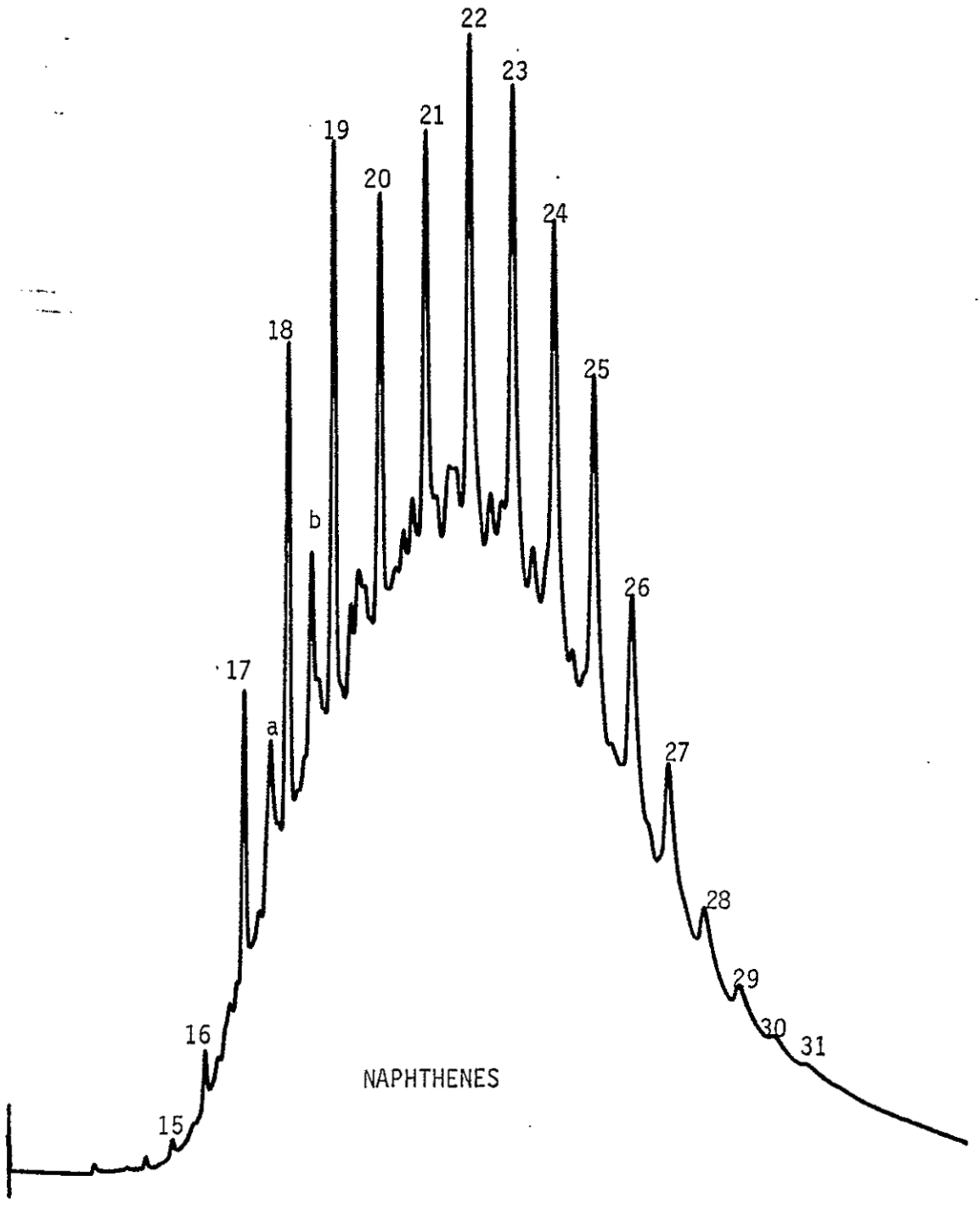


FIG. 2 G

-043



-049

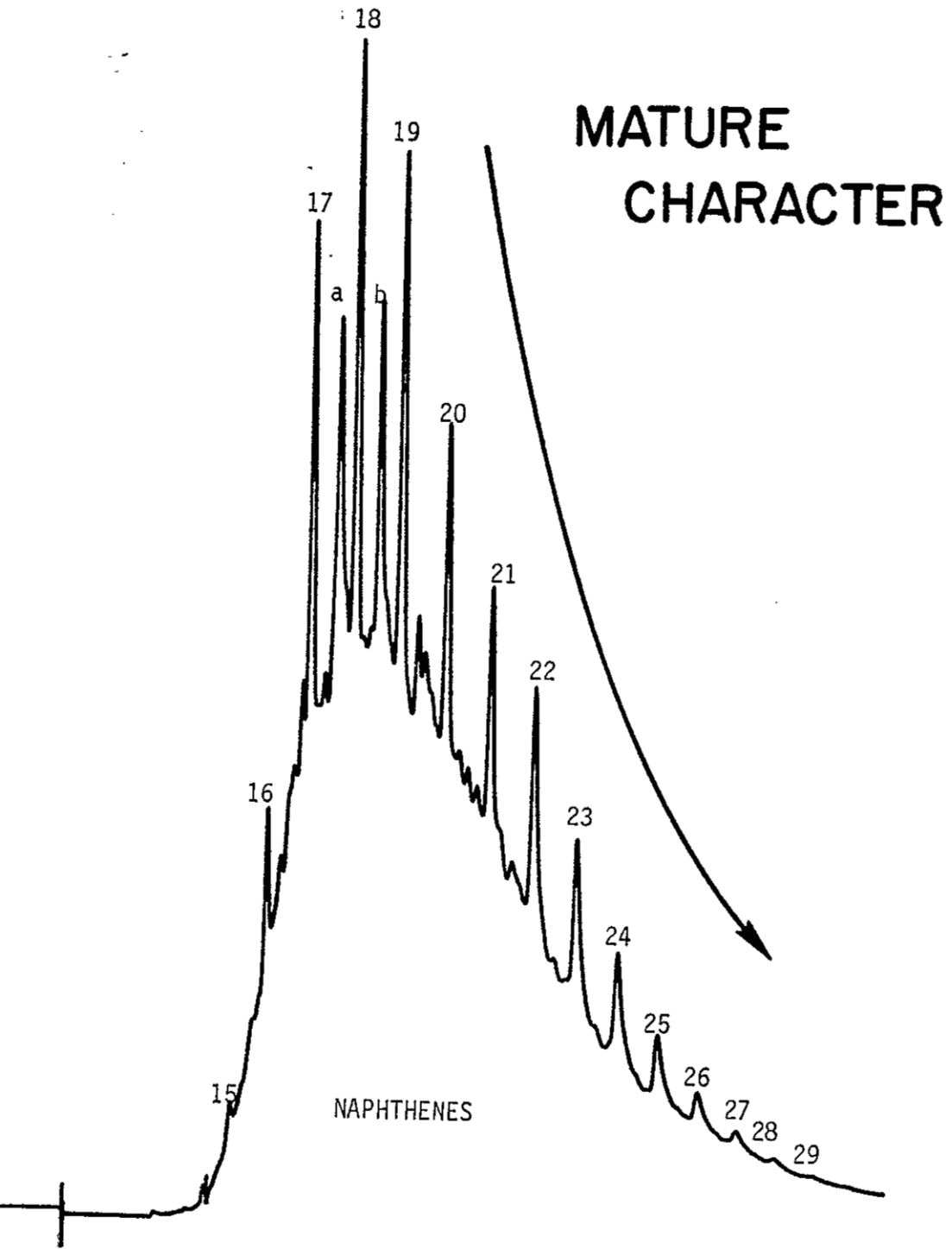

18
19
17
a
b
20
21
22
