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GEOCHEMICAL STUDIES OF ROCK AND OIL SAMPLES FROM 33/9-7, 33/12-6 AND 34/10-1, 2 AND 3, OFFSHORE NORWAY

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Reservoir Evaluation Division

September 1979

OMRÅDE: 33/9, 12 & 34/10

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EXXON PRODUCTION RESEARCH COMPANY

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GEOCHEMICAL STUDIES OF ROCK AND OIL SAMPLES FROM 33/9-7, 33/12-6 AND 34/10-1, 2 AND 3, OFFSHORE NORWAY

R. E. Metter

CONCLUSIONS

A. Hydrocarbon Source Patterns

1. The drilled sections in the five wells of this study all failed to reach a mature zone, as is indicated below:

Well	Deepest Sample Studied	
	Unit	Maturity
33/9-7	Statfjord	Immature
33/12-6	Triassic	Transitional
34/10-1	Statfjord	Immature
34/10-2	Triassic	Transitional
34/10-3	Triassic	Immature

   Of course, the equivalent intervals off-structure may be mature due to deeper burial and higher subsurface temperatures.

2. Shales from the Brent, Dunlin and Statfjord intervals, as well as Dogger shales overlying the Brent sand, include good to rich potential sources of gas and oil. No definite Malm shales were analyzed in this study, but we assume the Malm also includes good to rich potential source rocks that would generate considerable amounts of oil wherever they might be mature. All of the Jurassic units and some of the Cretaceous also contained shales that were rated as fair potential sources.

B. Correlations of Oils, Tars and Rock Extracts

1. Oils from the Brent sands in 34/10-1, 34/10-3 and 33/9-7, a condensate from the Brent in 34/10-2, an oil from the Statfjord unit in 34/10-2, and a tar from the Brent sand in 33/9-7 all come from a single genetically related oil family. The oils from 34/10-1 and 34/10-3 have been notably altered presumably by biodegradation and possibly by water washing. Perhaps the oil from 33/9-7 has been slightly altered by the same processes.

2. Three tars from the Triassic in well 33/12-6 are nearly identical to each other, but they represent a different family than the oils listed above.

3. Four cuttings samples from 34/10-3, representing Cretaceous, Brent and Dunlin shales, do not correlate with the oils and tars. The immaturity of the section in this well would not lead us to expect a good correlation in the first place.

4. Eight cuttings samples from the 34/10-2 well, representing the same three stratigraphic intervals as those from 34/10-3, include several whose hydrocarbon extracts by most of our correlation criteria resemble the oil sample from the Statfjord of 34/10-2. The Cretaceous samples, in particular, resemble the oil; but so do samples from the Brent and Dunlin intervals. This might indicate that the oil was generated by shales from the entire Jurassic and Cretaceous interval. However, we believe that the 34/10-2 cuttings have been contaminated by oil that was either introduced by adding Statfjord oil to the drilling mud, or by the natural upward migration of reservoired oil from the Statfjord sands through the younger strata. The apparent lack of mature beds in the section here supports the latter idea of migration.

5. We have not identified a specific source of the oils we analyzed. Perhaps the source was the Malm, which we did not sample. In any case, standard cores provide a much more reliable type of sample for this purpose than do cuttings, which are quite susceptible to contamination from mud additives or from mixing with oil-bearing reservoir sands within the mud stream.

BACKGROUND

Canned cuttings from the 34/10-2 and 34/10-3 wells, and dry unwashed (plus some washed) cuttings from 34/10-1, 33/9-7 and 33/12-6 wells were analyzed routinely for hydrocarbon source characteristics. The results were transmitted in four reports which are listed later at the end of the Discussion.

Five oil samples from wells 34/10-1, 34/10-2, 34/10-3 and 33/9-7, and four tars found in cuttings envelopes from 33/9-7 and 33/12-6, were analyzed for geochemical "fingerprint" characteristics, and these were compared with selected cuttings from wells 34/10-2 and 34/10-3. The purpose was to identify oil families among the samples and to identify possible sources of the reservoired hydrocarbons.

Standard core samples are best for providing rock extracts to compare with oils, but we did not have any suitable ones for this purpose. Also, we did not even have usable cuttings samples from the Malm, which is a prime candidate as the major source of oil in this area.

This work was authorized in the Technical Service Job Authorization No. 1119 of March 19, 1979 by J. Barrier of Esso Exploration and Production Norway, Inc. Work on the study has been assigned to Exxon Production Research Job No. 11392.

ANALYTICAL PROCEDURES

Source Analyses

Hydrocarbon source analysis procedures are discussed in the individual well reports listed at the end of the Discussion. Basically, they include a measure of total organic carbon in the samples, plus one or more analyses of hydrocarbons present. If canned cuttings were available, determinations were made of hydrocarbon gases (C_1-C_4), light gasolines (C_4-C_7) and on selected samples, heavy hydrocarbons (C_{15+}).

Although visual kerogen description is not a chemical technique, it is an integral part of source evaluation and was included as a part of the "geochemical" analysis. The visual kerogen in the 34/10 Block samples was studied by transmitted light and described according to the so-called "Staplin Method", whereby alterations of certain spores and pollen are rated on a 1 to 5 scale, with 1 being immature, 5 metamorphosed, and the 2+ to 3 range being mature. Types of kerogen are identified as amorphous and algal (oil-prone), coaly or woody (gas-prone) and herbaceous (oil and gas).

"Fingerprint" analyses

Samples of the crude oils were "topped" by heating at 45°C for 19 hours to drive off the gasoline-kerosine compounds. The remaining heavy fractions were then treated with pentane to remove asphaltenes, and the pentane-soluble portions were separated by liquid column chromatography into saturates, aromatics, eluted NSO compounds and "noneluted NSO's". These results are given in Table 3 under "Gross Composition". The four tars were similarly analyzed, but topping was not necessary. The heavy saturate fractions were analyzed by gas chromatography (Figs. 5 thru 13).

Both the heavy saturate and heavy aromatic fractions were analyzed by mass spectrometry for the molecular types of compounds in them (Table 3). They were also analyzed by a different type of mass spectrometer for their carbon isotope values, expressed as parts per thousand ($^{o}/oo$) deviation from the Pee Dee belemnite standard (Table 3). The molecular data and isotope data were plotted graphically (Figs. 2 and 3).

The light gasolines (C_4-C_7) in the crude oils were analyzed by gas chromatography (Table 4).

The canned cuttings provided the only samples we had that were adequate for "fingerprint" comparisons with crude oils. The dry cuttings samples were too small. Eight samples from 34/10-2 and four from 34/10-3 were sent to GeoChem Laboratories of Houston for heavy (C_{15+}) soluble organic matter analysis (Table 2). This consists of extractions of organic matter with methanol-methylene chloride solution and analysis of the extracts (after deasphaltening) by means of liquid column chromatography. Gas chromatograms were run on the heavy saturate fractions (Reports EPR.132ES.79 and EPR.134ES.79).

The twelve heavy (C_{15+}) hydrocarbon extracts from the cuttings were then analyzed by the same techniques described above that were used on the five crude oil samples and the four tar samples. Results are given in Table 2, and in Figures 2 and 4.

DISCUSSION

The analytical program of this study was in two phases. First, cuttings samples from the five wells (Fig. 1) were analyzed routinely for hydrocarbon source characteristics. These results were transmitted in the four EPR service reports listed at the end of this section. In addition, "fingerprint analyses" were used to compare five crude oils and four tar samples from these same wells with heavy hydrocarbons that were extracted from a suite of twelve lithologic samples taken in the 34/10-3 and 34/10-2 wells. The results on those comparisons are presented in this report.

Although most of the emphasis here is on the comparisons of the hydrocarbons, a brief discussion of both phases of the study is included below.

A. Source Analyses

Canned cuttings from 34/10-2 and 34/10-3 were analyzed and graphic summaries of the results are presented in Figs. 14 and 15. Details were given in reports EPR.132ES.79 and EPR.134ES.79. Dry unwashed cuttings from 33/9-7 and 33/12-6, and "wet" samples from 34/10-1 were also analyzed and results were given in reports EPR.135ES.79 and EPR.138ES.79. The latter three groups of samples were not suitable for gas (C_1-C_4) or light gasoline analyses, and they were also too small for heavy hydrocarbon (C_{15+}) analyses. A few core samples supplementated the cuttings studies.

The results may be summarized as follows:

Well	Approximate Depth of Immature Zone (meters)	Unit and Maturity of Deepest Sample	Potential Good to Rich Source Beds When Mature*
33/9-7	3052+	Statfjord-Immature	Shales in Dunlin
34/10-3	2802+	Triassic-Immature	Shales in Brent, Dunlin
34/10-1	2343+	Statfjord-Immature	Shales in Dogger & Dunlin
34/10-2	2889	Triassic-Transitional	Shales in Dogger, Dunlin, Statfjord
33/12-6	3450(?)	Triassic-Transitional	Shales in Dogger, Dunlin, Statfjord

*All of the Jurassic intervals and some of the Cretaceous include shales that are at least fair potential sources.

B. Comparisons by "Fingerprint" Analyses

Five oil samples, 4 tars and 12 rock samples were analyzed for comparisons (Table 1). The oils included four from the Brent sands and one from the Statfjord. Results of their analyses are listed in Tables 3 and 4 and they are shown graphically in Figures 2 thru 13. Below are listed our conclusions and the reasons for them:

1. The five oils are from the same family.

   a: The three Brent oils from 34/10-1, 34/10-3 and 33/9-7 have nearly identical isotope values (Fig. 2). The saturate fraction of the Brent condensate from 34/10-2 has about the same isotope value as the first three oils, but the aromatic fraction is about 1.5 $^o/oo$ less negative. The Statfjord oil from 34/10-2 has both saturate and aromatic values about 1.5 $^o/oo$ less negative than the other three oils (Fig. 2). The less negative values at 34/10-2 are tentatively attributed to a more mature state of the hydrocarbons there due to greater depth of burial. These data do not preclude the 34/10-2 samples from being genetically related to the other three oils or to each other.

b. The aromatic molecular patterns and the patterns of 4-ring naphthenes in the samples are similar (Fig. 3). However, the saturate molecular patterns are different due to alterations attributed to biodegradation. The paraffins are depleted in oils from 34/10-1 and 34/10-3 and there may be a slight depletion in paraffins in the 33/9-7 oil (Fig. 3). This paraffin depletion is strikingly shown in the suite of gas chromatograms of the saturate fractions (Figs. 5-9).

2. The three Triassic tars from 33/12-6 are nearly identical to each other, but they differ enough from the oils to be classed as a separate family.

a. Their isotope values (Fig. 2), their patterns of molecular types (Fig. 3), and the gas chromatograms of their heavy saturate fractions (Figs. 11-13) are essentially identical.

b. Their carbon isotope values and their aromatic molecular patterns definitely differ from those of the oils (Figs. 2, 3).

3. One of the rock extracts from 34/10-3 correlates with the oils (Fig. 3 vs. Fig. 4), but the other three do not. Isotopically the Cretaceous extract from 1751 meters is similar to the oil from 34/10-3, and the molecular patterns of the 4-ring naphthenes and heavy aromatics are also similar to those of that oil. The saturate molecular patterns are similar in that both show a depletion of paraffins, and their gas chromatograms both show a notable depletion of paraffins (Fig. 8 this report vs. Fig. 2 in EPR.132ES.79). However, there were no measurable gasolines in the 1751-meter sample and the sample was so lean in organic matter and hydrocarbons that it was rated as a poor source. It seems likely that this extract represents leakage upward from the Brent Reservoir rather than indigenous hydrocarbons.

4. Several of the 34/10-2 hydrocarbon extracts had isotope values similar to those of the 34/10-2 oils (Fig. 2), and they came from Upper Cretaceous, Brent and Dunlin intervals. The Cretaceous samples are closest to the oils in their values (Fig. 2). In molecular patterns there is also a resemblance between extracts and oils (Fig. 3 vs. Fig. 4). For example, the Brent extract from 3125 meters (Fig. 4) has molecular patterns that closely match patterns that would be produced by mixing the oil and condensate from 34/10-2. The isotope values would also be comparable. These two samples correlate chemically, but we are not confident that the extract is indigenous. The reason for suspecting it might not be indigenous is the fact that by these same criteria most of the extracts, from the Cretaceous sample at 2285 ft. down to the Dunlin sample at 3275 meters, can also be correlated with the oils (Fig. 3 vs. Fig. 4) and this suggests contamination. The contamination could be natural, due to migration upward through the section, or it could be due to possible use of Statfjord-derived oil as a mud additive. Shale core samples would help in resolving this problem.

