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# A PETROLEUM GEOCHEMICAL EVALUATION OF THE SECTION 1530m – 5020m OF THE NORSK HYDRO 15/5 - 3 WELL, NORWEGIAN NORTH SEA.



by

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# I

## INTRODUCTION

A petroleum geochemical evaluation has been carried out on the interval 1530 to 5020 metres of the Norsk Hydro 15/5-3 well, Norwegian North Sea. The well encountered sediments of Oligocene-?Eocene to ?Devonian age in the analysed section. The biostratigraphic information used in the text is taken from Robertson Research International Limited, Report No. 2615P/A entitled "Norsk Hydro 15/5-3 Norwegian North Sea Well : Biostratigraphy of the interval 225m to 5046m (T.D.).

The geochemical analyses on the well section comprise studies of thermal maturity and hydrocarbon source rock potential. Samples were received as canned ditch cuttings initially at intervals of 60 metres between 1530 and 3375 metres and then at 15 metre intervals between 3405 and 3825 metres. No samples were analysed from the Zechstein Salt between 3825 and about 4870 metres, although analyses were resumed again at 15 metre intervals between 4870 and 5020 metres.

The samples were analysed for Airspace ($C_1$-$C_4$) hydrocarbons, then washed free of adhering drilling mud and dried at less than 40°C in an air oven prior to brief lithological description. A portion of the dried rock cuttings was then crushed and the total organic carbon content measured. The results of these two analyses were reported to the client in late November, 1980. Further instructions were then received in December, 1980, for more thorough analyses including vitrinite reflectance and spore colour index, pyrolysis, solvent extraction and liquid and gas chromatography and in January, 1981, for carbon isotope analyses.

An oil sample recovered from behind the 9 " casing at 3525 metres was also submitted for thorough analysis.

The results of these analyses were reported at intervals to the client. It was realised at an early stage in the chemical analysis that contamination in the form of anomalously high amounts of solvent extractable organic matter was present in some samples. It was initially anticipated that this was due to lignosulphonate/lignite additives used between 2002 and 3525 metres and that the effects would not be seen below 3525 metres where only salt saturated mud was used. However, many of the samples continued to yield anomalously high extracts down to 3810 metres, although the samples between 3525 and 3600 metres show the most severe effects of contamination. A check was made to determine if the canned samples were more contaminated than the ditch cuttings received for biostratigraphic studies; some of the original canned samples were also re-analysed. Unexpectedly the biostratigraphy samples showed less or only minimal contamination and other basic parameters such as organic carbon content remained virtually unchanged. Repeat analysis of three canned ditch cuttings showed some decrease in extractable organic matter. Pyrolysis analysis was also repeated on several samples of canned ditch cuttings after extraction with solvents and in most cases the contaminant was reduced to an acceptable minimum so that it was possible to identify the actual source rock potential.

II

## RESULTS AND INTERPRETATION

### A. MATURITY EVALUATION

#### i. Summary of Maturity Evaluation

The quality of the maturity data is rather variable and very sparse in the Late Cretaceous.

The Tertiary sediments are immature for oil generation, at least to a depth of about 2400 metres. Through the upper part of the Late Cretaceous the lack of data does not permit any useful assumptions on the maturity level and it is not until a depth of about 3100 metres that any positive evidence points to entry into the early mature zone. Between 3100 and 3400 metres the sediments are early mature. The data suggest that Cretaceous and Jurassic sediments of approximately Cenomanian to early Kimmeridgian-late Oxfordian age all lie in the early mature zone. On the basis of vitrinite reflectance analysis, entry into the middle mature zone where major oil and minor gas generation could occur, would not be reached until a depth of at least 3900 metres, presuming that the palaeothermal gradient remained constant. Although only airspace gas analysis was conducted on the ?Devonian sediments between 4870 and 5020 metres, they appear to be within the late mature or condensate generation zones.

#### ii. Airspace ($C_1$-$C_4$) Hydrocarbons Analysis (Table 1 and Figure 1)

Airspace gas abundances and compositions are broadly related to changes in lithology in addition to burial history. In the uppermost sediments of Oligocene-?Eocene age between 1530 and 2010 metres total gas abundances are quite high at several thousand parts per million, although methane accounts for 99.6% to 89.0% of the total gas. In the Palaeocene sediments below 2070 metres the total gas content decreases slightly, but there is a marked progressive increase in wet gas content with depth. This trend continues to at least 2670 metres near the base of the Danian, where wet gas contents reach a maximum of 77.8%. Through the Late Cretaceous to a depth of 3270 metres, total gas contents are far lower than for the preceding intervals and wet gas contents decrease to values usually between 20% and 30%. Below 3270 metres there is a gradual increase in total gas contents and a large rise in wet gas content,a feature which continues into the Early Cretaceous and down to about 3660 metres. Below this depth wet gas contents continue to rise and remain high through the Late Jurassic sediments. Total gas contents range from 890 ppm to a maximum of 26640 ppm. Several samples were also analysed below the Zechstein Salt from ?Devonian sediments. Very low total gas contents were recorded, although the wet gas content is still fairly high at between 37.0% and 72.8%.

The data indicate that there may be migrant methane in the Eocene sediments and migrant wet gas in the Palaeocene and Danian sediments. It is difficult to identify the transition from immature to early mature sediments due to the probable presence of migrated wet gas, but lies between 2000 and 3400 metres. The sediments below 3400 metres appear mature for oil generation and the zone of maturity continues through the Late Jurassic sediments.

B. HYDROCARBON SOURCE ROCK EVALUATION

i. Organic Carbon Content (Table 3 and Enclosure)

Total organic carbon contents were determined on all canned ditch cuttings samples. The section may be discussed on the basis of the values obtained and the age of the sediments.

a. 1530 to 2670metres (Oligocene-?Eocene to Danian)

The majority of argillaceous sediments in this interval have below average organic carbon contents of 0.21% to 0.89%. Several samples have yielded average values in the Eocene.

b. 2730 to 3480 metres (Maastrichtian to Cenomanian)

Organic carbon contents throughout this interval are generally low and, with two exceptions, range from 0.22% to 0.63%. Higher contents of 1.01% and 1.70% were measured on a sample of mixed lithologies from 2850 metres and on a sample containing coaly and ?oil stained material from 3210 metres respectively.

c. 3495 to 3660 metres (Albian to early Valanginian-latest Ryazanian)

Organic carbon contents are low, 0.19% to 0.42%, at the top of this interval, but below 3540 metres contents are much higher and frequently lie between 0.75% and over 1%.

d. 3675 to 3825 metres (Ryazanian-Volgian to Permian)

These widely divergent ages are grouped together as they occupy a fairly small interval and for the convenience of discussion. Organic carbon contents rarely drop below 1% in this interval, the lowest value being 0.73%, although this is probably due to caving of younger shales into the Zechstein salt. Values are highest in the Ryazanian-Volgian to Kimmeridgian sediments where they reach as high as 3.89% between 3690 and 3705 metres.

e. 4870 to 4960 metres (?Devonian)

Although only four samples of darker lithology were analysed from this interval, they showed a wide variation in organic carbon content from 0.49% to 1.73%.

ii. Kerogen Composition (Table 2 and Enclosure)

Kerogen composition analysis was requested on selected samples of Oligocene-?Eocene and Palaeocene age, one of Campanian-Coniacian age and selected samples of Albian to Zechstein age.

The Oligocene-?Eocene to Palaeocene samples between 1530 and 2430 metres are generally humic with vitrinite or inertinite dominant. The sediments are mainly gas-prone, although small amounts of oil-prone material are seen in the deepest two samples and some sapropel in the deepest sample. The single sample of Campanian-Coniacian age from 3210 metres contained only vitrinitic coaly organic matter, although this could be lignitic additive rather than in situ coal.