16
23
24
25
26
27
28
29
15
NAPHTHENES
MATURE
CHARACTER

FIG. 2 I

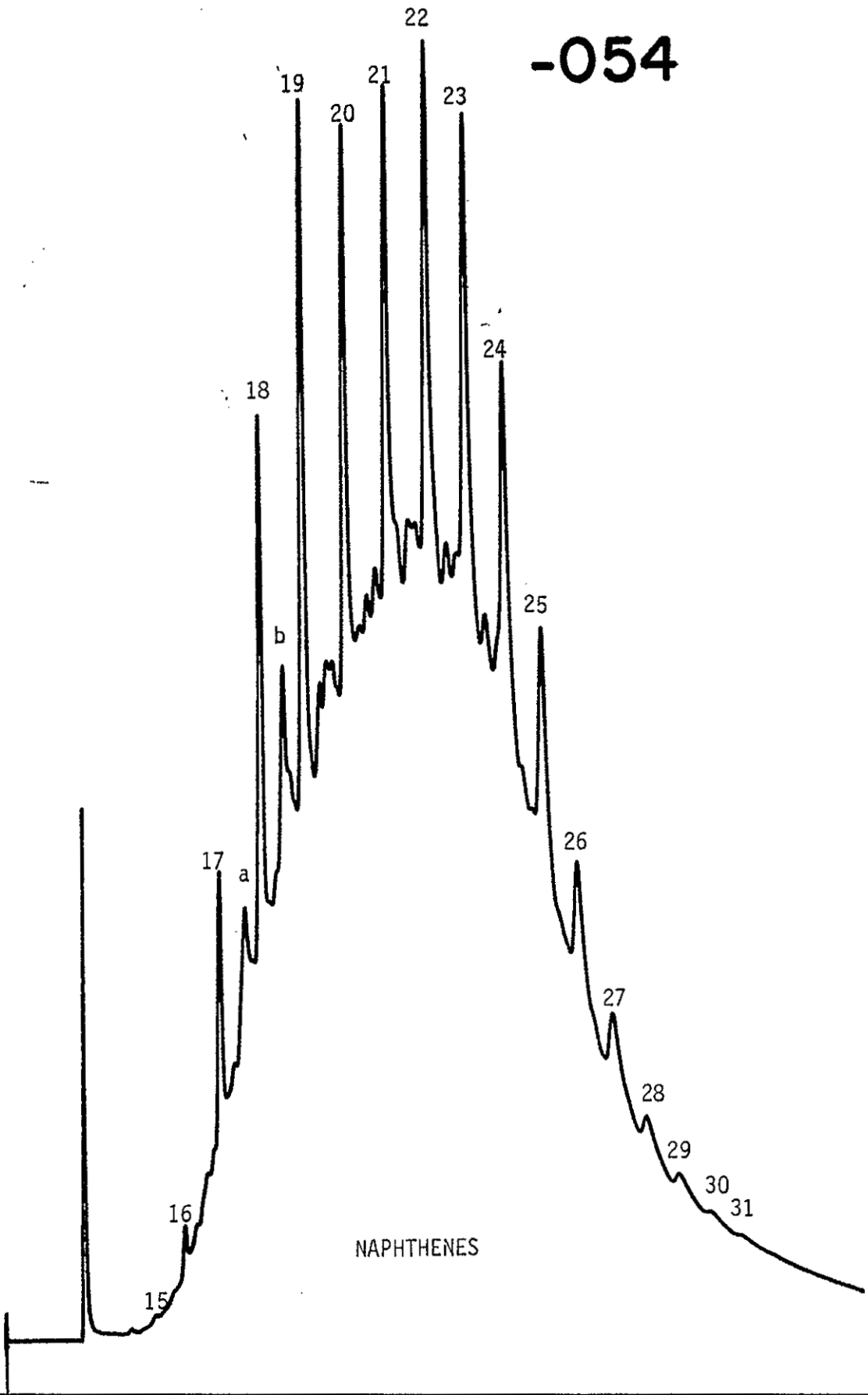


FIG. 2 J

-062