Kontaminering!

5. The three Triassic tars from 33/12-6 have carbon isotope values similar to those of the extracts of the Brent shales from 34/10-3, but their molecular patterns are different from those of the extracts (Figs. 2, 3 & 4). The Brent tar from 33/9-7 has isotope values nearly identical to those of the 34/10-2 oil, and the saturate and aromatic molecular patterns of the two are similar. We conclude that this tar is from the same family as the oils, and is different from the three Triassic tar samples.

6. Data on an oil sample from 25/11-6 was included in this report for purposes of general comparisons. This oil falls between the 34/10-2 oil and the other three oils in isotopic values, and in molecular patterns it resembles these oils, except for a lesser amount of steranes (C_{27}-C_{29} in the 4-ring naphthenes). This oil is assigned to the same oil family as the 34-Block oils.

7. The gasoline data (Table 4) do not help clarify the correlations. None of the oils correlate well with the rock extracts (see previous reports). The oil and condensate from 34/10-2 are distinctly different from the 34/10-1, 34/10-3 and 33/9-7 oils in their gasoline compositions. Gasoline data are influenced to considerable extents by migration and maturation histories, and are not always useful in "fingerprinting" samples. The 34/10-1 and 34/10-3 oils, which have similar geologic and geographic positions, also have similar gasoline patterns.

RELATED EPR SERVICE REPORTS

*EPR.132ES.79 "Hydrocarbon Source Analyses of Samples from STATOIL 34/10-3, Norway" by R. E. Metter, August 1979.

*EPR.134ES.79 "STATOIL 34/10-2, Norway: Hydrocarbon Source Patterns" by R. E. Metter, August 1979.

EPR.135ES.79 "Source Analyses on Samples from Wells 33/9-7 and 34/10-1, Offshore Norway" by R. E. Metter, August 1979.

EPR.138ES.79 "Hydrocarbon Source Profiles, Mobil 33/12-6, Offshore Norway" by R. E. Metter, August 1979.

* Samples were all canned cuttings which were analyzed for hydrocarbon gases (C_1-C_4) and light gasolines (C_4-C_7) as well as for total organic carbon (TOC) and visual kerogen. Samples from 33/9-7, 33/12-6 and 34/10-1 were dry cuttings; therefore C_1-C_7 analyses were not made on these.

Table 1 Samples Included in Correlation Study

Well	Depth (meters)	EPR No.	Sample	Unit	Remarks	°API (at 60°F)	% Sulfur
OIL SAMPLES							
34/10-1	1788-92*	69423	DST-3	Brent	Separator Oil	28.7	.61
34/10-2	-	70334	DST-2	Statfjord	Flow 2; Pour Point about 21°C	32.0	.02
"	-	70335	DST-5	Brent	Condensate from gas	42.4	.01
34/10-3	1935-60*	70089	DST-2	Brent	Flow 2	29.3	.32
33/9-7	(2491-93)?	69786	?	Brent(?)	Sample not clearly identified	37.2	.11
25/11-6	-	69605	?		0 psi Flash	23.4	.65
TAR SAMPLES							
33/9-7	2497+98	70210-U	cttgs	Brent	Tar and sand mixture		
33/12-6	4356+59	70211-B	"	Triassic	"		
	4383+86	70211-C	"	"	"		
	4512	70211-D	"	"	"		
CUTTINGS EXTRACTS							
34/10-2	2275-85	69783-J	cttgs	Cret.	See Report EPR.134ES.79		
	2345-75	69783-M	"	"	"		
	2700	69784-D	"	"	"		
	2975-3005	69784-N	"	Brent	"		
	3035	69784-O	"	"	"		
	3125	69784-R	"	"	"		
	3185	69784-T	"	Dunlin	"		
	3275	69785-C	"	"	"		
34/10-3	1751	70081-A	"	U. Cret.	See Report EPR.132ES.79		
	1906+	70083-A	core	Brent	"		
	1945+	70083-B	core	"	"		
	2348	70081-R	cttgs	Dunlin	"		

*Perforated Interval

TABLE 2 Heavy (C_{15+}) Molecular Compositions and Carbon Isotope Values of Cuttings Extracts

(M.S. by R. Barrientos; C^{13}/C^{12} by P. Gregory)

Well	34/10-2								34/10-3			
Depth (meters)	2275-85	2345-75	2700	2975-3005	3035	3125	3185	3275	1751	1906+	1945+	2348
EPR No.	69783-J	69783-M	69784-D	69784-H	69784-O	69784-R	69784-T	69785-C	70081-A	70083-A	70083-B	70081-R
Unit	Cret.	Cret.	Cret.	Brent	Brent	Brent	Dunlin	Dunlin	U. Cret.	Brent	Brent	Dunlin
Total Organic Carbon (%)	.38	.50	.80(?)	3.17	3.04	2.55	1.96	2.15	.35	2.1	7.1	.67
Soluble Organic Matter (ppm)	645	322	499	2264	1534	1746	1647	[illegible]	1011	935	2588	431
Composition of Soluble O.M. (%)												
Saturates*	11.9	23.3	21.8	13.1	7.7	5.1	18.6	17.0	22.2	3.7	4.4	22.3
Aromatics	11.5	27.6	29.0	27.4	14.3	10.4	21.5	[illegible]	37.2	19.1	20.1	26.7
Eluted NSO's	9.8	17.1	15.8	13.7	11.1	8.0	12.4	12.8	15.5	12.8	10.0	18.1
Noneluted NSO's	12.9	7.8	7.8	16.7	37.2	36.1	13.4	13.2	0.1	11.7	15.6	0.0
Asphaltenes	51.5	20.8	19.3	26.2	25.5	33.8	24.2	24.6	17.2	49.1	46.9	22.7
Sulfur	2.5	3.4	6.3	2.9	4.3	6.7	10.5	5.3	7.3	3.5	3.0	11.1
Saturate Molecular Types (%)												
Paraffins	25.4	37.2	19.3	52.4	52.0	45.7	42.0	41.1	.8	32.6	25.4	17.6
1-Ring Naphthenes	31.3	35.0	30.1	24.0	17.7	21.0	30.9	25.6	16.2	13.4	3.3	22.1
2- " "	19.7	13.4	22.9	10.0	9.6	11.7	12.2	13.6	27.5	9.4	4.9	23.3
3- " "	11.6	7.4	13.1	6.2	7.4	8.4	7.3	8.0	23.9	15.3	21.2	16.4
4- " "	7.2	4.8	8.5	4.5	7.2	7.6	6.4	6.9	20.1	9.1	11.5	11.5
5- " "	3.3	2.3	3.9	2.1	3.1	3.1	1.3	2.8	7.9	11.2	20.0	5.7
6- " "	1.6	0.0	2.2	.6	3.0	2.5	0.0	2.0	3.5	9.0	13.8	3.5
4-Ring Naphthenes												
20 Carbon Atoms	14.8	35.7	14.0	14.4	11.0	11.1	0.0	12.9	12.1	11.4	12.0	9.5
21 " "	12.0	35.7	12.3	14.4	11.4	11.1	28.6	11.4	11.6	10.0	8.1	9.4
22 " "	11.3	0.0	11.2	12.6	9.3	9.7	0.0	11.0	9.7	8.1	6.2	8.5
23 " "	9.9	0.0	10.1	9.9	9.3	9.3	0.0	9.5	8.3	7.6	5.7	8.4
24 " "	9.2	0.0	9.5	9.0	8.5	8.8	23.8	8.5	7.7	8.1	6.7	8.1
25 " "	7.0	0.0	7.8	8.1	7.7	7.5	0.0	7.6	6.8	6.6	5.3	7.6
26 " "	7.0	0.0	6.7	7.2	6.9	7.5	23.8	7.3	6.2	6.2	4.3	7.8
27 " "	8.5	0.0	7.8	9.0	10.6	10.6	23.8	9.8	8.5	8.1	7.2	10.4
28 " "	7.7	0.0	7.3	7.2	8.5	8.4	0.0	8.2	8.2	9.5	13.9	9.2
29 " "	7.0	0.0	6.1	8.1	9.3	8.4	0.0	7.6	8.7	11.8	20.1	9.1
30 " "	5.6	0.0	4.5	0.0	4.9	4.9	0.0	4.1	7.0	6.6	7.2	6.5
31 " "	0.0	0.0	2.8	0.0	2.4	2.7	0.0	2.2	3.2	3.8	3.3	3.4
32 " "	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	2.4	0.0	2.2
Aromatic Molecular Types (%)												
Benezenes (B)	20.5	16.3	20.2	12.9	9.5	12.3	12.0	17.4	10.8	1.9	3.6	2.0
Indanes (I)	10.5	7.1	9.8	5.4	5.7	6.5	6.7	7.0	10.1	1.2	2.5	1.0
Indenes (IN)	17.4	14.6	17.3	11.2	8.3	10.3	14.1	12.3	16.1	2.5	5.2	2.9
Naphthalenes (N)	4.9	7.5	6.3	4.7	3.1	3.5	5.3	4.5	3.1	2.1	3.8	4.1
Tetrahydrophenanthrenes (T)	8.9	12.1	9.9	9.8	10.9	10.1	9.9	8.8	10.3	8.5	9.9	9.7
Dihydrophenanthrenes (D)	21.8	22.0	22.0	36.8	24.5	26.9	39.2	32.9	22.3	24.2	27.1	22.5
Phenanthrenes (P)	12.6	13.1	10.4	19.1	27.4	23.2	12.6	17.1	13.1	46.9	45.8	30.6
Pyrenes (PY)	0.0	0.0	0.0	0.0	10.6	7.3	0.0	0.0	4.2	8.3	1.7	22.4
Chrysenes (C)	0.0	.2	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	4.7
Benzothiophenes (BT)	1.7	3.6	3.2	0.0	0.0	0.0	0.1	0.0	.9	0.0	0.0	0.0
Dibenzothiophenes (DB)	1.7	3.4	.9	0.0	0.0	0.0	0.0	0.0	4.0	4.4	0.2	0.0
Thiophenophenanthrenes (TP)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	0.0	0.0	0.0
Carbon Isotope Values (o/oo from PDB)												
Saturates	-28.3	-28.3	-28.5	-28.5	-29.2	-28.8	-28.8	-28.7	-29.8	-27.2	-27.7	-27.5
Aromatics	-27.1	-27.3	-27.5	-26.2	-26.8	-27.1	-27.4	-26.8	-28.8	-26.8	-26.8	-23.0

*See Figs. for gas chromatograms of heavy saturates.