Between 3555 and 3660 metres in the Albian to Barremian-late Hauterivian sediments the kerogen is almost entirely restricted to inertinite with only minor vitrinite and no sapropel. Samples of Ryazanian-Volgian age from 3675 and 3690 metres contain about 60% sapropelic amorphous material and may therefore be oil-prone. The remaining kerogen is 30% inertinite and 10% vitrinite. All the remaining samples between 3705 and 3810 metres are dominated by inertinite and would therefore appear to have little hydrocarbon potential. Vitrinite does not exceed 10% in any of the samples, although sapropel accounts for at least minor quantities of the kerogen and reaches a maximum of 20% at 3795 metres.

iii. Pyrolysis Evaluation (Table 3 and Enclosure)

Pyrolysis analysis was requested by the client on the organically richest horizons and has been carried out using the "Rock-Eval" method. However, the presence of a contaminant was indicated by high production indices. Some analyses were repeated and analyses were also carried out on samples which had been solvent extracted to remove contaminants such as diesel or oil. Analysis was also conducted on samples received from biostratigraphic studies over equivalent intervals. The results split the section into three parts for discussion.

a. 2070 to 2310 metres (Palaeocene)

Samples from this small interval gave low hydrogen indices and high oxygen indices which suggests that the organic matter is a mixture of inertinite and vitrinite probably with inertinite predominating. Production indices are mainly higher than expected and even for extracted residues some contamination appears to have remained. Potential yields are very low at 100 ppm to 800 ppm and no hydrocarbon source potential is anticipated.

b. 3150 to 3675 metres (Campanian-Coniacian to Ryazanian-Volgian)

Hydrogen indices are low within this part of the section while oxygen indices are frequently anomalously high, possibly due to contamination. Potential yields are low and do not exceed 2000 ppm in these sediments. The data suggest that the kerogen is likely to be inertinitic and no hydrocarbon source potential is likely.

c. 3690 to 3810 metres (Ryazanian-Volgian to Permian, (Zechstein))

Hydrogen indices are low throughout this part of the section and do not exceed a value of 159. Oxygen and production indices are lower than in the section above. Potential yields are highest in the Ryazanian-Volgian sediments between 3690 and 3720 metres and in this interval the kerogen is humic, being a mixture of vitrinite and inertinite with only subordinate sapropel. The deeper sediments between 3720 and 3820 metres gave low potential yields of 100 ppm to

1100 ppm and no potential source rocks are identified.

iv. Extraction and Fractionation of Organic Matter (Table 3 and Enclosure)

This analysis was requested by the client on the same samples as were analysed by pyrolysis. The effects of contamination are seen in several samples submitted for this analysis. In the middle part of the section contamination is identified by high amounts of extract, e.g. 3210 and 3330 metres. In the deeper part of the section fairly high extractabilities are accompanied by high hydrocarbon concentrations, e.g. 3690-705 metres. The variation in the parameters suggests contamination by an organic material, low in hydrocarbons such as lignosulphonate/lignite. This also occurs in samples between 2310 and 3585 metres which fits well with the mud programme over this interval. Similar contamination occurs occasionally in deeper samples, although where hydrocarbon concentrations are high, below about 3660 metres, hydrocarbon staining seems prevalent.

The canned samples and biostratigraphic samples from equivalent depths give differing data, the canned samples having higher contents of extractable organic matter and hydrocarbons, although each pair of samples give similar organic carbon contents. It seems probable that the different methods of collection and storage has led to contamination of the geochemistry samples by mud fluids. Bearing these factors in mind, the following interpretation of source rock quality can be made.

a. 2070 to 2310 metres (Palaeocene)

Extract and hydrocarbon concentrations are generally low. The proportion of hydrocarbons in the extracts is also low which again suggests that no mature hydrocarbon source rocks are present.

b. 3150 to 3675 metres (Campanian-Coniacian to Ryazanian-Volgian)

Apart from the occasional high extractabilities referred to above, there is a high hydrocarbon abundance of 5400 ppm at 3555 metres. This may be related to the testing of a small amount of oil from behind the casing point at 3525 metres. The remaining samples show generally low extractabilities and comparitively low hydrocarbon contents and again suggest that no mature source rocks are present.

c. 3690 to 3810 metres (Ryazanian-Volgian to Permian, Zechstein)

Extract amounts are very variable in this part of the section and seem to relate to the type of samples analysed. However, the values obtained are not exceptionally high in relation to organic carbon contents. Only in the upper part of this group of sediments are hydrocarbon concentrations particularly high and these sediments are the richest source rocks identified by the other analytical methods. However, some hydrocarbon abundances are far too high to relate only to indigenous hydrocarbons and some oil staining must be present, for example, at 3690-705 metres. The samples from the lower part of the group have more moderate hydrocarbon abundances and appear to have a limited potential as oil or oil and gas sources.

v. Gas Chromatography of Alkane Fractions (Figures 4-24)

Gas chromatography was carried out on the alkane fractions of most of the rock extracts. As a further check for contamination the alkane fractions of the extracts from the biostratigraphic samples were also analysed between 3690-705 metres and 3765-780 metres. The chromatograms show that the geochemical and biostratigraphic samples from the same depth contain very similar alkane contents, but through the analysed section the chromatograms show considerable change.

a. 2070 to 2310 and 3210 metres

Four of the five chromatograms in this group show very similar distributions of alkanes; the sample from 3150 metres is similar to that from 3330 metres and is described in the next section. All give two maxima, at n/ $C_{18}$-n-$C_{19}$ and at n-$C_{27}$. A pronounced peak between n-$C_{19}$ and n-$C_{20}$ may be attributable to a resane derived from land plant material. A complex of unresolved components in the chromatogram at the higher molecular weight end of the chromatogram may indicate the presence of drilling contaminant or biodegraded migrant oil. Steranes and triterpanes betweeen n-$C_{27}$ and n-$C_{32}$ and a dominance of odd numbered n-alkanes (CPI>1) indicate the presence of land derived organic matter in an immature state. Pristane and phytane are in unexpectedly low abundance considering the immature to early level of maturity for these sediments. The hand picked shale from 2310 metres also shows the presence of contamination, but its n-alkanes show an oil-like distribution.

b. 3150 and 3330 metres

The chromatograms of these samples show strong similarities; both of these poor quality source rocks have alkane distributions typical of oils from early mature source rocks. The contaminant oil has been generated by an early mature source rock containing dominantly terrestrially derived waxy organic matter deposited in a transitionally anoxic environment in view of the slight dominance of even numbered carbon chain lengths.

c. 3555 metres.

The alkane chromatogram of this sample shows a complex of unresolved peaks representing high molecular weight material (figure 11). The sample contains a very large amount of extractable organic matter and either oil staining by migrant biodegraded oil or the presence of contaminants such as pipe grease or a similar compound is indicated.

d. 3570 to 3810 metres

The source rocks represented in this interval are of low quality and contain dominantly humic kerogens. Their pyrolysis analyses and solvent extraction data suggest that they are contaminated by minor amounts of migrant oil. This is confirmed by the general similarity of the alkane chromatograms obtained from the samples in this interval; they are also similar to the alkane gas chromatograms of 3150 and 3330 metres. A wide range of components from n-$C_{15}$ to n-$C_{36}$ is seen, together with a slight tendency for predominance of even-numbered over odd-numbered n-alkanes and significant amounts of pristane and phytane. The chromatograms are similar enough to suggest that the oil at various levels comes from the same source, but subtle differences in composition could suggest that they represent fractions generated at different times during maturation of the source rock, or that there is a lateral change in kerogen composition within the drainage area of this structure. The source rock kerogen which generated the oil appears to be dominantly a waxy sapropel derived from land plant detritus.

vi. <u>Carbon Isotope Analysis</u> (Table 4 and Figure 27)

Carbon isotope ratios were determined for the saturate and aromatic fractions of eight rock extracts and for kerogen concentrates isolated from the four deepest samples. The results are illustrated graphically in Figure 27, together with comparable data for the oil sample from about 3525 metres depth. The results may be considered in three groups based on intervals analysed and values obtained.

The samples from 2190, 2310 and 3150 metres are all fairly similar with alkane values of about-27.6‰ and aromatics -27.0‰ suggestive of hydrocarbons derived from marine algal organic matter mixed with lesser proportions of terrestrially derived organic matter. In all three samples the amounts of hydrocarbons extracted are low at 135 to 160 ppm and the chromatograms have already been described. It seems likely that some of the hydrocarbons from 2190 and 2310 metres are indigenous to the formation and represent poor quality, transitionally mature source rocks, but may contain some contamination. The interval represented by the sample from 3150 metres has no significant source potential and it is believed that the hydrocarbons are contaminants introduced by migration or by drilling.

The interval represented by the sample from 3330 metres is clearly contaminated by migrant oil and has no indigenous source potential. The hydrocarbons extracted at 3330 metres have isotope values of -30.3‰ and -29.5‰ for alkanes and aromatics respectively which suggest derivation from predominantly land derived "waxy" sapropelic organic matter. The values themselves are very similar to those obtained for the oil.

The upper part of the Kimmeridge Clay Formation is represented by the samples from 3675, 3690, 3705 and 3720 metres. In this interval the source rock is of poor quality, as indicated by the pyrolysis data, but the relatively high hydrocarbon contents suggest better source potential. It is considered likely that at least some of the hydrocarbons analysed are indigenous, but are probably admixed with oil migrated perhaps from lateral equivalents of the source bed off-structure. The gas chromatograms suggest at least an early mature oil-like alkane distribution. The isotope values at about-29.2‰ and -28.5‰ for alkanes and aromatics respectively suggest derivation from a mixed "waxy" sapropel (land derived) and marine algal kerogen.