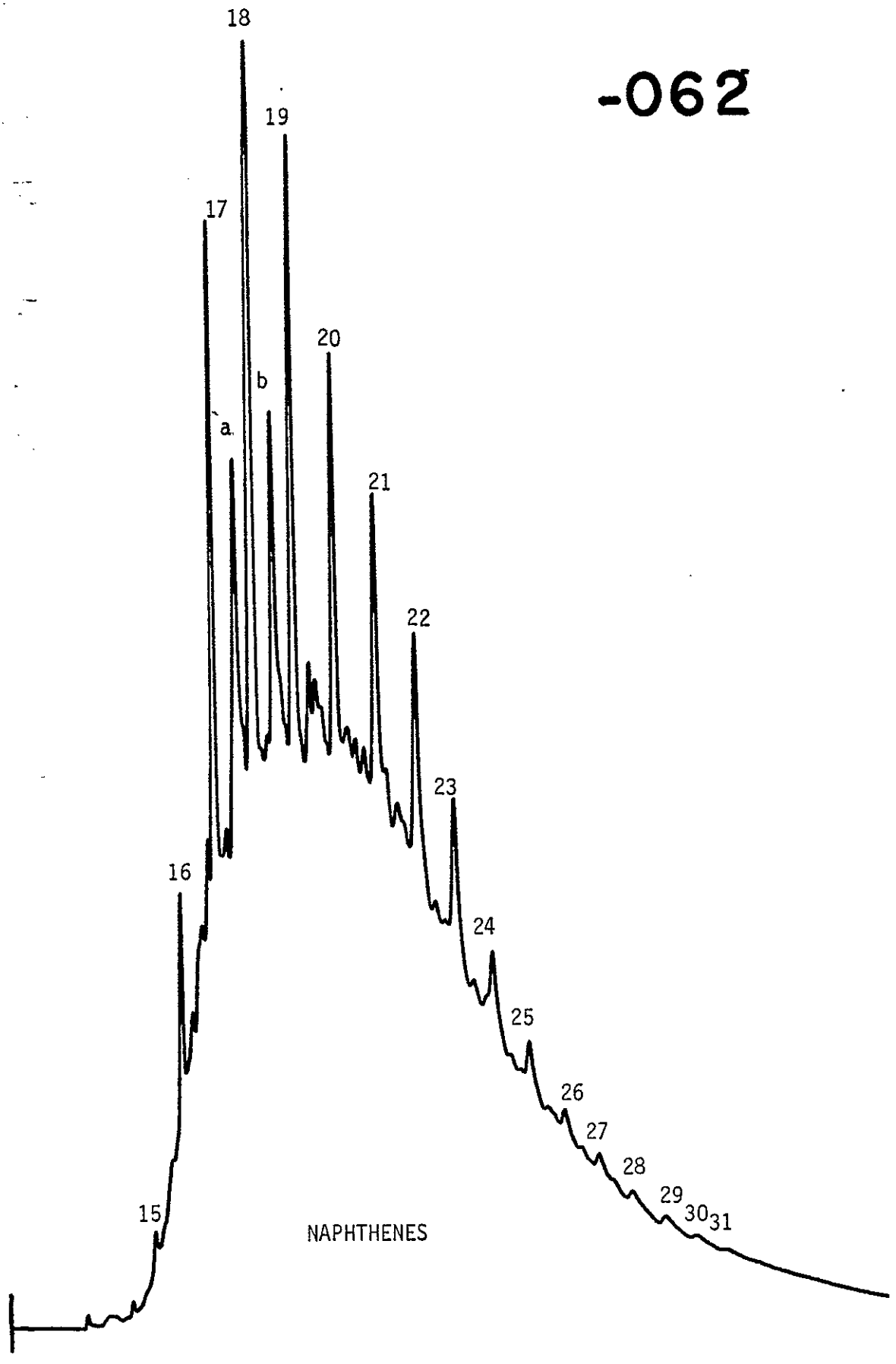


FIG. 2 K

-064

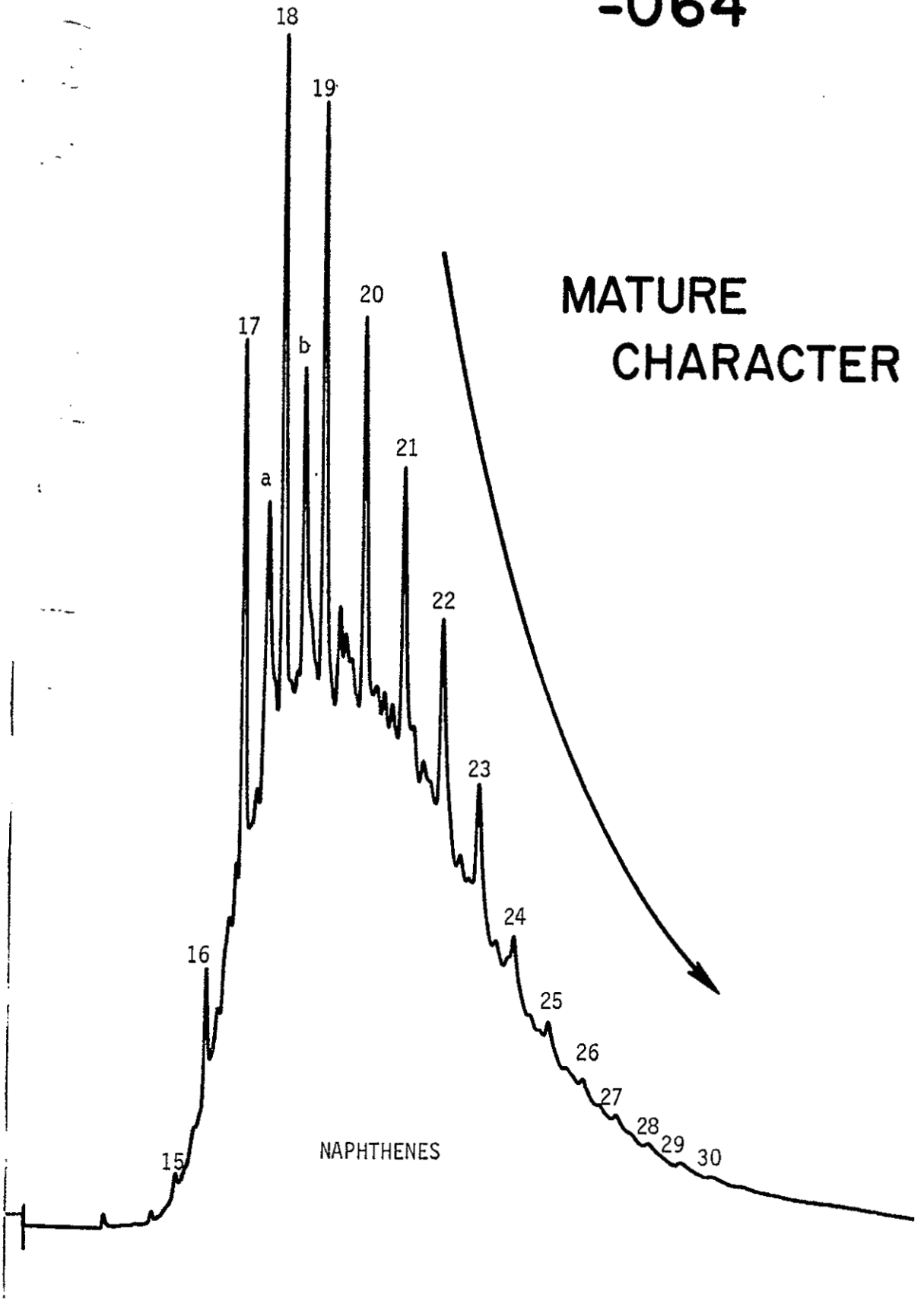

18
19
17
b
20
a
21
22
23
24
16
25
26