Table 3 Heavy (C_{15+}) Molecular Compositions and Carbon Isotope Values for Oils and Tars

(Chromatography by Everett, M. S. by Barrientos, C^{13}/C^{12} by Gregory)

Well	34/10-1	34/10-2		34/10-3	33/9-7	25/11-6	33/9-7	33/12-6		
Depth (meters)	1788-92	-	-	1935-60			2498	4359	4386	4512
EPR No.	69423	70334	70335	70089	69786	69605	70210-U	70211-B	70211-C	70211-D
Sample	DST-3	DST-2	DST-5	DST-2	DST-1(?)	?	Tar*	Tar*	Tar*	Tar*
Unit	Brent	Statfjord	Brent	Brent	Brent(?)	?	Brent	Triassic	Triassic	Triassic
C_{15+} in Total Oil (%)	77.1	80.7	49.7	72.4	65.1	86.9	-	-	-	-
Gross Composition (%)										
Saturates*	47.4	75.5	70.0	47.5	49.0	39.1	18.7	14.7	16.1	14.7
Aromatics	30.3	18.4	12.3	34.4	22.3	29.3	13.8	18.4	17.6	17.4
Eluted NSO's	9.7	2.7	3.3	6.0	8.7	13.3	12.4	17.4	17.1	15.6
Noneluted NSO's	9.9	0.1	14.2	8.9	17.6	13.5	8.7	5.9	5.3	2.3
Asphaltenes	2.7	3.3	0.3	3.2	2.5	4.8	46.5	43.6	44.0	50.0
Saturates (%)										
Paraffins	21.5	45.5	50.2	20.1	36.3	32.4	42.1	37.5	46.5	40.6
1-Ring Naphthenes	23.9	20.5	22.6	29.9	23.9	23.0	25.4	23.6	20.6	21.3
2-Ring Naphthenes	19.3	13.3	12.0	21.2	16.3	20.5	14.8	16.8	13.8	15.4
3-Ring Naphthenes	14.7	9.4	6.9	13.2	10.5	13.4	8.1	11.3	9.0	10.2
4-Ring Naphthenes	14.4	7.0	4.6	9.8	8.1	7.1	5.4	6.5	5.6	7.2
5-Ring Naphthenes	4.1	2.2	1.5	3.4	2.7	2.5	2.2	2.7	2.8	3.4
6-Ring Naphthenes	2.2	2.0	2.1	2.5	2.3	1.0	1.9	1.6	1.8	2.1
4-Ring Naphthenes										
20 Carbon Atoms	8.3	11.5	11.1	10.0	11.0	20.6	13.9	11.1	12.6	12.0
21 Carbon Atoms	7.2	10.9	11.5	9.6	11.0	19.2	15.0	9.6	10.9	10.0
22 Carbon Atoms	6.1	0.0(?)	11.5	8.3	9.5	15.8	13.9	8.1	9.1	8.1
23 Carbon Atoms	5.3	7.7	10.6	6.9	8.1	11.5	12.4	7.5	7.8	8.1
24 Carbon Atoms	5.0	6.7	10.6	6.6	7.4	8.9	10.5	7.2	7.4	6.9
25 Carbon Atoms	4.8	5.8	9.6	6.4	6.8	6.6	7.5	6.9	6.5	6.6
26 Carbon Atoms	5.5	6.1	9.1	6.4	7.0	4.9	6.4	6.6	6.5	6.9
27 Carbon Atoms	10.2	10.6	10.6	10.0	9.9	4.9	6.4	9.3	8.3	9.3
28 Carbon Atoms	12.3	11.5	8.7	10.2	9.7	3.2	4.9	9.6	7.8	8.1
29 Carbon Atoms	14.8	13.8	6.7	11.0	9.2	2.9	4.5	9.3	7.8	8.9
30 Carbon Atoms	11.7	9.3	0.0	7.9	6.1	1.7	3.0	7.2	7.0	6.9
31 Carbon Atoms	5.3	3.8	0.0	4.0	2.7	0.0	1.9	4.5	4.8	4.6
32 Carbon Atoms	3.4	2.2	0.0	2.7	1.8	0.0	0.0	3.0	3.5	3.5
Aromatics (%)										
Benzenes (B)	17.8	17.3	19.5	24.7	16.4	13.0	21.2	11.7	11.3	8.5
Indanes (I)	12.4	9.7	11.0	14.1	11.2	10.8	10.7	6.0	6.6	4.6
Indenes (IN)	11.4	11.9	14.7	14.8	9.8	12.9	13.9	7.8	7.3	6.7
Naphthalenes (N)	3.7	3.7	5.5	4.1	2.6	5.4	3.4	3.7	4.1	4.1
Tetrahydrophenanthrenes (T)	11.2	9.2	13.3	9.1	10.0	13.4	7.9	13.9	13.7	15.4
Dihydrophenanthrenes (D)	19.4	21.8	25.2	22.3	18.9	23.4	15.9	23.8	22.5	25.6
Phenanthrenes (P)	12.3	18.7	6.9	9.3	17.9	10.1	13.4	8.0	7.7	8.0
Pyrenes (PY)	2.4	5.8	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0
Chrysenes (C)	1.1	0.2	0.3	0.0	2.4	0.8	0.0	0.0	0.0	0.0
Benzothiophenes (BT)	3.8	1.2	0.9	1.6	3.1	2.0	5.7	8.3	7.5	7.4
Dibenzothiophenes (DB)	4.5	0.5	2.8	0.1	4.3	8.3	7.7	16.9	19.4	19.8
Thiophenophenanthrenes (TP)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Isotope Values (‰ from PDB)										
Saturates	-29.4	-28.3	-29.3	-29.4	-29.7	-28.9	-28.2	-27.0	-27.2	-27.2
Aromatics	-28.6	-27.7	-27.3	-28.8	-29.0	-28.2	-27.5	-26.6	-26.8	-27.0

Table 4 Light Gasolines (C_4-C_7) of Oils

69423 34/10-1 DST-3 1788-1792 meters Brent

	TOTAL PERCENT	NORM PERCENT		TOTAL PERCENT	NORM PERCENT
METHANE	0.000		CHEX	0.499	10.32
ETHANE	0.000		33-DMP	0.000	0.00
PROPANE	0.032		11-DMCP	0.134	2.76
IBUTANE	0.068	1.40	2-MHEX	0.000	0.00
NBUTANE	0.087	1.80	23-DMP	0.183	3.79
IPENTANE	0.224	4.63	3-MHEX	0.221	4.56
NPENTANE	0.116	2.39	1C3-DMCP	0.131	2.70
22-DMB	0.022	0.46	1T3-DMCP	0.111	2.29
CPENTANE	0.071	1.47	1T2-DMCP	0.215	4.44
23-DMB	0.050	1.03	3-EPENT	0.000	0.00
2-MP	0.199	4.12	224-TMP	0.000	0.00
3-MP	0.125	2.59	NHEPTANE	0.162	3.35
NHEXANE	0.134	2.77	1C2-DMCP	0.031	0.63
MCP	0.358	7.40	MCH	0.994	20.54
22-DMP	0.000	0.00	ECP	0.024	0.49
24-DMP	0.047	0.96	BENZENE	0.039	0.80
223-TMB	0.000	0.00	TOLUENE	0.596	12.31

TOTALS

ALL COMP	4.870
GASOLINE	4.839

SIG COMP RATIOS

C1/C2	1.93
A /D2	1.34
D1/D2	2.87
C1/D2	7.37
PENT/IPENT	0.52
CH/MCP	1.39

70334 OFF. NORWAY 34/10-2 DST-2 STATFJORD

	TOTAL PERCENT	NORM PERCENT		TOTAL PERCENT	NORM PERCENT
METHANE	0.000		CHEX	0.453	9.53
ETHANE	0.008		33-DMP	0.000	0.00
PROPANE	0.062		11-DMCP	0.107	2.26
IBUTANE	0.037	0.77	2-MHEX	0.000	0.00
NBUTANE	0.132	2.77	23-DMP	0.000	0.00
IPENTANE	0.099	2.08	3-MHEX	0.098	2.07
NPENTANE	0.160	3.36	1C3-DMCP	0.026	0.55
22-DMB	0.000	0.00	1T3-DMCP	0.026	0.55
CPENTANE	0.033	0.69	1T2-DMCP	0.061	1.27
23-DMB	0.000	0.00	3-EPENT	0.000	0.00
2-MP	0.101	2.13	224-TMP	0.000	0.00
3-MP	0.070	1.47	NHEPTANE	0.388	8.16
NHEXANE	0.266	5.59	1C2-DMCP	0.000	0.00
MCP	0.183	3.85	MCH	1.062	22.35
22-DMP	0.000	0.00	ECP	0.000	0.00
24-DMP	0.000	0.00	BENZENE	0.353	7.42
223-TMB	0.000	0.00	TOLUENE	1.098	23.10

TOTALS

ALL COMP	4.823
GASOLINE	4.753

SIG COMP RATIOS

C1/C2	5.49
A /D2	6.65
D1/D2	14.75
C1/D2	16.50
PENT/IPENT	1.61
CH/MCP	2.48

70335 OFF. NORWAY 34/10-2 DST-5 BRENT CONDENSATE

	TOTAL PERCENT	NORM PERCENT		TOTAL PERCENT	NORM PERCENT
METHANE	0.000		CHEX	0.773	7.13
ETHANE	0.002		33-DMP	0.000	0.00
PROPANE	0.011		11-DMCP	0.319	2.94
IBUTANE	0.008	0.07	2-MHEX	0.000	0.00
NBUTANE	0.035	0.32	23-DMP	0.104	0.96
IPENTANE	0.054	0.50	3-MHEX	0.306	2.82
NPENTANE	0.110	1.02	1C3-DMCP	0.121	1.11
22-DMB	0.000	0.00	1T3-DMCP	0.097	0.89
CPENTANE	0.027	0.24	1T2-DMCP	0.204	1.88
23-DMB	0.018	0.17	3-EPENT	0.000	0.00
2-MP	0.138	1.27	224-TMP	0.000	0.00
3-MP	0.093	0.86	NHEPTANE	1.303	12.01
NHEXANE	0.408	3.76	1C2-DMCP	0.033	0.31
MCP	0.279	2.58	MCH	2.751	25.35
22-DMP	0.000	0.00	ECP	0.000	0.00
24-DMP	0.024	0.22	BENZENE	0.453	4.18
223-TMB	0.000	0.00	TOLUENE	3.192	29.41

TOTALS		SIG COMP RATIOS	
ALL COMP	10.865	C1/C2	5.23
GASOLINE	10.852	A /D2	5.59
		D1/D2	11.92
		C1/D2	12.57
		PENT/IPENT	2.03
		CH/MCP	2.77

70089 OFF. NORWAY 34/10-3 1935-60 M. DST-2 Brent

	TOTAL PERCENT	NORM PERCENT		TOTAL PERCENT	NORM PERCENT
METHANE	0.000		CHEX	0.515	10.14
ETHANE	0.013		33-DMP	0.000	0.00
PROPANE	0.019		11-DMCP	0.155	3.05
IBUTANE	0.062	1.22	2-MHEX	0.000	0.00
NBUTANE	0.054	1.06	23-DMP	0.186	3.65
IPENTANE	0.176	3.46	3-MHEX	0.169	3.33
NPENTANE	0.044	0.87	1C3-DMCP	0.135	2.65
22-DMB	0.000	0.00	1T3-DMCP	0.118	2.32
CPENTANE	0.062	1.21	1T2-DMCP	0.237	4.67
23-DMB	0.029	0.58	3-EPENT	0.000	0.00
2-MP	0.145	2.86	224-TMP	0.000	0.00
3-MP	0.100	1.97	NHEPTANE	0.144	2.83
NHEXANE	0.053	1.03	1C2-DMCP	0.000	0.00
MCP	0.362	7.12	MCH	1.272	25.03
22-DMP	0.000	0.00	ECP	0.031	0.61
24-DMP	0.020	0.38	BENZENE	0.000	0.00
223-TMB	0.000	0.00	TOLUENE	1.013	19.94

TOTALS		SIG COMP RATIOS	
ALL COMP	5.114	C1/C2	2.28
GASOLINE	5.082	A /D2	1.16
		D1/D2	5.98
		C1/D2	11.47
		PENT/IPENT	0.25
		CH/MCP	1.42

69786 OFF. NORWAY NORTH SEA 33/9-7 WELL DST-1 (?)

	TOTAL PERCENT	NORM PERCENT		TOTAL PERCENT	NORM PERCENT
METHANE	0. 000		CHEX	75. 799	7. 31
ETHANE	1. 582		33-DMP	0. 000	0. 00
PROPANE	20. 681		11-DMCP	32. 313	3. 12
IBUTANE	11. 559	1. 12	2-MHEX	16. 469	1. 59
NBUTANE	49. 114	4. 74	23-DMP	0. 000	0. 00
IPENTANE	36. 626	3. 53	3-MHEX	34. 373	3. 32
NPENTANE	85. 602	8. 26	1C3-DMCP	15. 311	1. 48
22-DMB	0. 000	0. 00	1T3-DMCP	10. 869	1. 05
CPENTANE	10. 382	1. 00	1T2-DMCP	26. 217	2. 53
23-DMB	4. 552	0. 44	3-EPENT	0. 000	0. 00
2-MP	38. 815	3. 74	224-TMP	0. 000	0. 00
3-MP	23. 881	2. 30	NHEPTANE	112. 361	10. 84
NHEXANE	87. 193	8. 41	1C2-DMCP	0. 000	0. 00
MCP	54. 135	5. 22	MCH	149. 079	14. 38
22-DMP	0. 000	0. 00	ECP	2. 841	0. 27
24-DMP	3. 678	0. 35	BENZENE	28. 351	2. 73
223-TMB	0. 000	0. 00	TOLUENE	127. 085	12. 26