The isotope data for the kerogen is consistent with the humic nature of the source organic matter at these depths being a mixture of predominantly vitrinite (-31‰) and inertinite (-22‰). The values are not inconsistent with there being some land derived "waxy" sapropel present in the humic mixture.

## C. OIL SAMPLE ANALYSIS (Table 5 and Figures 25-26)

A sample of oil, recovered from behind the 9 " casing point at 3525 metres, was analysed to define its source and type. An API gravity of approximately 33° was determined on the oil. It was found that gasolines accounted for about 6% of the oil (Table 5) and showed a range of components which was almost complete and suggesting that the oil is from a middle mature source rock. "Topping" analysis showed that 12% of the oil was volatilised by heating at 60°C for one hour and the topped oil was then separated by column chromatography to give alkane, aromatic and resene fractions and asphaltenes were calculated by difference. The results show that by weight the topped oil contains 40% alkanes, 17% aromatic, 24% resenes and 19% asphaltenes.

The whole oil gas chromatogram, Figure 25, shows the hydrocarbon distribution in the oil and Figure 26 shows the normal alkane distribution after fractionation. This latter chromatogram shows a slight predominance of even numbered n-alkanes. Pristane and phytane are less than half as abundant as the adjacent $C_{17}$ and $C_{18}$ n-alkanes; pristane is in greater abundance than phytane. The distribution of n-alkanes shows an abundance of the heavier "waxy" alkanes.

It is concluded that the oil is a fresh, unflushed and non-biodegraded oil from a middle mature source rock. Carbon isotope data concur with the chromatography data in suggesting that the oil was probably sourced from waxy land derived organic matter probably deposited in an anoxic environment.

On the basis of the carbon isotope, gas chromatography and source rock data the sediments with organic matter of a nature most likely to produce such an oil are those from depths between 3675 and 3720 metres in the analysed section. These sediments, belonging to the Kimmeridge Clay Formation of Ryazanian-Volgian age, are considered to contain the most oil-prone sediments in the entire section, although their level of maturity appears to be lower than the source of the oil. It is therefore probable that the oil has been generated in laterally equivalent sediments off-structure, and at a greater depth of burial where the level of maturity would then be adequate, and where these source rocks are likely to be richer in oil generating kerogen.

III

## CONCLUSIONS

As a result of a geochemical evaluation of the section 1530 to 5020 metres of the Norsk Hydro 15/5-3 well it is concluded that:-

i. The sediments are likely to be immature for hydrocarbon generation to a depth of at least 2400 metres.

ii. The zone of early maturity is reached between 3100 and 3400 metres and encompasses the whole of the Early Cretaceous and Late Jurassic age sediments. Only minor oil and gas generation could have taken place from any source rocks present in this interval.

iii. The ?Devonian sediments between 4870 and 5020 metres are probably within the late mature or condensate generation zones.

iv. Throughout most of the analysed section the effects of contamination have been seen and have made interpretation of source rock quality difficult.

v. Apart from the Ryazanian-Volgian sediments, the remaining part of the section appears to be dominated by inertinitic kerogen or, to a lesser extent, vitrinitic organic matter with only occasional subordinate sapropel and therefore has no potential to source significant volumes of oil and very little potential to source gas.

vi. The Ryazanian-Volgian sediments between 3675 and 3720 metres are organically rich and contain fair amounts of sapropelic oil-prone organic matter. However, they do not appear sufficiently rich to produce more than fair amounts of oil.

vii. Analysis of an oil sample from a depth of approximately 3525 metres showed that the oil is from a mature source rock and has not been flushed or biodegraded.

viii. In the section analysed only the Ryazanian-Volgian sediments are of a suitable quality to have produced such an oil. However, as they are only early mature it is assumed that the oil has migrated from a generating zone off-structure where the quality of the oil-prone organic matter in sediments of equivalent age may be enhanced.

ix. The samples from depths of 3150 and 3330 metres are both contaminated by migrant oil one of marine algal source aspect and the other of "waxy" land derived sapropel aspect. The oil staining at 3330 metres resembles the tested oil from 3525 metres.

**COMPANY:** NORSK HYDRO **WELL:** 15/5-3 **LOCATION:** NORWEGIAN NORTH SEA

| SAMPLE DEPTH (METRES) | RELATIVE GASEOUS HYDROCARBON COMPONENT ABUNDANCE (%) | | | | | TOTAL ABUNDANCE (ppm) | TOTAL $C_2$ - $C_4$ (%) | RATIO *i*-Butane / *n*-Butane |
|---|---|---|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | *i*-$C_4$ | *n*-$C_4$ | | | |
| 1530 | 99.4 | 0.5 | 0.1 | 0 | 0 | 8370 | 0.6 | * |
| 1590 | 99.6 | 0.3 | 0.1 | 0 | 0 | 2950 | 0.4 | * |
| 1650 | 99.2 | 0.7 | 0.1 | 0 | 0 | 4860 | 0.8 | * |
| 1710 | 98.4 | 1.1 | 0.4 | 0 | 0 | 1580 | 1.6 | * |
| 1770 | 99.4 | 0.5 | 0.1 | 0 | 0 | 13080 | 0.60 | * |
| 1830 | 98.6 | 1.0 | 0.2 | 0.1 | 0.1 | 5220 | 1.4 | 1.0 |
| 1890 | 97.7 | 1.8 | 0.4 | 0.1 | 0 | 10800 | 2.3 | * |
| 1950 | 92.1 | 3.9 | 1.9 | 1.1 | 0.9 | 5920 | 7.9 | 1.3 |
| 2010 | 89.0 | 4.0 | 2.3 | 3.5 | 1.3 | 3150 | 11.0 | 2.7 |
| 2070 | 71.2 | 12.0 | 6.8 | 8.4 | 1.6 | 6620 | 28.8 | 5.2 |
| 2130 | 63.5 | 17.6 | 11.5 | 4.3 | 3.1 | 5420 | 36.5 | 1.4 |
| 2190 | 63.7 | 16.7 | 12.7 | 2.3 | 4.6 | 15690 | 36.3 | 0.5 |
| 2250 | 59.4 | 16.1 | 15.4 | 2.8 | 6.3 | 4290 | 40.6 | 0.4 |
| 2310 | 46.8 | 21.4 | 20.8 | 3.8 | 7.2 | 8610 | 53.2 | 0.5 |
| 2370 | 31.0 | 14.7 | 32.1 | 5.7 | 16.5 | 5180 | 69.0 | 0.3 |
| 2430 | 40.3 | 21.9 | 27.0 | 2.6 | 8.1 | 11660 | 59.7 | 0.3 |
| 2490 | 42.3 | 12.8 | 27.6 | 3.9 | 13.4 | 3360 | 57.7 | 0.3 |
| 2550 | 51.7 | 13.5 | 21.8 | 3.2 | 9.8 | 1440 | 48.3 | 0.3 |
| 2610 | 22.2 | 17.2 | 34.3 | 7.3 | 19.0 | 910 | 77.8 | 0.4 |
| 2670 | 36.7 | 12.7 | 25.2 | 7.4 | 18.0 | 200 | 63.3 | 0.4 |

Note: Total gaseous hydrocarbon abundance values are expressed as volume of hydrocarbon gases relative to volume of airspace