27
28
29
30
15
NAPHTHENES
MATURE
CHARACTER

FIG. 2L

-075

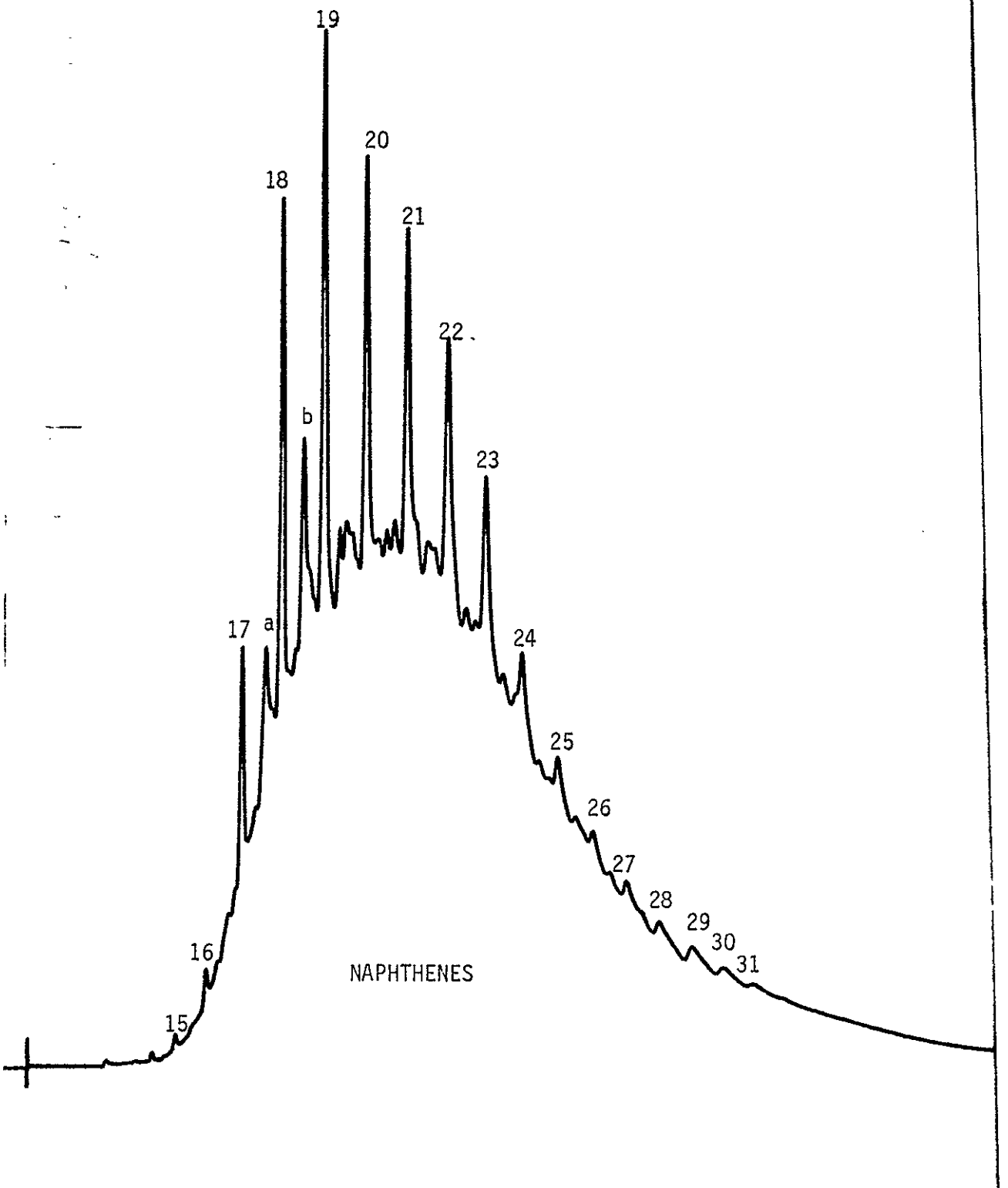


FIG. 2 M

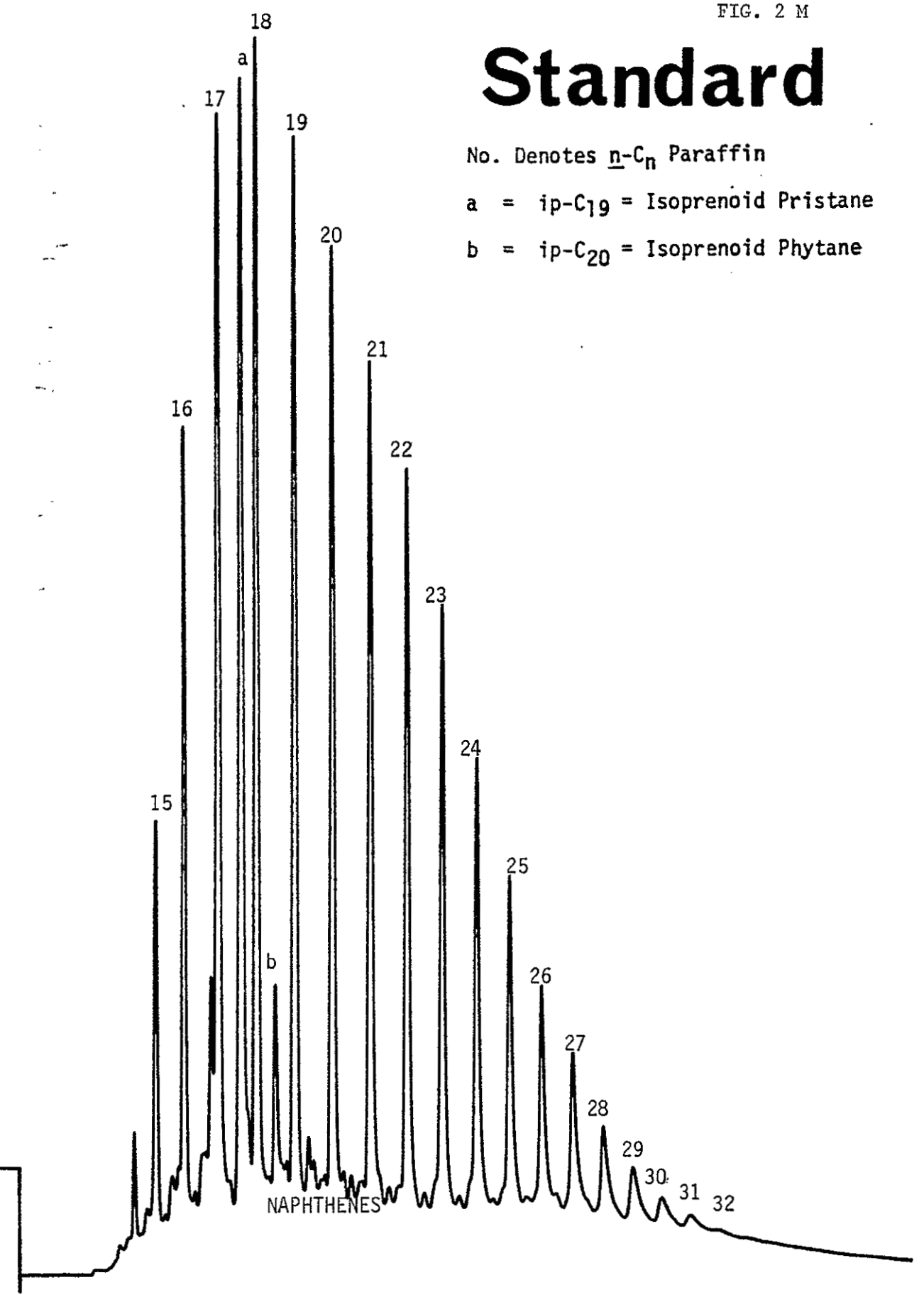