TOTALS		SIG COMP RATIOS	
ALL COMP	1058. 867	C1/C2	2. 57
GASOLINE	1036. 605	A /D2	5. 81
		D1/D2	4. 52
		C1/D2	7. 96
		PENT/IPENT	2. 34
		CH/MCP	1. 40

69605 25/11-6

	TOTAL PERCENT	NORM PERCENT		TOTAL PERCENT	NORM PERCENT
METHANE	0. 000		CHEX	0. 443	15. 97
ETHANE	0. 009		33-DMP	0. 000	0. 00
PROPANE	0. 023		11-DMCP	0. 03.	1. 16
IBUTANE	0. 045	1. 64	2-MHEX	0. 000	0. 00
NBUTANE	0. 059	2. 12	23-DMP	0. 122	4. 42
IPENTANE	0. 074	2. 66	3-MHEX	0. 052	1. 86
NPENTANE	0. 044	1. 60	1C3-DMCP	0. 068	2. 47
22-DMB	0. 011	0. 39	1T3-DMCP	0. 060	2. 15
CPENTANE	0. 036	1. 29	1T2-DMCP	0. 110	3. 97
23-DMB	0. 032	1. 17	3-EPENT	0. 000	0. 00
2-MP	0. 075	2. 72	224-TMP	0. 000	0. 00
3-MP	0. 051	1. 84	NHEPTANE	0. 024	0. 85
NHEXANE	0. 035	1. 27	1C2-DMCP	0. 015	0. 53
MCP	0. 253	9. 13	MCH	0. 926	33. 43
22-DMP	0. 000	0. 00	ECP	0. 014	0. 50
24-DMP	0. 061	2. 21	BENZENE	0. 017	0. 61
223-TMB	0. 000	0. 00	TOLUENE	0. 111	4. 02

TOTALS		SIG COMP RATIOS	
ALL COMP	2. 803	C1/C2	2. 77
GASOLINE	2. 770	A /D2	1. 14
		D1/D2	2. 48
		C1/D2	27. 14
		PENT/IPENT	0. 60
		CH/MCP	1. 75

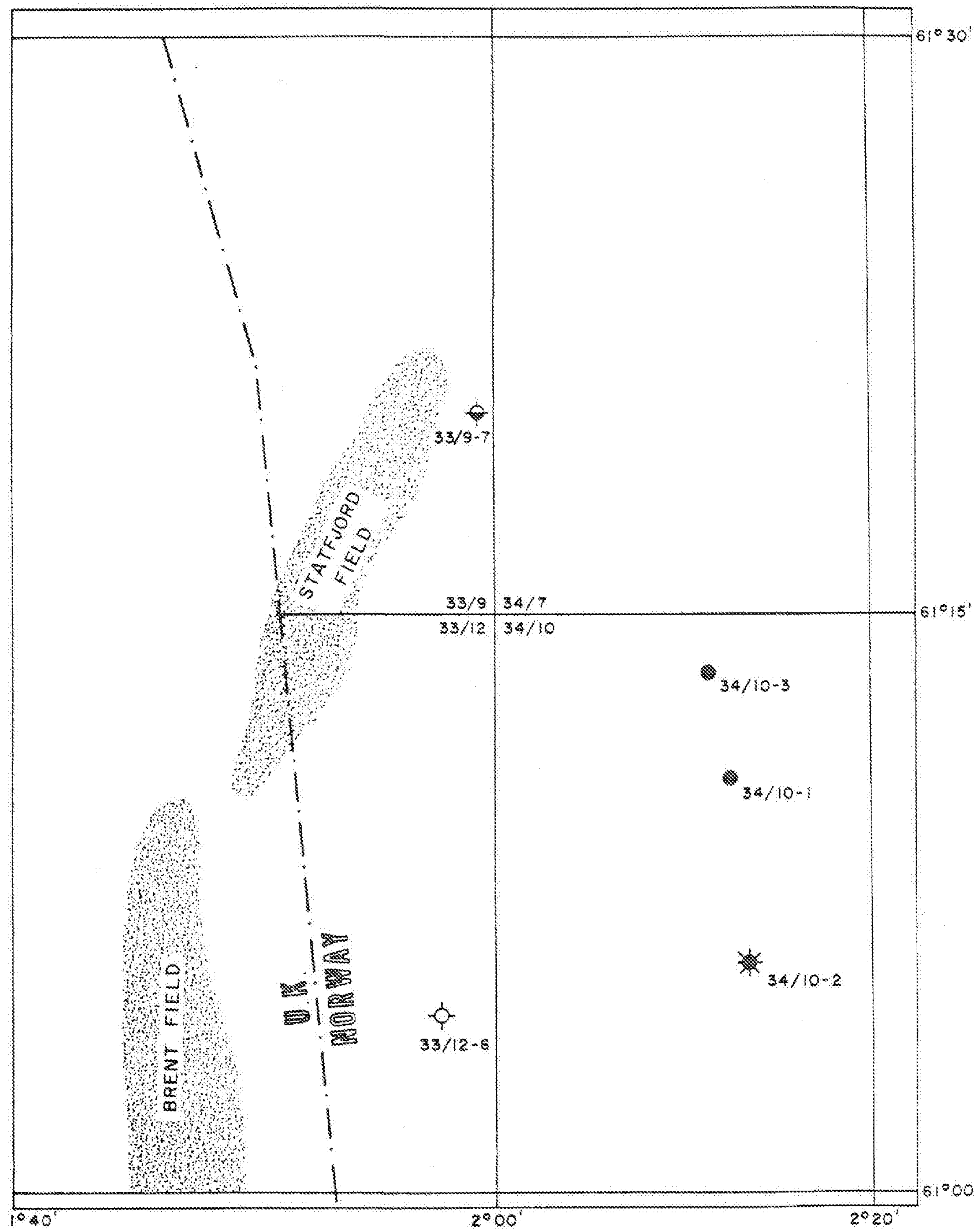

FIG. 1 - SAMPLE LOCATIONS.

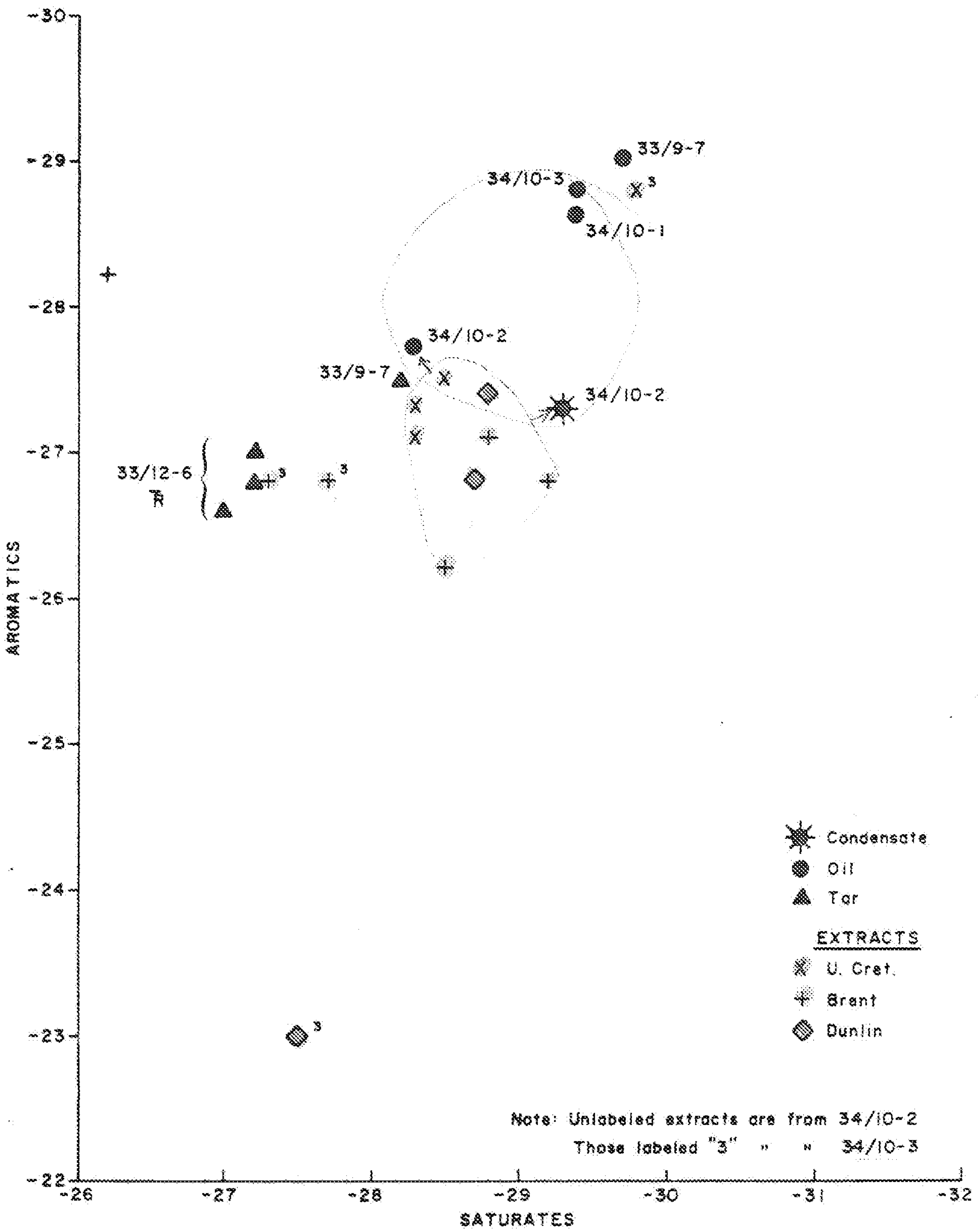

FIG. 2 – CARBON ISOTOPE VALUES OF OILS, TARS AND CUTTINGS EXTRACTS.

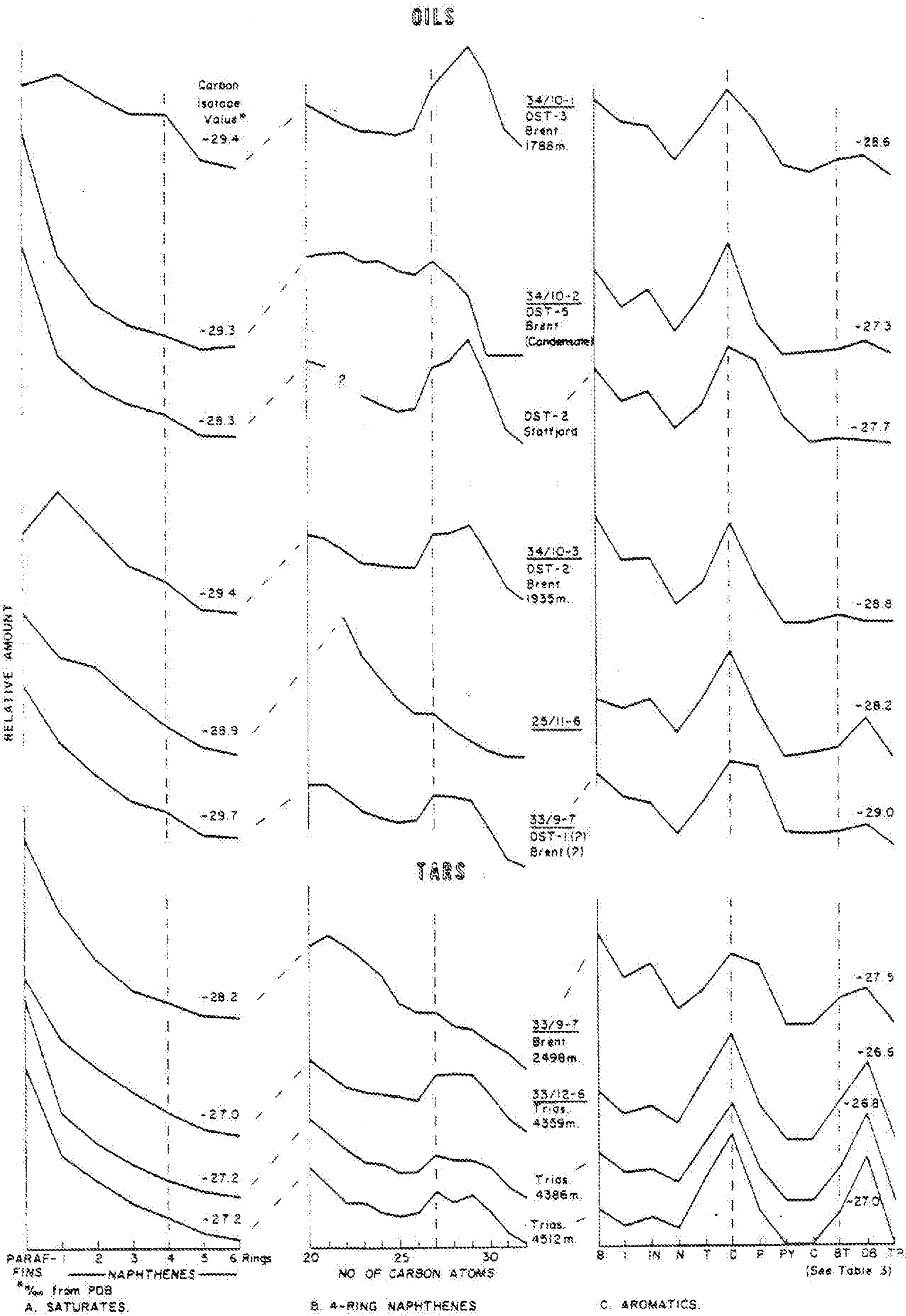

FIG. 3 - OILS AND TARS: CARBON ISOTOPE VALUES AND MOLECULAR TYPES OF COMPOUNDS IN C_{15+} FRACTIONS.