**TABLE 1A** Airspace Gaseous Hydrocarbon Analysis Data

**COMPANY:** NORSK HYDRO **WELL:** 15/5-3 **LOCATION:** NORWEGIAN NORTH SEA

| SAMPLE DEPTH (METRES) | RELATIVE GASEOUS HYDROCARBON COMPONENT ABUNDANCE (%) | | | | | TOTAL ABUNDANCE (ppm) | TOTAL $C_2$-$C_4$ (%) | RATIO *i*-Butane / *n*-Butane |
|---|---|---|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | *i*-$C_4$ | *n*-$C_4$ | | | |
| 2790 | 79.4 | 13.1 | 4.8 | 0.7 | 2.1 | 180 | 20.6 | 0.3 |
| 2850 | 66.9 | 9.4 | 12.4 | 2.5 | 8.8 | 150 | 33.1 | 0.3 |
| 2910 | 56.2 | 15.9 | 19.4 | 1.9 | 6.6 | 270 | 43.8 | 0.3 |
| 2970 | 22.9 | 9.4 | 25.4 | 9.2 | 33.1 | 380 | 77.1 | 0.3 |
| 3030 | 70.8 | 10.6 | 11.0 | 1.6 | 6.0 | 80 | 29.2 | 0.3 |
| 3090 | 66.7 | 12.9 | 11.5 | 3.2 | 5.8 | 110 | 33.3 | 0.6 |
| 3150 | 66.1 | 15.4 | 11.9 | 1.6 | 4.9 | 8320 | 33.9 | 0.3 |
| 3210 | 69.4 | 14.4 | 7.8 | 1.7 | 6.7 | 290 | 30.6 | 0.3 |
| 3270 | 67.4 | 13.2 | 11.3 | 1.8 | 6.3 | 230 | 32.6 | 0.3 |
| 3330 | 11.5 | 13.5 | 40.2 | 8.8 | 25.8 | 5100 | 88.5 | 0.3 |
| 3375 | 57.9 | 18.0 | 15.6 | 2.0 | 6.4 | 1020 | 42.1 | 0.3 |
| 3405 | 35.6 | 19.3 | 28.7 | 3.6 | 12.7 | 1220 | 64.4 | 0.3 |
| 3420 | 26.4 | 27.6 | 30.7 | 3.4 | 12.0 | 320 | 73.6 | 0.3 |
| 3435 | 25.8 | 28.8 | 28.4 | 4.8 | 12.2 | 1820 | 74.2 | 0.4 |
| 3465 | 42.2 | 26.2 | 25.2 | 1.7 | 4.6 | 470 | 57.8 | 0.4 |
| 3480 | 40.8 | 18.8 | 23.5 | 4.4 | 12.5 | 340 | 59.2 | 0.4 |
| 3495 | 17.6 | 24.2 | 37.4 | 6.4 | 14.4 | 950 | 82.4 | 0.4 |
| 3510 | 11.9 | 21.0 | 38.4 | 7.8 | 20.9 | 1700 | 88.1 | 0.4 |
| 3525 | 24.2 | 28.0 | 30.9 | 4.9 | 12.0 | 290 | 75.8 | 0.4 |
| 3540 | 29.8 | 24.4 | 28.5 | 5.1 | 12.1 | 310 | 70.2 | 0.4 |
| 3555 | 55.3 | 17.8 | 18.4 | 2.1 | 6.4 | 1080 | 44.7 | 0.3 |
| 3570 | 37.5 | 29.3 | 25.2 | 2.3 | 5.7 | 790 | 62.5 | 0.4 |
| 3585 | 46.3 | 27.5 | 20.1 | 1.6 | 4.5 | 500 | 53.7 | 0.4 |
| 3600 | 34.0 | 41.7 | 21.6 | 0.6 | 2.2 | 660 | 66.0 | 0.3 |
| 3615 | 38.3 | 40.5 | 17.7 | 0.7 | 2.8 | 290 | 61.7 | 0.3 |
| 3630 | 43.6 | 38.7 | 15.1 | 0.5 | 2.1 | 2640 | 56.4 | 0.2 |

**Note:** Total gaseous hydrocarbon abundance values are expressed as volume of hydrocarbon gases relative to volume of airspace

**TABLE 1B Airspace Gaseous Hydrocarbon Analysis Data**

**COMPANY:** NORSK HYDRO **WELL:** 15/5-3 **LOCATION:** NORWEGIAN NORTH SEA

| SAMPLE DEPTH (METRES) | RELATIVE GASEOUS HYDROCARBON COMPONENT ABUNDANCE (%) | | | | | TOTAL ABUNDANCE (ppm) | TOTAL $C_2-C_4$ (%) | RATIO *i*-Butane / *n*-Butane |
|---|---|---|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | *i*-$C_4$ | *n*-$C_4$ | | | |
| 3645 | 34.3 | 36.5 | 20.9 | 1.2 | 7.1 | 5480 | 65.7 | 0.2 |
| 3660 | 47.7 | 30.5 | 16.7 | 1.1 | 3.9 | 5570 | 52.3 | 0.3 |
| 3675 | 27.2 | 22.4 | 28.9 | 4.3 | 17.1 | 2170 | 72.8 | 0.3 |
| 3690 | 28.1 | 24.6 | 31.0 | 3.5 | 12.7 | 1310 | 71.9 | 0.3 |
| 3705 | 18.4 | 26.1 | 35.0 | 4.1 | 16.3 | 26640 | 81.6 | 0.3 |
| 3720 | 17.0 | 21.1 | 36.4 | 4.9 | 20.6 | 9250 | 83.0 | 0.2 |
| 3735 | 25.7 | 22.5 | 33.9 | 4.0 | 13.9 | 6270 | 74.3 | 0.3 |
| 3750 | 23.2 | 23.5 | 31.4 | 4.7 | 17.2 | 5070 | 76.8 | 0.3 |
| 3765 | 30.3 | 26.5 | 27.3 | 3.6 | 12.2 | 5630 | 69.7 | 0.3 |
| 3780 | 19.2 | 30.7 | 34.3 | 3.6 | 12.2 | 1140 | 80.8 | 0.3 |
| 3795 | 33.8 | 26.4 | 27.0 | 2.9 | 10.0 | 3900 | 66.2 | 0.3 |
| 3810 | 33.3 | 29.9 | 25.8 | 2.8 | 8.2 | 2590 | 66.7 | 0.3 |
| 3825 | 49.2 | 25.5 | 20.5 | 0.1 | 4.7 | 890 | 50.8 | 0.1 |
| 4870 | 27.2 | 13.2 | 27.2 | 6.0 | 26.5 | 30 | 72.8 | 0.2 |
| 4885 | 41.8 | 20.4 | 25.5 | 4.1 | 8.1 | 20 | 58.2 | 0.5 |
| 4900 | 44.2 | 14.4 | 29.8 | 2.8 | 8.8 | 50 | 55.8 | 0.3 |
| 4915 | 35.5 | 19.3 | 29.5 | 3.6 | 12.0 | 40 | 64.5 | 0.3 |
| 4930 | 53.0 | 12.1 | 24.2 | 3.8 | 6.8 | 30 | 47.0 | 0.6 |
| 4945 | 50.8 | 19.7 | 21.2 | 3.0 | 5.3 | 30 | 49.2 | 0.6 |
| 4960 | 63.0 | 13.7 | 16.4 | 2.7 | 4.1 | 10 | 37.0 | 0.7 |
| 4975 | 58.2 | 12.7 | 17.1 | 5.7 | 6.3 | 30 | 41.8 | 0.9 |
| 4990 | 62.6 | 14.3 | 17.7 | 2.7 | 2.7 | 30 | 37.4 | 1.0 |
| 5005 | 50.7 | 20.0 | 17.3 | 6.7 | 5.3 | 10 | 49.3 | 1.3 |
| 5020 | 60.6 | 15.4 | 19.2 | 0 | 4.8 | 20 | 39.4 | * |

Note: Total gaseous hydrocarbon abundance values are expressed as volume of hydrocarbon gases relative to volume of airspace

TABLE 1C Airspace Gaseous Hydrocarbon Analysis Data

| SAMPLE DEPTH (METRES) | SAMPLE TYPE | GENERALISED LITHOLOGY | SPORE COLOUR INDEX (1-10) | VITRINITE REFLECTIVITY IN OIL, R av % | KEROGEN COMPOSITION (%) | | |
|---|---|---|---|---|---|---|---|
| | | | | | INERTINITE | VITRINITE | SAPROPEL |
| 1530 | Can Ctgs | MDST, brn-gy, slty+30% MDST, ol-gy, slty+20% SH, ol-gy | 2-2.5 | 0.29(7) | 20 | 80 | * |
| 1650 | " | SH, dk gn-gy, slty+50% SH, dk yel-brn, slty | - | 0.29(18) | - | - | - |
| 1770 | " | SH, a/a+30% SH, a/a | 2.5 | 0.32(17) | 20 | 80 | * |
| 1890 | " | SH, a/a+20% SH, a/a | 2.5-3 | 0.34(12)<br>0.44(2) | 60 | 40 | * |
| 2070 | " | SH, med/dk gy+ 10% SH, gy-brn | 2-2.5 | 0.38(12)<br>0.46(2) | 20 | 80 | * |
| 2130 | " | SH, a/a+mnr SH, a/a | - | 0.40(10) | - | - | - |
| 2190 | " | SH, a/a+tr SH, a/a+mnr SH, gn-gy+tr SST | - | 0.33(8) | - | - | - |
| 2310 | " | SH, dk gn-gy+ 50% SH, gn-gy | 2.5-3 | 0.34(5) | 60 | 40 | *<br>mnr Sp |
| 2430 | " | SH, ol-gy+40% SH, gn-gy+20% SND+tr COAL | 2.5 | 0.55(18) | 60 | 20 | 10<br>10 Sp |
| 2550 | " | SND+30% SH, med/ dk gy+mnr CMT | - | 0.43(20)<br>0.57(5) | - | - | - |
| 2670 | " | SH, lt ol-gy+ 30% SH, ol-gy/ gn-gy | - | 0.33(4)<br>0.46(2) | - | - | - |
| 2790 | " | CHK, bl-gy/gn-gy 10% SH, ol-blk | - | * | - | - | - |
| 2910 | " | CHK/MDST, lt pnk -gy+tr LST, wht +20% SH, ol-gy/ gn-gy | - | 0.43(2) | - | - | - |
| 3150 | " | MARL, lt gy+15% MARL, lt brn-gy +10% SH, med/dk gy, slty, calc. | - | * | - | - | - |