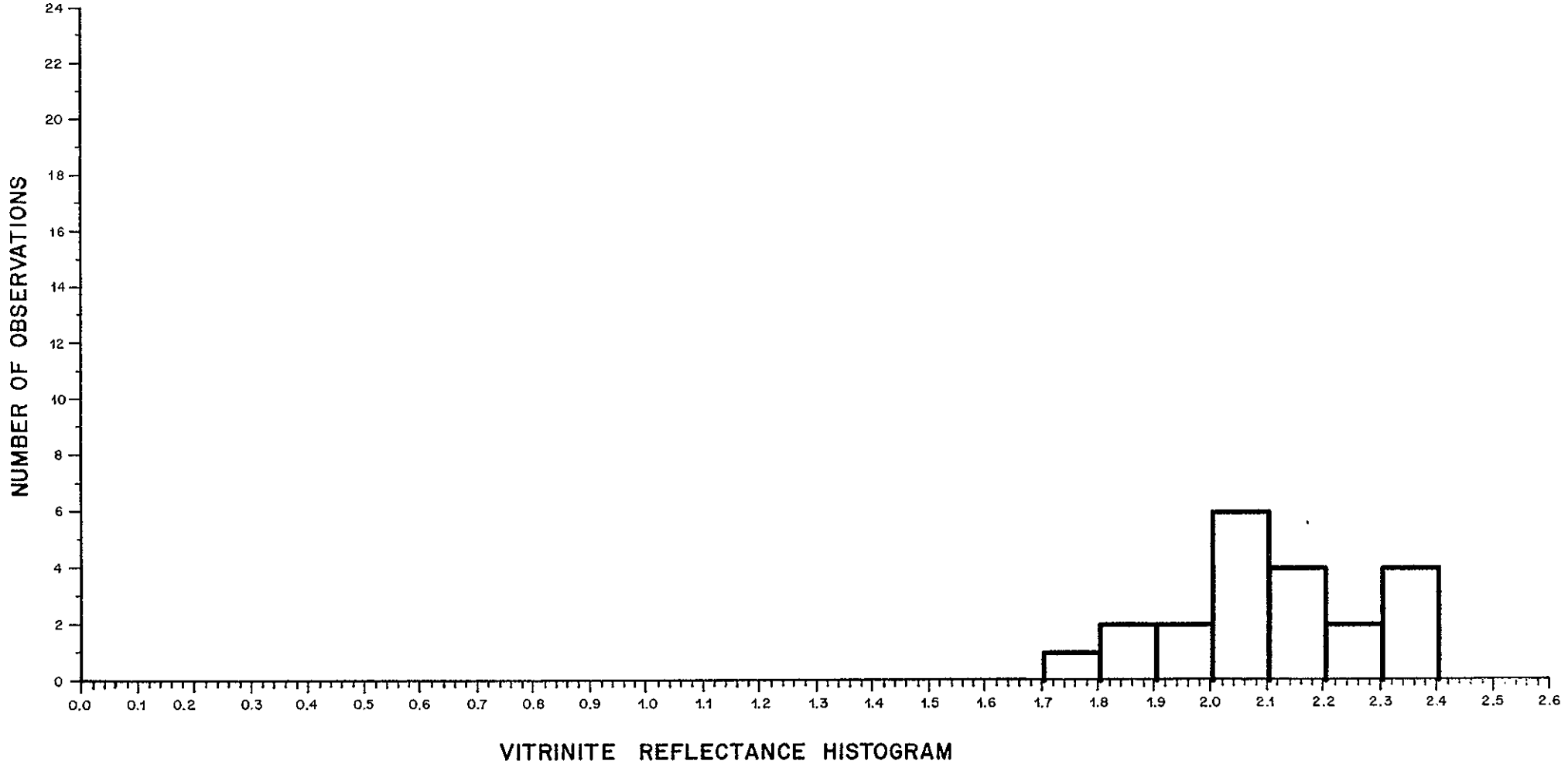

Standard
No. Denotes n-C_n Paraffin
a = ip-C_{19} = Isoprenoid Pristane
b = ip-C_{20} = Isoprenoid Phytane
15
16
17
18
a
19
b
20
21
22
23
24
25
26
27
28
29
30
31
32
NAPHTHENES

Figure 3

COMPANY Humble Oil Company GEOCHEM NO. 1001-49D NUMBER OF OBSERVATIONS 21

WELL OR OUTCROP Well LOCATION Hidalgo Co., N.M. DEPTH OR SAMPLE NO. 10050' - 10060'

MIN. REFLECTANCE 1.76 (%Ro) MAX. REFLECTANCE 2.36 (%Ro) AVG. REFLECTANCE 2.10 (%Ro)



VITRINITE REFLECTANCE HISTOGRAM