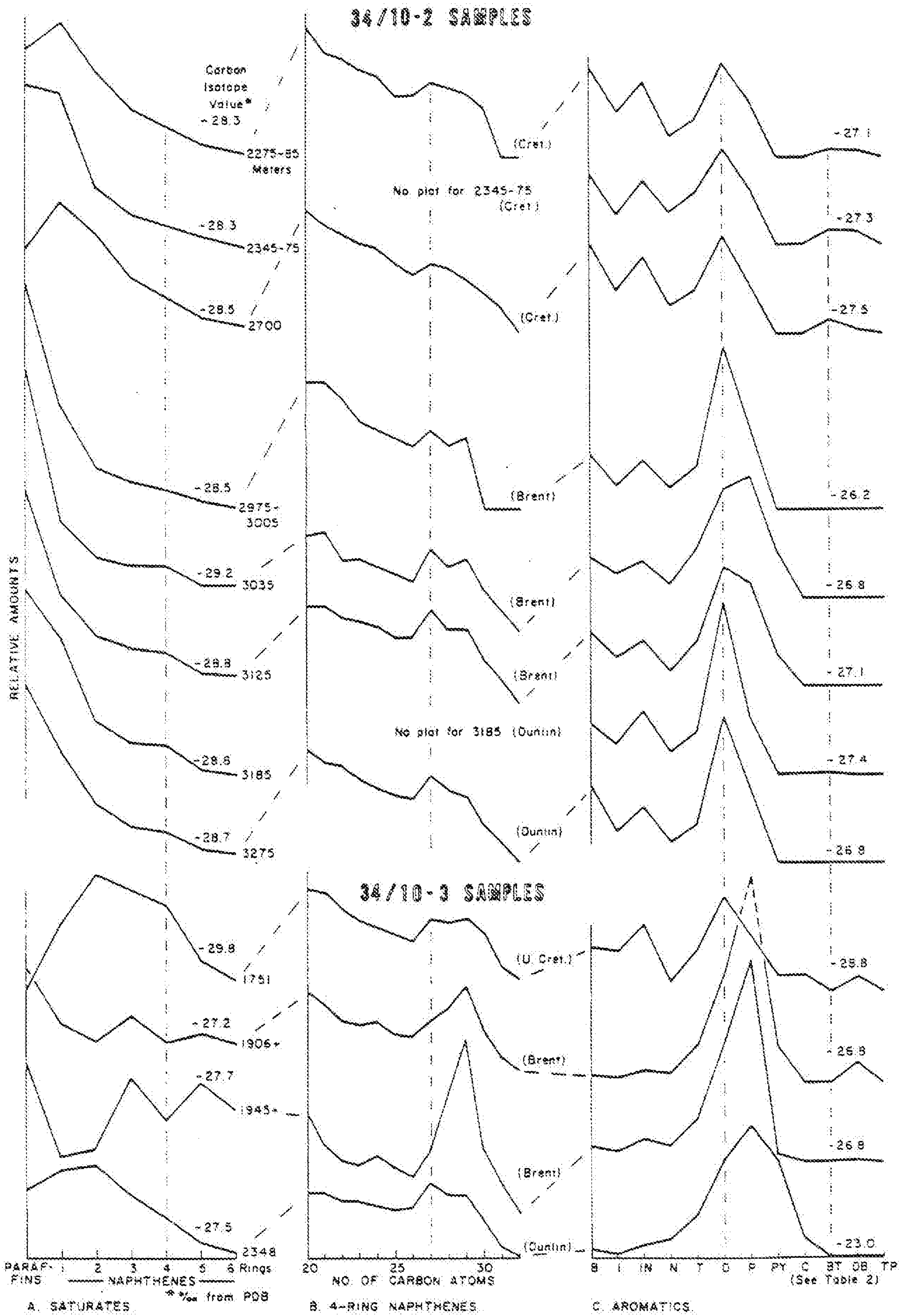

FIG. 4 – MOLECULAR TYPES OF COMPOUNDS AND CARBON ISOTOPE VALUES, ROCK C_{15+} EXTRACTS.