TABLE 2A Maturity Evaluation Data

COMPANY: NORSK HYDRO WELL: 15/5-3 LOCATION: NORWEGIAN NORTH SEA

| SAMPLE DEPTH (METRES) | SAMPLE TYPE | GENERALISED LITHOLOGY | SPORE COLOUR INDEX (1-10) | VITRINITE REFLECTIVITY IN OIL, R av % | KEROGEN COMPOSITION (%) | | |
|---|---|---|---|---|---|---|---|
| | | | | | INERTINITE | VITRINITE | SAPROPEL |
| 3210 | Can Ctgs | MARL, med/lt gy +10% MARL, lt red+10% SH, med/ dk gy, slty, calc +tr COAL, oil stained. | 2-3 | * | * | ~100 add? | * |
| 3330 | " | MARL, pnk-gy+10% MARL, med/lt gy+ 10% SH, a/a+mnr SH, dk gn-gy, calc. | - | 0.36(1)<br>0.48(1)<br>0.63(2) | - | - | - |
| 3435 | " | SH, med/lt gy+ 60% SH, dk gy+ 10% SH, gy-brn+ 10% LST, lt gy | - | 0.73(1)<br>1.06(1) | - | - | - |
| 3555 | " | SH, med/dk gy+70% LST, lt ol-gy | ?8 | 0.96(2) | ~100 | mnr | * |
| 3600 | " | SH, a/a+50% SH, brn-gy | ?8 | 0.93(5) | ~100 | mnr | * |
| 3660 | " | SH, gy-blk+40% SH, med gy+20% SH, brn-gy+mnr LST, pnk-gy | 3-3.5 | 0.93(5) | ~100 | mnr | * |
| 3675 | " | SH, a/a+20% SH, a/a+30% SH, a/a +mnr LST, a/a | 4 | * | 30 | 10 | 60 |
| 3690 | " | SH, brn-blk+20% SH, a/a+20% SH, a/a+mnr LST, a/a | 3.5-4 | 0.42(2) | 30 | 10 | 60 |
| 3705 | " | SH, a/a+30% SH, a/a+30% SH, a/a +mnr LST, a/a | 4-4.5 | * | 90+ | mnr | mnr |
| 3720 | " | SH, a/a+30% SH, dk gy+20% SH, a/a+mnr LST, v lt gy | 4 | * | 90+ | mnr | mnr |
| 3735 | " | SH, dk gy+30% SH, med gy+40% SH, a/a+mnr LST, a/a | 4 | * | 90 | * | 10 |

TABLE 2B Maturity Evaluation Data

COMPANY: NORSK HYDRO WELL: 15/5-3 LOCATION: NORWEGIAN NORTH SEA

| SAMPLE DEPTH (METRES) | SAMPLE TYPE | GENERALISED LITHOLOGY | SPORE COLOUR INDEX (1-10) | VITRINITE REFLECTIVITY IN OIL, R av % | KEROGEN COMPOSITION (%) | | |
|---|---|---|---|---|---|---|---|
| | | | | | INERTINITE | VITRINITE | SAPROPEL |
| 3750 | Can Ctgs | SH, dk gy+30% SH, med gy+40% SH, brn-gy+mnr LST, v lt gy | 4-4.5 | * | 80 | 10 | 10 |
| 3765 | " | SH, a/a+50% SH, a/a+30% SH, a/a +mnr LST, a/a | 3.5-4 | * | 90 | 10 | mnr |
| 3780 | " | SH, a/a+40% SH, a/a+20% SH, a/a +10% LST, a/a | 4 | * | ∿100 | mnr | mnr |
| 3795 | " | SH, a/a+30% SH, a/a+20% SH, a/a +mnr LST, a/a | 4 | * | 80 | mnr | 20 mnr Sp |
| 3810 | " | SH, a/a+30% SH, a/a+30% SH, a/a +10% LST, a/a | 4 | * | 90 | mnr | 10 |

TABLE 2C Maturity Evaluation Data

## Table 3A CHEMICAL ANALYSIS DATA

**COMPANY:** NORSK HYDRO **WELL:** 15/5-3 **LOCATION:** NORWEGIAN NORTH SEA

| GENERAL DATA | | | CHEMICAL ANALYSIS DATA | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | PYROLYSIS | | | | | SOLVENT EXTRACTION | | | | | |
| | | | | | | | | | | | | HYDROCARBONS | | |
| SAMPLE DEPTH METRES | SAMPLE TYPE | ANALYSED LITHOLOGY | ORGANIC CARBON % OF ROCK | TEMP-ERATURE °C | HYDROGEN INDEX | OXYGEN INDEX | PRODUCTION INDEX | POTENTIAL YIELD (ppm) | TOTAL EXTRACT (ppm) | HYDRO-CARBONS (ppm) | EXTRACT % OF ORGANIC CARBON | mg/g OF ORGANIC CARBON | % OF EXTRACT | ALKANES % OF HYDRO-CARBONS |
| | | OLIGOCENE-? EOCENE-FRIGG FORMATION | | | | | | | | | | | | |
| 1530 | Can Ctgs | MDST, brn-gy, slty+30% MDST, ol-gy, slty+20% SH, ol-gy | 1.37 | | | | | | | | | | | |
| 1590 | " | SH, dk gn-gy, slty+40% SH, dk yel-brn, slty | 0.53 | | | | | | | | | | | |
| | | MIDDLE EOCENE | | | | | | | | | | | | |
| 1650 | " | SH, a/a+50% SH, a/a | 1.04 | | | | | | | | | | | |
| 1710 | " | SH, a/a+30% SH, a/a | 0.49 | | | | | | | | | | | |
| 1770 | " | A/a | 0.74 | | | | | | | | | | | |
| 1830 | " | SH, a/a+10% SH, a/a | 0.52 | | | | | | | | | | | |
| | | EARLY EOCENE | | | | | | | | | | | | |
| 1890 | " | SH, a/a+20% SH, a/a | 0.42 | | | | | | | | | | | |
| 1950 | " | SH, a/a+10% SH, a/a | 0.29 | | | | | | | | | | | |
| 2010 | " | SH, dk gn-gy+10% SH, dk yel-brn | 0.29 | | | | | | | | | | | |
| | | PALAEOCENE-BALDER FM | | | | | | | | | | | | |
| 2070 | " | SH, med/dk gy+10% SH, gy-brn | 0.78 | 440 | 53 | 38 | 0.10 | 400 | 810 | 85 | 10.4 | 11 | 11 | 62 |
| | | SELE FM | | | | | | | | | | | | |
| 2130 | " | SH, a/a+mnr SH, a/a | 1.10 | | | | | | | | | | | |
| | | HEIMDAL FM | | | | | | | | | | | | |
| 2190 | " | SH, a/a+tr SH, a/a+mnr SH, gn-gy+tr SST | 1.61 | 441 | 47 | 45 | 0.03 | 800 | 445 | 135 | 2.8 | 8 | 30 | 60 |
| " | " | Repeat | 1.70 | | | | | | | | | | | |
| 2250 | " | SH, med/dk gy+20% SND+mnr SH, dk gn-gy | - | | | | | | | | | | | |
| " | Can Pick | SH, med-dk gy | 0.89 | | | | | | | | | | | |
| 2310 | Can Ctgs | SH, dk gn-gy+50% SH, gn-gy | 1.26 | 441 | 36 | 54 | 0.10 | 500 | 1370 | 140 | 10.9 | 11 | 10 | 57 |
| " | " | Repeat | 1.19 | - | - | - | - | - | 310 | 100 | 2.6 | 8 | 32 | 57 |
| " | " | Repeat on Extracted Residue | 1.41 | 445 | 27 | 48 | 0.30 | 400 | - | - | - | - | - | - |
| " | Can Pick | SH, dk gn-gy | 0.41 | 448 | 35 | 125 | 0.20 | 100 | 3485 | 180 | 85.0 | 44 | 5 | 76 |
| 2370 | Can Ctgs | SH, ol-blk+10% SH, gn-gy+20% SND | 0.41 | | | | | | | | | | | |
| 2430 | " | SH, ol-gy+40% SH, gn-gy+20% SND+tr COAL | 0.78 | | | | | | | | | | | |
| 2490 | " | SND+50% SH, med/dk gy | 0.54 | | | | | | | | | | | |
| 2550 | " | SND+30% SH, a/a+mnr CMT | 0.32 | | | | | | | | | | | |
| | | DANIAN-EKOFISK FM | | | | | | | | | | | | |
| 2610 | " | SH, ol-gy+60% SH, gn-gy+tr SH, ol-blk | 0.37 | | | | | | | | | | | |