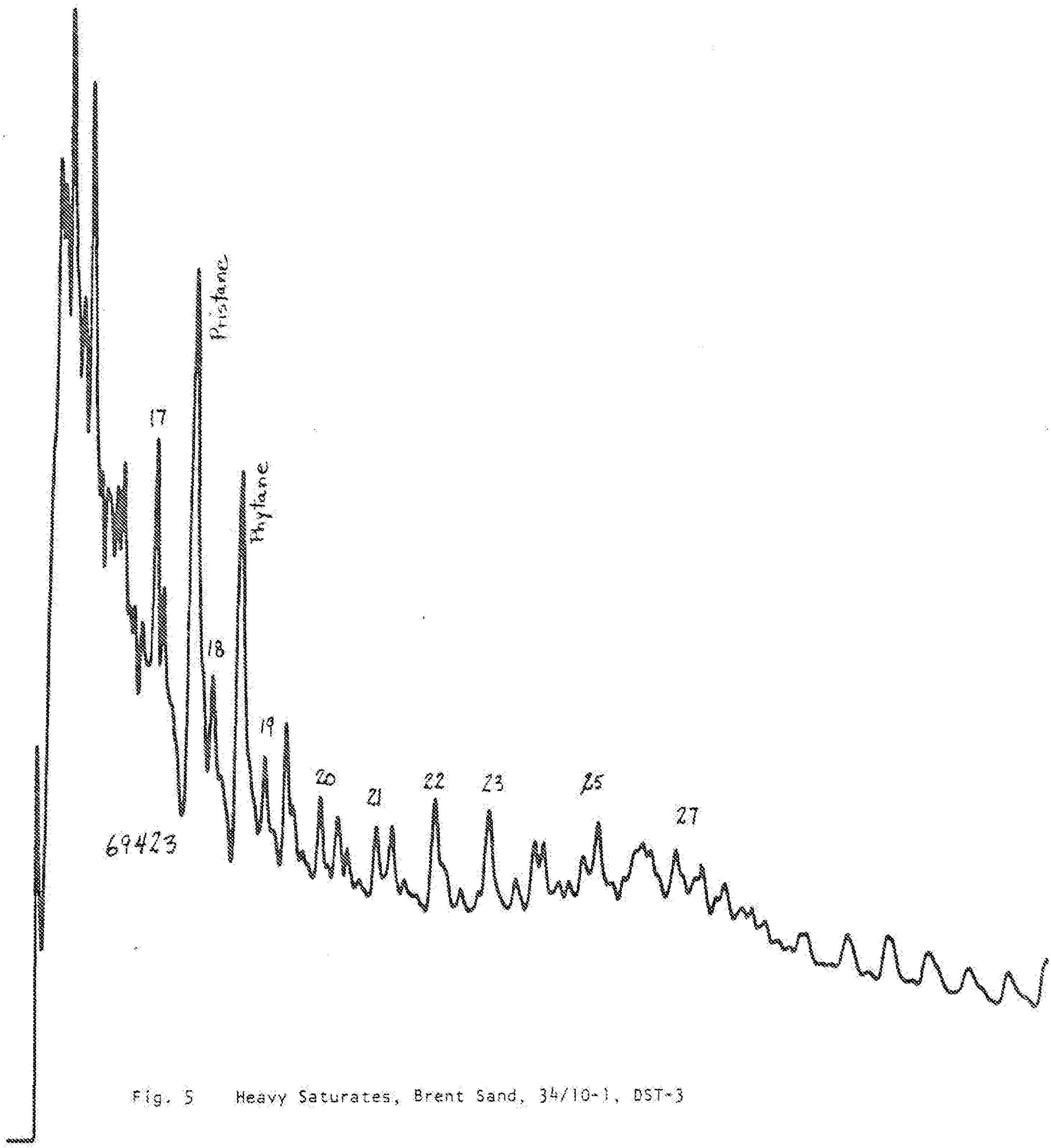

Fig. 5 Heavy Saturates, Brent Sand, 34/10-1, DST-3

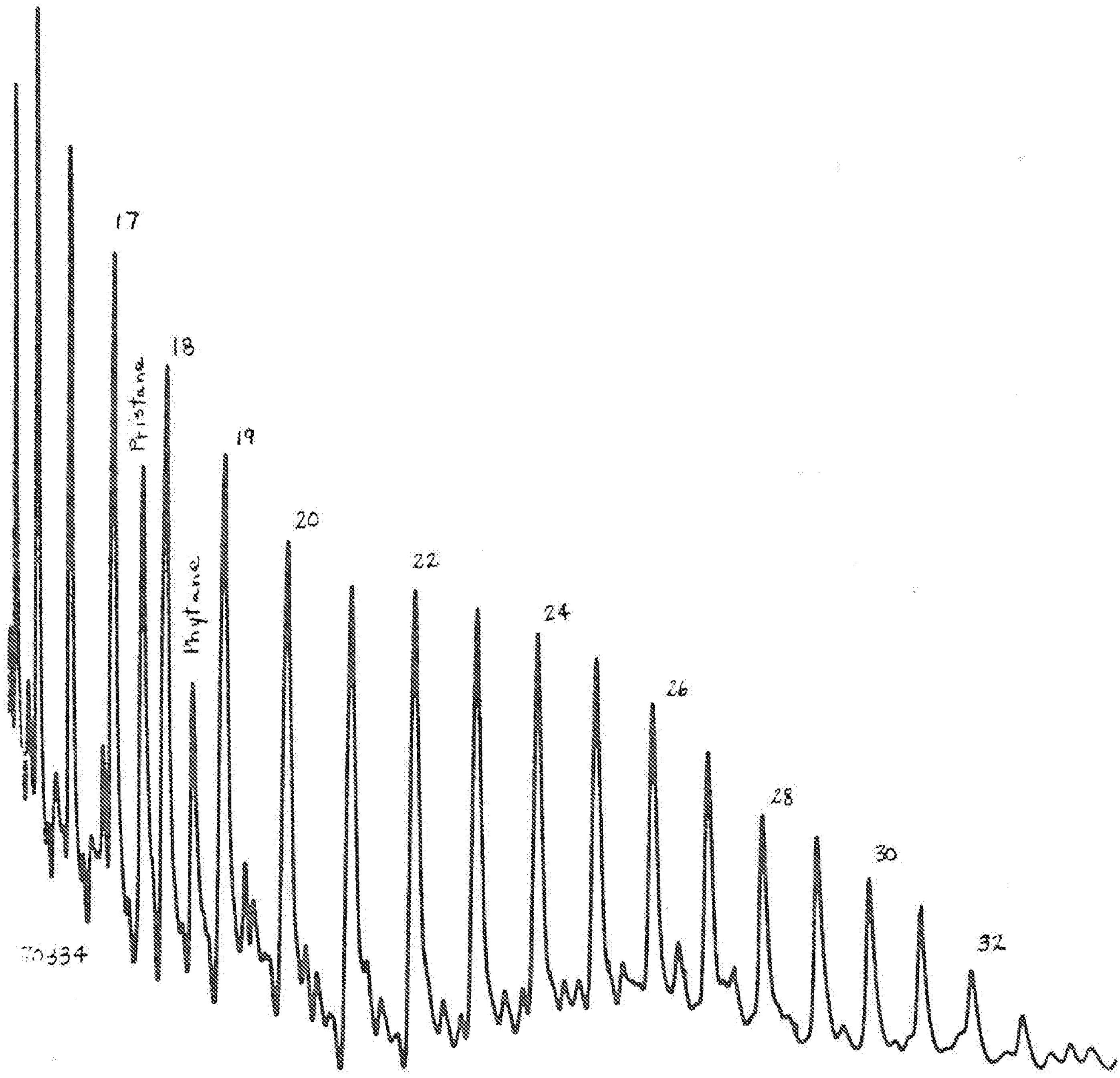

Fig. 6 Heavy Saturates, Statfjord Sand, 34/10-2, DST-2

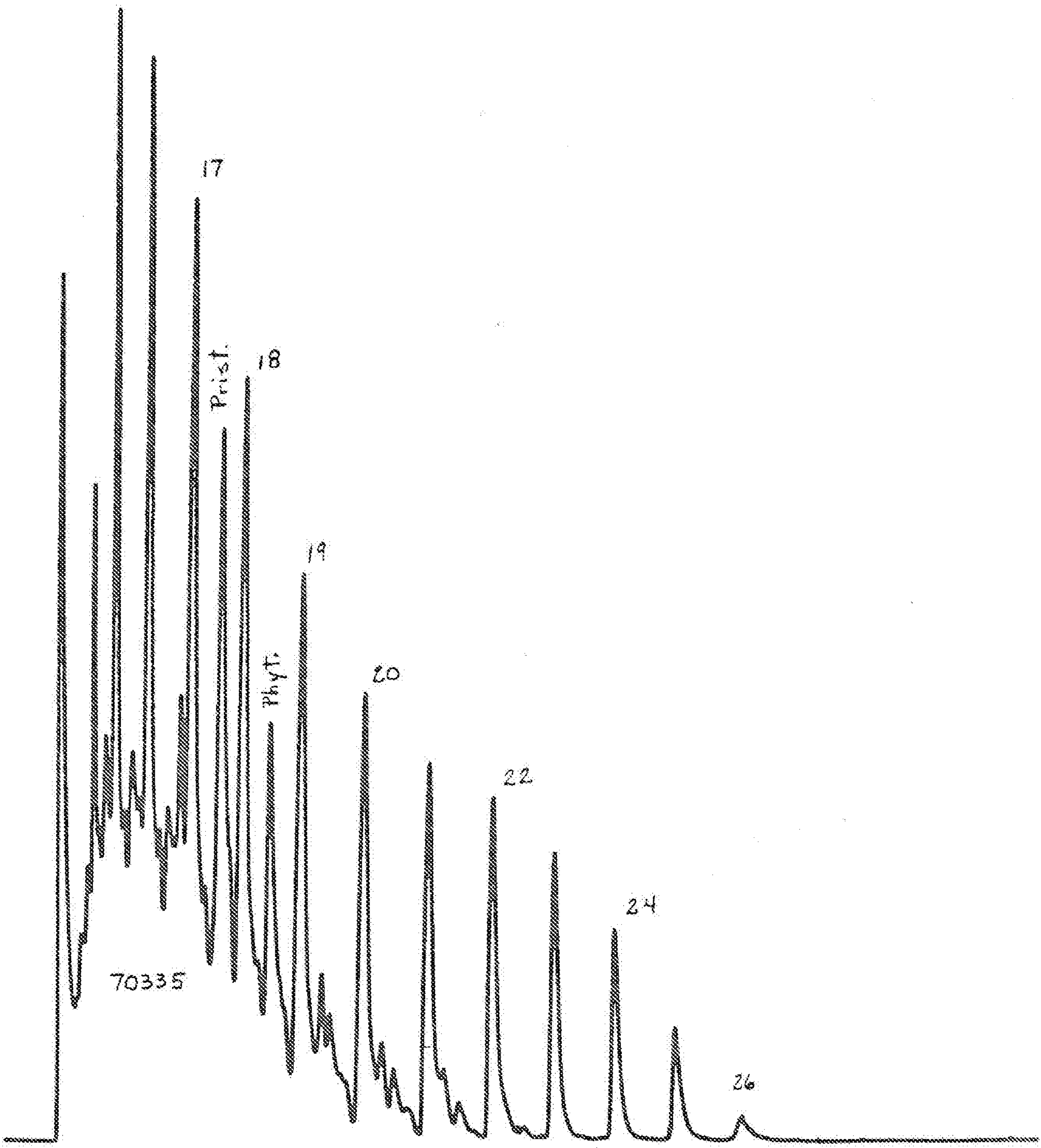

Fig. 7 Heavy Saturates, Brent Sand, 34/10-2, DST-5 (condensate)

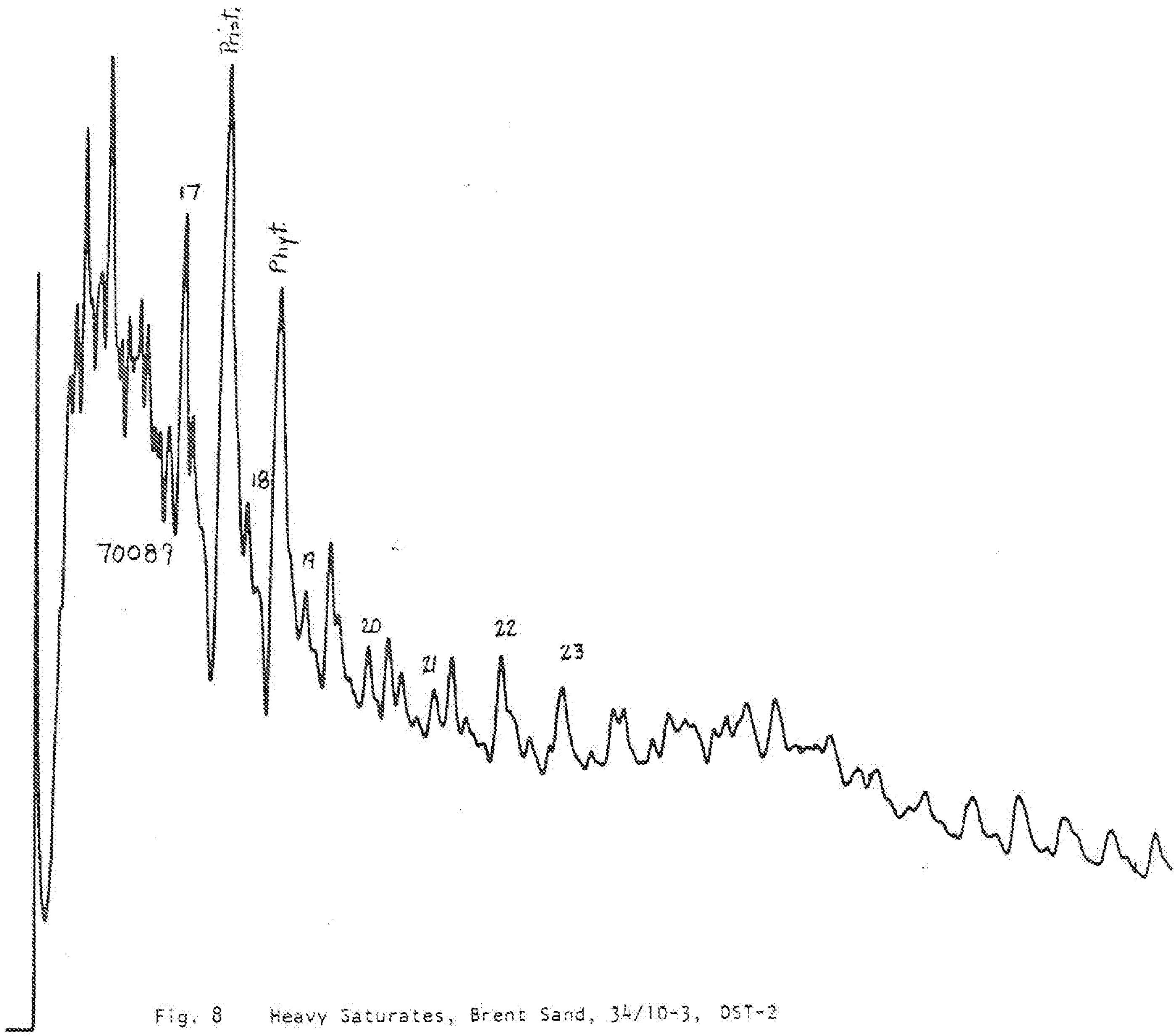

Fig. 8 Heavy Saturates, Brent Sand, 34/10-3, DST-2

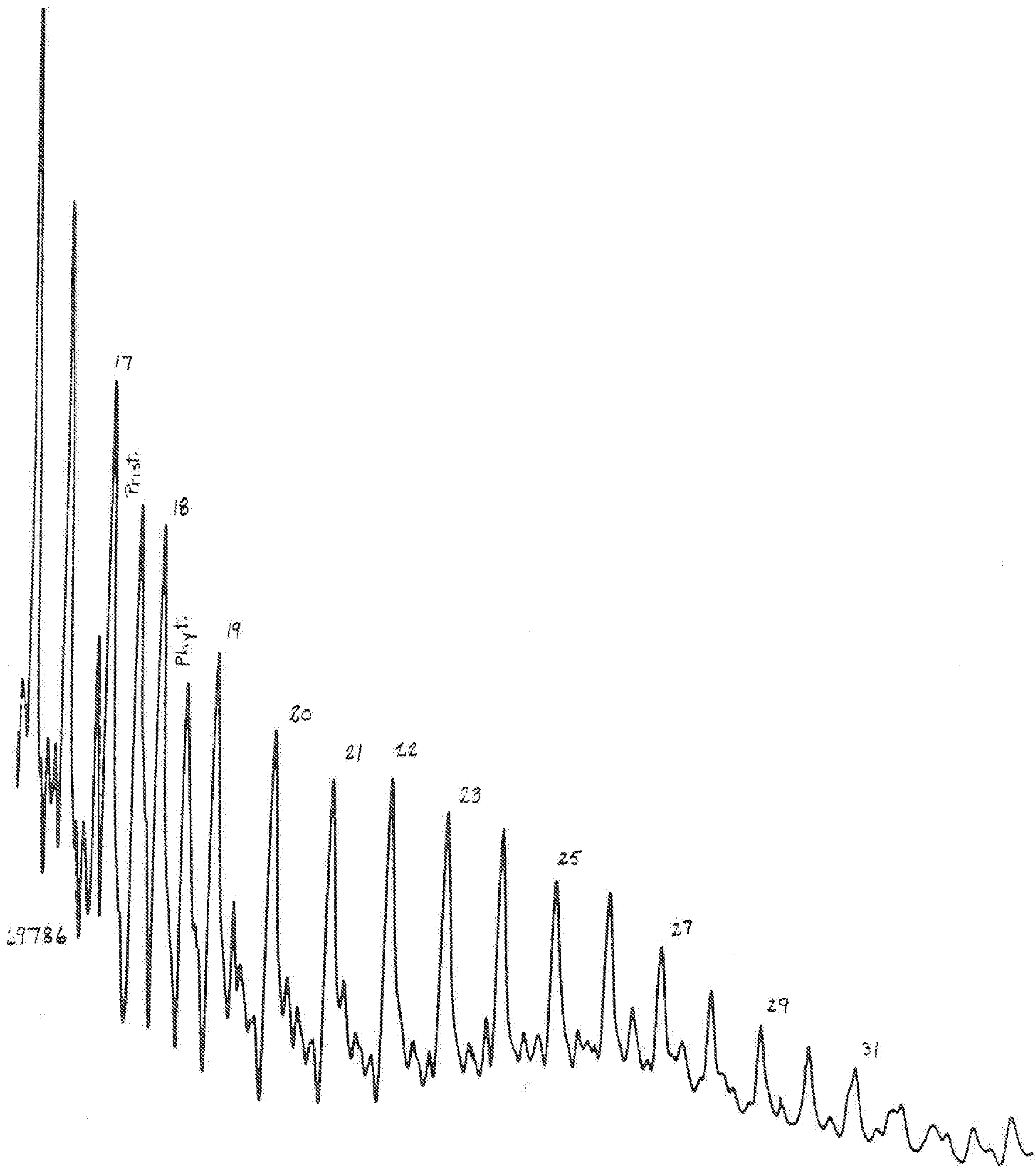

Fig. 9 Heavy Saturates, Brent Sand, 33/9-7, DST-1(?)