## Table 3B CHEMICAL ANALYSIS DATA

**COMPANY:** NORSK HYDRO **WELL:** 15/5-3 **LOCATION:** NORWEGIAN NORTH SEA

| GENERAL DATA | | | CHEMICAL ANALYSIS DATA | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | PYROLYSIS | | | | | SOLVENT EXTRACTION | | | | | |
| | | | | | | | | | | | | HYDROCARBONS | | |
| SAMPLE DEPTH METRES | SAMPLE TYPE | ANALYSED LITHOLOGY | ORGANIC CARBON % OF ROCK | TEMP-ERATURE °C | HYDROGEN INDEX | OXYGEN INDEX | PRODUCTION INDEX | POTENTIAL YIELD (ppm) | TOTAL EXTRACT (ppm) | HYDRO-CARBONS (ppm) | EXTRACT % OF ORGANIC CARBON | mg/g OF ORGANIC CARBON | % OF EXTRACT | ALKANES % OF HYDRO-CARBONS |
| | | TOR FM | | | | | | | | | | | | |
| 2670 | Can Ctgs | SH, lt ol-gy+30% SH, ol-gy/gn-gy | 0.21 | | | | | | | | | | | |
| | | MAASTRICHTIAN | | | | | | | | | | | | |
| 2730 | " | SH, bl-gy/gn-gy+mnr LST/CHK | 0.41 | | | | | | | | | | | |
| 2790 | " | CHK/MDST, lt gy, v calc+10% SH, ol-blk | 0.27 | | | | | | | | | | | |
| " | Can Pick | SH, ol-blk | 0.28 | | | | | | | | | | | |
| 2850 | Can Ctgs | CHK/MDST, a/a+mnr SH, a/a | 1.01 | | | | | | | | | | | |
| " | Can Pick | SH, ol-blk | 0.29 | | | | | | | | | | | |
| | | ?EARLY MAASTRICHTIAN | | | | | | | | | | | | |
| 2910 | Can Ctgs | CHK/MDST, lt pnk-gy+tr LST, wht+20% SH, ol-gy/gn-gy | 0.34 | | | | | | | | | | | |
| " | Can Pick | SH, ol-gy/gn-gy | 0.26 | | | | | | | | | | | |
| | | CAMPANIAN-CONIACIAN-FLOUNDER FM | | | | | | | | | | | | |
| 2970 | Can Ctgs | SH, med/dk gy, calc+20% MARL, med/lt gy*60% MARL, lt red+mnr MARL, wht | 0.26 | | | | | | | | | | | |
| 3030 | " | SH, a/a+90% MARL, a/a+mnr MARL, a/a+mnr SH, med brn-gy, calc | 0.24 | | | | | | | | | | | |
| 3090 | " | SH, a/a+70% MARL, lt gy+15% MARL, lt red | 0.27 | | | | | | | | | | | |
| 3150 | " | MARL, a/a+15% MARL, lt brn-gy+10% SH, med/dk gy, slty, calc | 0.38 | * | 21 | 205 | 0.10 | 100 | 730 | 160 | 19.3 | 42 | 22 | 72 |
| 3210 | " | MARL, med/lt gy+10% MARL lt red+10% SH, a/a+tr COAL. Oil stained. | 1.70 | 448 | 54 | 105 | 0.04 | 900 | 855 | 290 | 5.0 | 17 | 34 | 43 |
| " | Can Pick | SH, med/dk gy, slty, calc | 0.34 | * | 26 | 142 | 0.30 | 100 | 5630 | 80 | 165.6 | 24 | 1 | 77 |
| 3270 | Can Ctgs | SH, med gy, calc+80% MARL, med/lt gy | 0.63 | | | | | | | | | | | |
| | | TURONIAN-HERRING FM. | | | | | | | | | | | | |
| 3330 | " | MARL, pnk-gy+10% MARL, med/lt gy+10% SH, med/dk gy+mnr SH, dk gn-gy, calc | 0.27 | 434 | 75 | 387 | 0.40 | 200 | 1775 | 935 | 65.8 | 346 | 53 | 61 |
| 3375 | " | MARL, a/a+mnr SH, lt ol-gy, calc+30% SH, med gy, slty, calc. | 0.44 | | | | | | | | | | | |
| " | Can Pick | SH, med gy, slty, calc | 0.22 | * | 30 | 259 | 0.20 | 100 | | | | | | |

# Table 3C CHEMICAL ANALYSIS DATA

**COMPANY:** NORSK HYDRO **WELL:** 15/5-3 **LOCATION:** NORWEGIAN NORTH SEA

| GENERAL DATA | | | CHEMICAL ANALYSIS DATA | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | PYROLYSIS | | | | | SOLVENT EXTRACTION | | | | | |
| | | | | | | | | | | | | HYDROCARBONS | | |
| SAMPLE DEPTH METRES | SAMPLE TYPE | ANALYSED LITHOLOGY | ORGANIC CARBON % OF ROCK | TEMP-ERATURE °C | HYDROGEN INDEX | OXYGEN INDEX | PRODUCTION INDEX | POTENTIAL YIELD (ppm) | TOTAL EXTRACT (ppm) | HYDRO-CARBONS (ppm) | EXTRACT % OF ORGANIC CARBON | mg/g OF ORGANIC CARBON | % OF EXTRACT | ALKANES % OF HYDRO-CARBONS |
| 3405 | Can Ctgs | SH, dk gn-gy+70% LST, v lt gy | 0.33 | | | | | | | | | | | |
| | | HIDRA FM. | | | | | | | | | | | | |
| 3420 | " | SH, med/dk gy+60% LST, a/a | 0.26 | | | | | | | | | | | |
| | | CENOMANIAN | | | | | | | | | | | | |
| 3435 | " | SH, med/lt gy+60% SH, dk gy +10% SH, gy-brn+10% LST, a/a | 0.59 | | | | | | | | | | | |
| 3450 | " | SH, ol-gy+40% SH, med/lt gy+ 10% SH, gy-brn+20% LST, v. lt gy | 0.28 | | | | | | | | | | | |
| 3465 | " | SH, a/a+mnr SH, a/a+mnr SH, a/a+30% LST, a/a | 0.44 | | | | | | | | | | | |
| 3480 | " | SH, a/a+mnr SH, a/a+10% SH, a/a+30% LST, a/a | 0.52 | | | | | | | | | | | |
| 3495 | " | SH, a/a+mnr SH, a/a+10% SH, a/a+40% LST, a/a | 0.19 | | | | | | | | | | | |
| | | ALBIAN | | | | | | | | | | | | |
| 3510 | " | SH, med/dk gy+60% SH, dk gn-gy+10% SH, gy-brn+20% LST, lt brn-gy | 0.11 | | | | | | | | | | | |
| | | RØDBY FM. | | | | | | | | | | | | |
| 3525 | " | A/a | 0.23 | | | | | | | | | | | |
| 3540 | " | SH, a/a+70% SH, a/a+mnr SH, a/a+20% LST, a/a | 0.42 | | | | | | | | | | | |
| 3555 | " | SH, a/a+70% LST, lt ol-gy | 1.33 | * | 150 | 242 | 0.90 | 2000 | 7500 | 5400 | 56.4 | 406 | 72 | 63 |
| " | Can Pick | SH, med/dk gy | 0.28 | * | 34 | 233 | 0.30 | 100 | 100090 | 305 | 360.0 | 109 | 3 | 86 |
| 3570 | Can Ctgs | SH, med/dk gy+30% LST | 1.66 | | | | | | | | | | | |
| " | Can Pick | SH, med/dk gy | 0.75 | 442 | 63 | 135 | 0.30 | 500 | 29250 | 1815 | 390.0 | 242 | 6 | 78 |
| | | EARLY ALBIAN-APTIAN-VALHALL FM. | | | | | | | | | | | | |
| 3585 | Can Ctgs | SH, a/a+60% SH, brn-gy+10% LST, lt ol-gy | 1.28 | | | | | | | | | | | |
| " | Can Pick | SH, med/dk gy/brn-gy | 0.57 | 365 | 49 | 71 | 0.10 | 300 | 16855 | 525 | 296.0 | 92 | 3 | 84 |
| " | " | Repeat | 1.53 | 443 | 54 | 27 | 0.20 | 800 | 915 | 160 | 6.0 | 11 | 18 | 45 |
| " | " | Repeat on Extracted Residue | 1.49 | * | 6 | 21 | 0.20 | 100 | - | - | - | - | - | - |
| 3600 | Can Ctgs | SH, med/dk gy+50% SH, brn-gy | 0.43 | * | 13 | 117 | 0.20 | 50 | 830 | 100 | 19.3 | 23 | 12 | 35 |
| " | Can Pick | SH, med/dk | 0.88 | * | 4 | 38 | 0.60 | 50 | 3000 | 70 | 34.1 | 8 | 2 | 84 |
| 3615 | Can Ctgs | SH, med/dk gy+40% SH, brn-gy | 0.66 | | | | | | | | | | | |