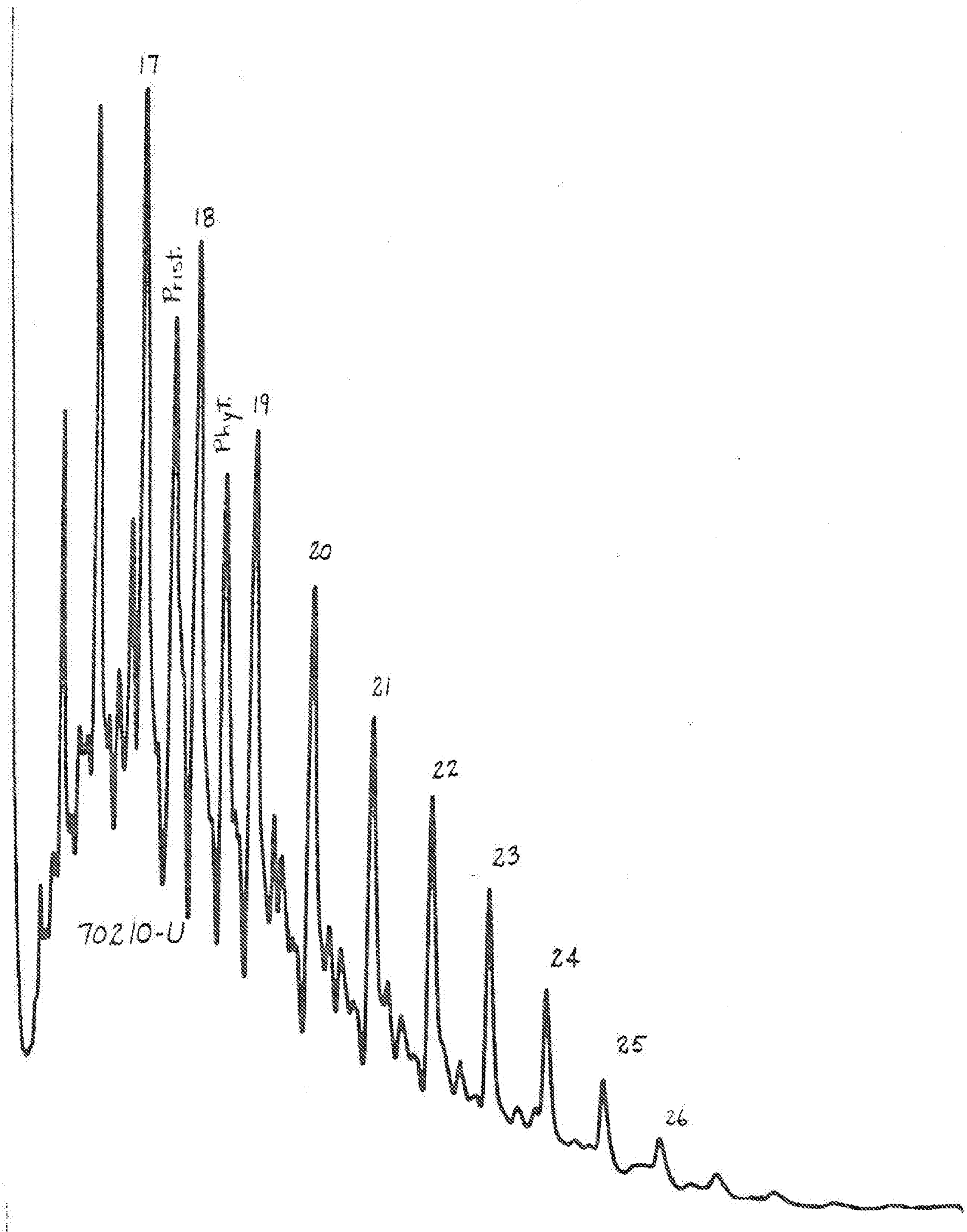

Fig. 10 Heavy Saturates, Brent Sand, 33/9-7, tar from cuttings, 2498 m.

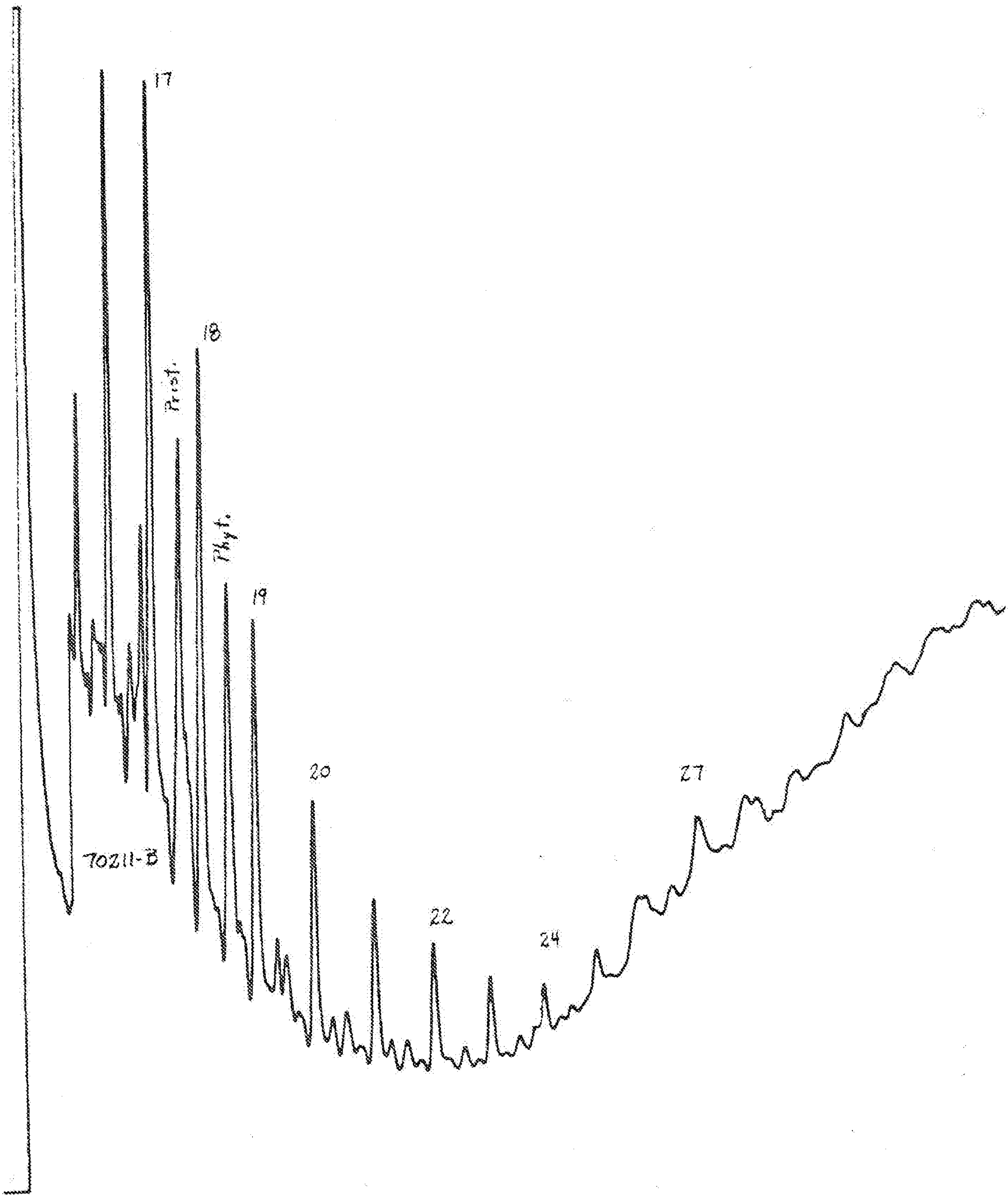

Fig. 11 Heavy Saturates, Triassic, 33/12-6, tar from cuttings, 4359 m.

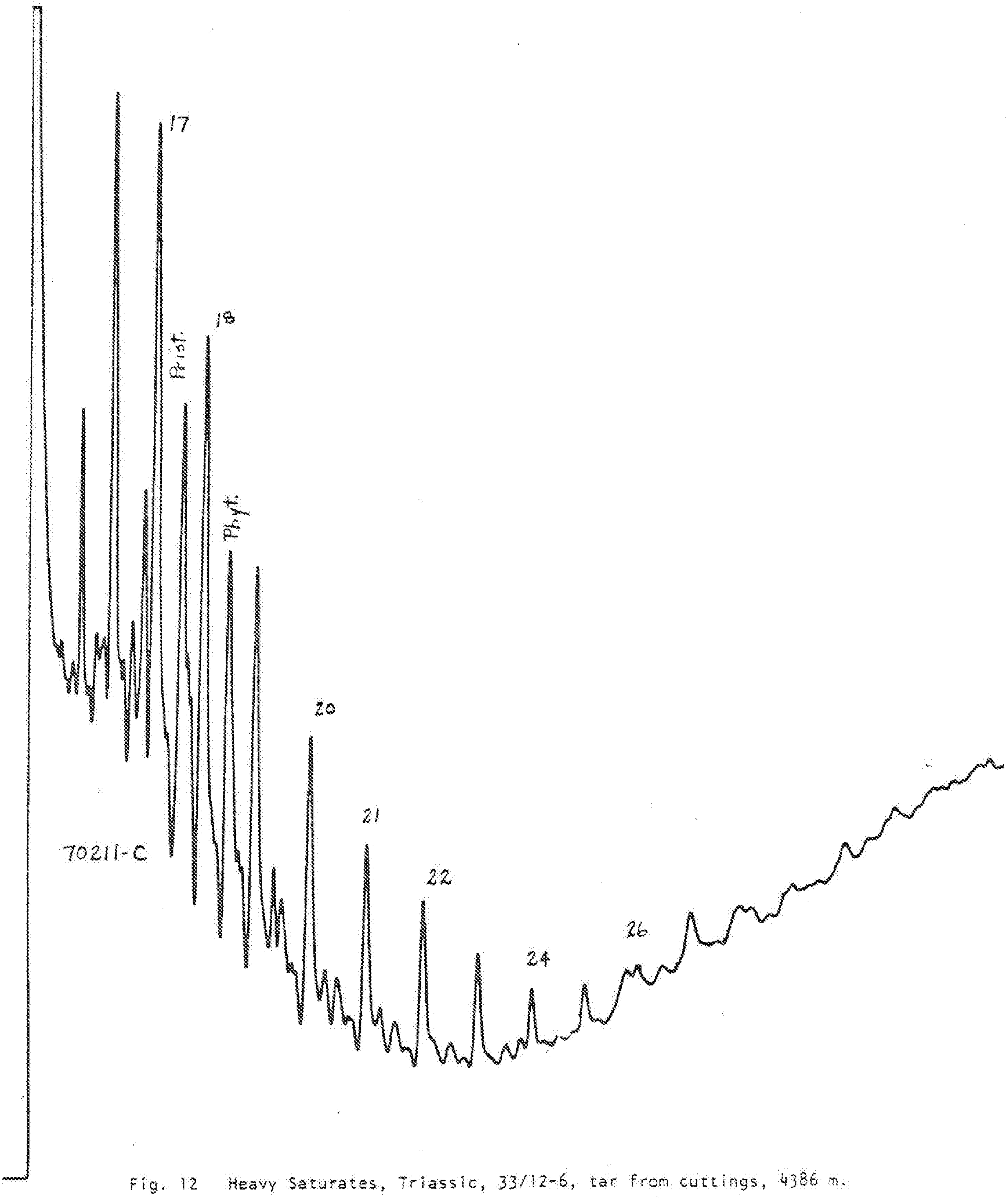

Fig. 12 Heavy Saturates, Triassic, 33/12-6, tar from cuttings, 4386 m.