## Table 3D CHEMICAL ANALYSIS DATA

**COMPANY:** NORSK HYDRO **WELL:** 15/5-3 **LOCATION:** NORWEGIAN NORTH SEA

| GENERAL DATA | | | CHEMICAL ANALYSIS DATA | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | PYROLYSIS | | | | | SOLVENT EXTRACTION | | | | | |
| | | | | | | | | | | | | HYDROCARBONS | | |
| SAMPLE DEPTH METRES | SAMPLE TYPE | ANALYSED LITHOLOGY | ORGANIC CARBON % OF ROCK | TEMP-ERATURE °C | HYDROGEN INDEX | OXYGEN INDEX | PRODUCTION INDEX | POTENTIAL YIELD (ppm) | TOTAL EXTRACT (ppm) | HYDRO-CARBONS (ppm) | EXTRACT % OF ORGANIC CARBON | mg/g OF ORGANIC CARBON | % OF EXTRACT | ALKANES % OF HYDRO-CARBONS |
| | | BARREMIAN-LATE HAUTERIVIAN | | | | | | | | | | | | |
| 3630 | Can Ctgs | SH, med/dk gy+40% SH, brn-gy | 0.68 | | | | | | | | | | | |
| 3645 | " | SH, gy-blk, mic+40% SH, med gy, mic+20% SH, brn-gy+10% LST, pnk-gy | 0.82 | | | | | | | | | | | |
| | | EARLY VALANGINIAN-LATE RYAZANIAN | | | | | | | | | | | | |
| 3660 | Can Ctgs | SH, a/a+40% SH, a/a+20% SH, a/a+mnr LST, a/a | 0.80 | 449 | 23 | 47 | 0.30 | 200 | 670 | 180 | 8.4 | 23 | 27 | 62 |
| 3660 | " | Repeat | 0.95 | 445 | 32 | 38 | 0.10 | 300 | 645 | 375 | 6.8 | 40 | 58 | 68 |
| " | " | Repeat on Extracted Residue | 0.95 | * | 21 | 59 | 0.20 | 200 | - | - | - | - | - | - |
| | | RYAZANIAN-VOLGIAN-KIMMERIDGE CLAY FM. | | | | | | | | | | | | |
| 3675 | " | SH, gy-blk, mic+20% SH, med gy, mic+30% SH, brn-gy+mnr LST, pnk-gy | 1.07 | 448 | 47 | 40 | 0.30 | 500 | 6150 | 1295 | 57.5 | 121 | 21 | 31 |
| 3690 | " | SH, brn-blk+20% SH, med gy+ 20% SH, brn-gy+mnr LST, a/a | 2.77 | 443 | 159 | 27 | 0.30 | 4400 | 5765 | 3090 | 20.8 | 112 | 54 | 58 |
| 3690-705 | Ctgs | Biostrat Sample: SH, dk gy+ 10% SH, gy-red+10% SH, med gy | 3.89 | 440 | 93 | 20 | 0.10 | 3600 | 3415 | 3175 | 8.8 | 82 | 93 | 49 |
| 3690 | Can Ctgs | Repeat on Extracted Residue | 2.54 | 454 | 117 | 12 | 0.02 | 3000 | - | - | - | - | - | - |
| 3705 | Can Ctgs | SH, brn-blk+30% SH, med gy+ 30% SH, brn-gy+mnr LST, a/a | 2.19 | 446 | 108 | 21 | 0.30 | 2400 | 3705 | 2660 | 16.9 | 122 | 72 | 63 |
| 3705-720 | Ctgs | Biostrat Sample: SH, dk gy+ 20% SH, gy-red+10% SH, med gy | 2.41 | 444 | 131 | 30 | 0.10 | 3200 | 1695 | 1150 | 7.0 | 48 | 68 | 56 |
| 3705 | Can Ctgs | Repeat on Extracted Residue | 2.05 | 455 | 85 | 11 | 0.04 | 1800 | - | - | | - | - | - |
| 3720 | Can Ctgs | SH, brn-blk+30% SH, dk gy+20% SH, brn-gy+mnr LST, v lt gy | 1.52 | 446 | 59 | 33 | 0.30 | 900 | 2430 | 1760 | 16.0 | 116 | 72 | 60 |
| 3720-735 | Ctgs | Biostrat Sample: SH, dk gy+ 30% SH, gy-red+10% SH, med gy | 1.41 | 443 | 39 | 50 | 0.10 | 600 | 270 | 160 | 1.9 | 11 | 60 | 69 |
| 3720 | Can Ctgs | Repeat on Extracted Residue | 1.48 | 456 | 47 | 21 | 0.04 | 700 | - | - | - | - | - | - |
| | | KIMMERIDGIAN | | | | | | | | | | | | |
| 3735 | Can Ctgs | SH, dk gy+30% SH, med gy+40% SH, brn-gy+mnr LST, a/a | 1.61 | 446 | 71 | 28 | 0.30 | 1100 | 2570 | 1370 | 16.0 | 85 | 53 | 56 |
| 3735-750 | Ctgs | Biostrat Sample: SH, dk gy+ 20% SH, gy-red+20% SH, med gy | 1.33 | 440 | 49 | 32 | 0.10 | 700 | 495 | 280 | 3.7 | 21 | 57 | 66 |
| 3735 | Can Ctgs | Repeat on Extracted Residue | 1.66 | 455 | 45 | 15 | 0.10 | 700 | - | - | - | - | - | - |
| | | EARLY KIMMERIDGIAN-LATE OXFORDIAN | | | | | | | | | | | | |
| 3750 | Can Ctgs | SH, dk gy+30% SH, med gy+40% SH, brn-gy+mnr LST, a/a | 0.94 | 445 | 18 | 53 | 0.40 | 200 | 1960 | 505 | 20.9 | 54 | 26 | 58 |

## Table 3E CHEMICAL ANALYSIS DATA

**COMPANY:** NORSK HYDRO **WELL:** 15/5-3 **LOCATION:** NORWEGIAN NORTH SEA

| SAMPLE DEPTH METRES | SAMPLE TYPE | ANALYSED LITHOLOGY | ORGANIC CARBON % OF ROCK | PYROLYSIS: TEMP-ERATURE °C | HYDROGEN INDEX | OXYGEN INDEX | PRODUCTION INDEX | POTENTIAL YIELD (ppm) | SOLVENT EXTRACTION: TOTAL EXTRACT (ppm) | HYDRO-CARBONS (ppm) | EXTRACT % OF ORGANIC CARBON | HYDROCARBONS: mg/g OF ORGANIC CARBON | % OF EXTRACT | ALKANES % OF HYDRO-CARBONS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3750-765 | Ctgs | Biostrat Sample: SH, dk gy+ 30% SH, gy-red+20% SH, med gy+tr SND/SST | 1.09 | 441 | 36 | 44 | 0.10 | 400 | 395 | 215 | 3.6 | 20 | 55 | 67 |
| 3750 | Can Ctgs | Repeat on Extracted Residue | 0.97 | 445 | 25 | 34 | 0.20 | 200 | - | - | - | - | - | - |
| 3765 | Can Ctgs | SH, dk gy+50% SH, med gy+30% SH, brn-gy+mnr LST, v lt gy | 0.86 | 447 | 21 | 54 | 0.40 | 200 | 1410 | 480 | 16.4 | 56 | 34 | 59 |
| 3765-780 | Ctgs | Biostrat Sample: SH, dk gy+ 30% SH, gy-red+10% SH, med gy+tr SND/SST | 0.97 | 442 | 34 | 33 | 0.10 | 300 | 420 | 215 | 4.4 | 22 | 51 | 72 |
| 3765 | Can Ctgs | Repeat on Extracted Residue | 0.88 | * | 28 | 43 | 0.20 | 200 | - | - | - | - | - | - |
| 3780 | " | SH, dk gy+40% SH, med gy+20% SH, brn-gy+10% LST, v lt gy | 0.83 | 446 | 15 | 79 | 0.40 | 100 | 1740 | 385 | 21.0 | 46 | 22 | 49 |
| 3780 | " | Repeat on Extracted Residue | 0.98 | * | 17 | 39 | 0.20 | 200 | - | - | - | - | - | - |
| 3795 | " | SH, a/a+30% SH, a/a+20% SH, a/a+mnr LST, a/a | 0.98 | 446 | 32 | 78 | 0.30 | 300 | 570 | 110 | 5.8 | 11 | 19 | 54 |
| | | LATE PERMIAN-ZECHSTEIN | | | | | | | | | | | | |
| 3810 | " | SH, a/a+30% SH, a/a+30% SH, a/a+10% LST a/a | 0.86 | 447 | 17 | 62 | 0.40 | 200 | 1785 | 325 | 20.8 | 37 | 18 | 54 |
| " | " | Repeat on Extracted Residue | 0.93 | 445 | 23 | 47 | 0.40 | 200 | - | - | - | - | - | - |
| 3825 | " | SH, a/a+30% SH, a/a+30% SH, a/a+10% LST, a/a | 0.73 | | | | | | | | | | | |
| | | ?DEVONIAN | | | | | | | | | | | | |
| 4870 | " | SND/SST, vgt+30% SH, gy-red | 1.73 | | | | | | | | | | | |
| 4885 | " | SND/SST, a/a+20% SH, a/a | 0.49 | | | | | | | | | | | |
| 4945 | " | SND/SST, a/a+SH, a/a+pipe scale | 0.72 | | | | | | | | | | | |
| 4960 | " | A/a | 0.83 | | | | | | | | | | | |