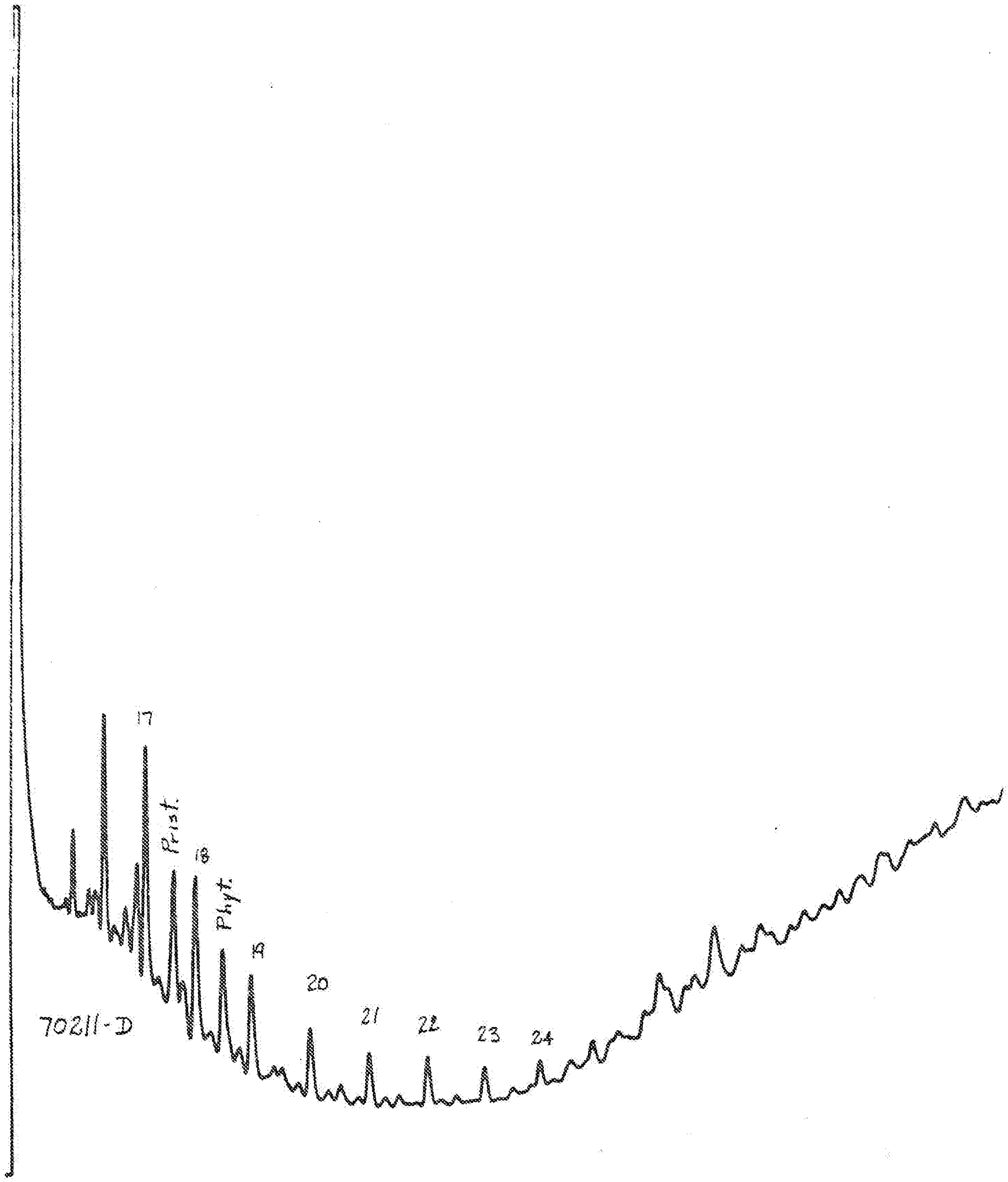

Fig. 13 Heavy Saturates, Triassic, 33/12-6, tar from cuttings, 4512 m.

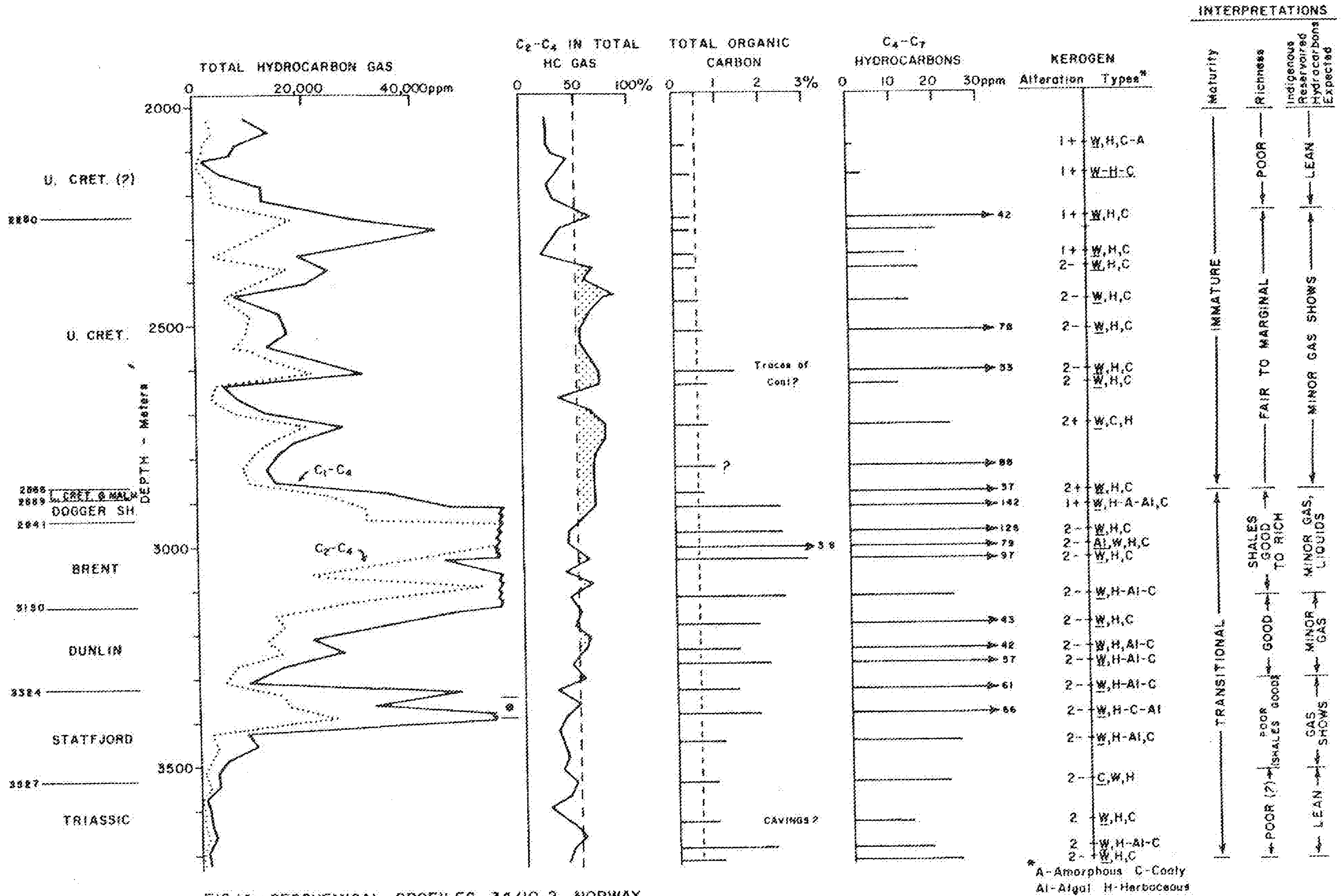

FIG.14 - GEOCHEMICAL PROFILES, 34/10-2, NORWAY.

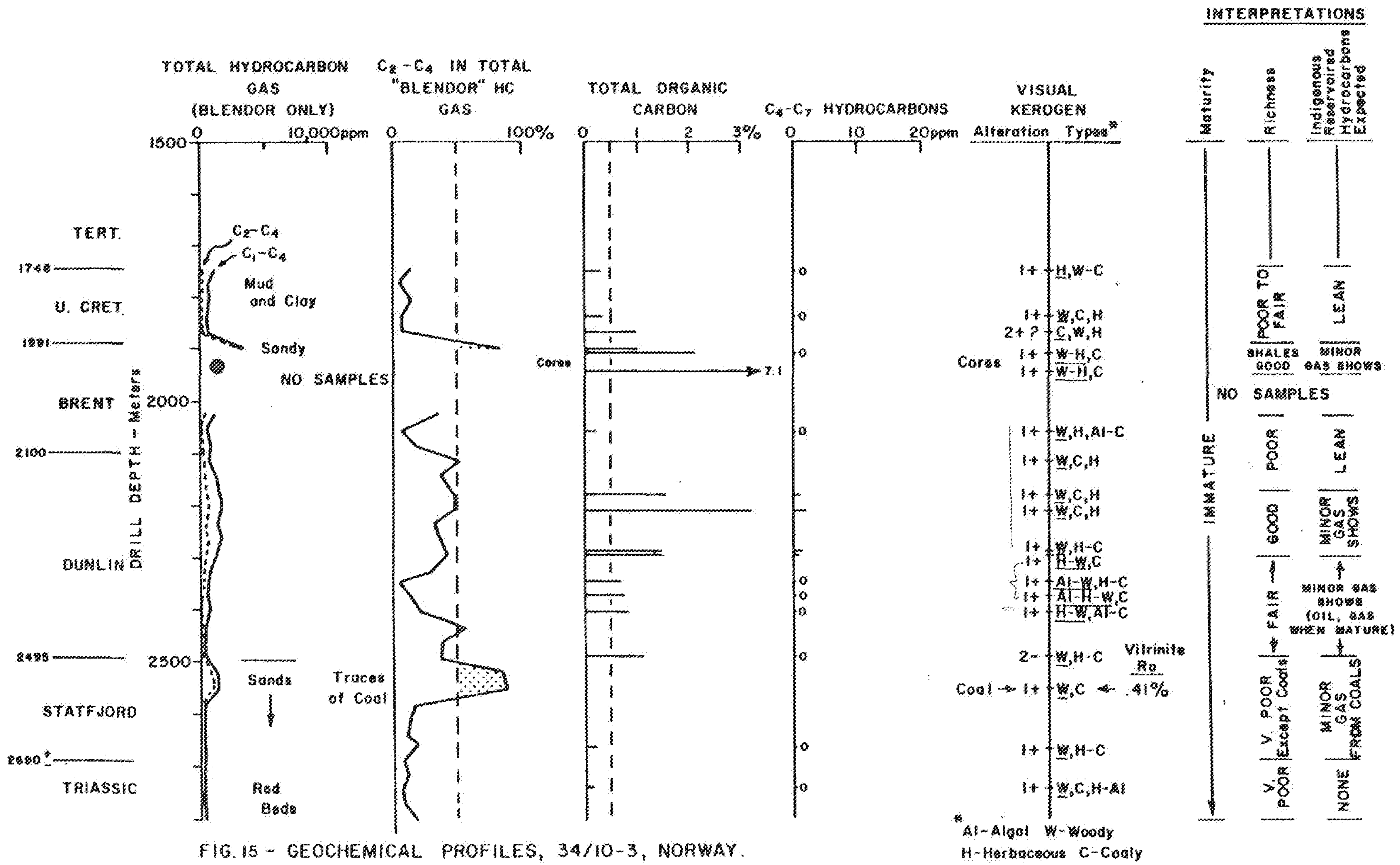

FIG. 15 - GEOCHEMICAL PROFILES, 34/10-3, NORWAY.