TABLE 4

CARBON ISOTOPE ANALYSIS DATA

COMPANY: NORSK HYDRO    WELL: 15/5-3    LOCATION: NORWEGIAN NORTH SEA

| SAMPLE DEPTH (M) | $\delta C^{13}$ Saturate Fraction | $\delta C^{13}$ Aromatic Fraction | $\delta C^{13}$ Kerogen |
|---|---|---|---|
| 2190 | -27.31 | -26.91 | - |
| 2310 | -27.66 | -27.12 | - |
| 3150 | -28.26 | -27.17 | - |
| 3330 | -30.31 | -29.54 | - |
| 3675 | -28.84 | -27.91 | -27.14 |
| 3690 | -29.39 | -28.63 | -27.87 |
| 3705 | -29.29 | -28.47 | -26.54 |
| 3720 | -29.17 | -28.27 | -26.28 |
| | | | $\delta C^{13}$(NSO) |
| OIL SAMPLE (3525 metres) | -30.94 | -29.44 | -28.33 |

Note: Results are quoted in parts per thousand difference relative to the P.D.B. Standard.

COMPANY: NORSK HYDRO WELL: 15/5-3 LOCATION: NORWEGIAN NORTH SEA

| DEPTH: (METRES) | OIL 3525 | | | | | | |
|---|---|---|---|---|---|---|---|
| GASOLINE HYDROCARBON COMPONENTS | RELATIVE GASOLINE HYDROCARBON COMPONENT ABUNDANCES (%) | | | | | | |
| *i*-BUTANE | 4.2 | | | | | | |
| *n*-BUTANE | 11.1 | | | | | | |
| *i*-PENTANE | 9.2 | | | | | | |
| *n*-PENTANE | 16.3 | | | | | | |
| 2,2 – DIMETHYL BUTANE | 0.1 | | | | | | |
| CYCLOPENTANE | 2.5 | | | | | | |
| 2,3 – DIMETHYL BUTANE | * | | | | | | |
| 2 – METHYL PENTANE | 4.6 | | | | | | |
| 3 – METHYL PENTANE | 2.6 | | | | | | |
| *n* – HEXANE | 8.2 | | | | | | |
| 2,2 – DIMETHYL PENTANE / METHYL CYCLOPENTANE | 4.7 | | | | | | |
| 2,4 – DIMETHYL PENTANE | 0.4 | | | | | | |
| BENZENE | 2.4 | | | | | | |
| 3,3 – DIMETHYL PENTANE | * | | | | | | |
| CYCLOHEXANE | 4.5 | | | | | | |
| 2 – METHYL HEXANE | 2.8 | | | | | | |
| 1,1 – DIMETHYL CYCLOPENTANE | 0.4 | | | | | | |
| 3 – METHYL HEXANE | 2.4 | | | | | | |
| 1, *cis* – 3 – DIMETHYL CYCLOPENTANE | 0.8 | | | | | | |
| 1, *trans* – 3 – DIMETHYL CYCLOPENTANE | 1.1 | | | | | | |
| 1, *trans* – 2 – DIMETHYL CYCLOPENTANE | 2.0 | | | | | | |
| 3 – ETHYL PENTANE | – | | | | | | |
| *n* – HEPTANE | 6.5 | | | | | | |
| 1, *cis* – 2 – DIMETHYL CYCLOPENTANE / METHYL CYCLOHEXANE | 8.8 | | | | | | |
| ETHYL CYCLOPENTANE | 1.1 | | | | | | |
| TOLUENE | 3.3 | | | | | | |
| TOTAL ABUNDANCE (ppb) | 56800 | | | | | | |
| ORGANIC CARBON (%) | – | | | | | | |
| GASOLINE ABUNDANCE AT 1% ORGANIC CARBON | – | | | | | | |

Note: Total gasoline abundance values are expressed as weight of gas relative to volume of oil.

TABLE 5 Gasoline Hydrocarbon Analysis Data

COMPANY: NORSK HYDRO WELL: 15/5-3 LOCATION: NORWEGIAN NORTH SEA

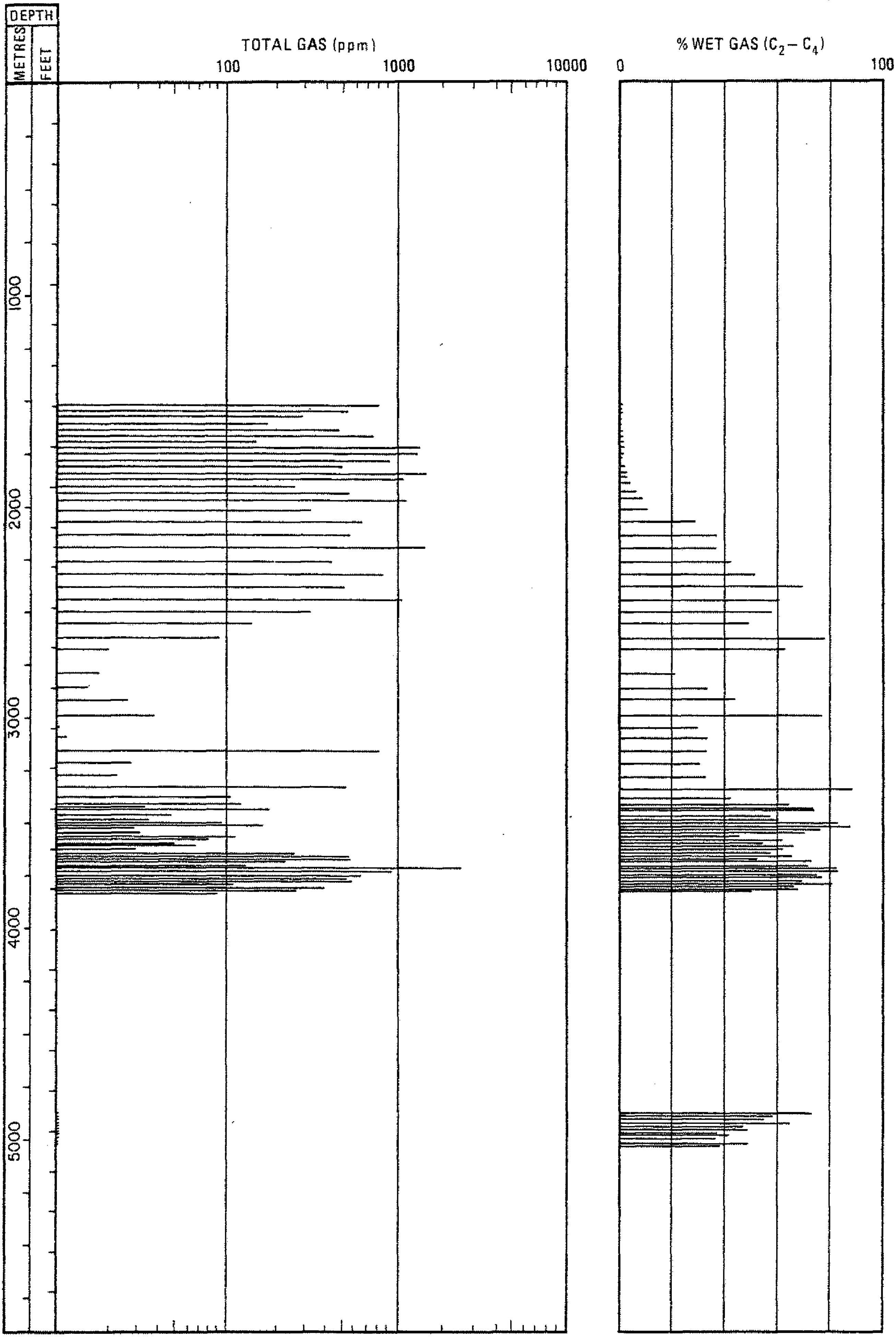



FIGURE 1 Airspace ($C_1$- $C_4$) Hydrocarbons against Depth

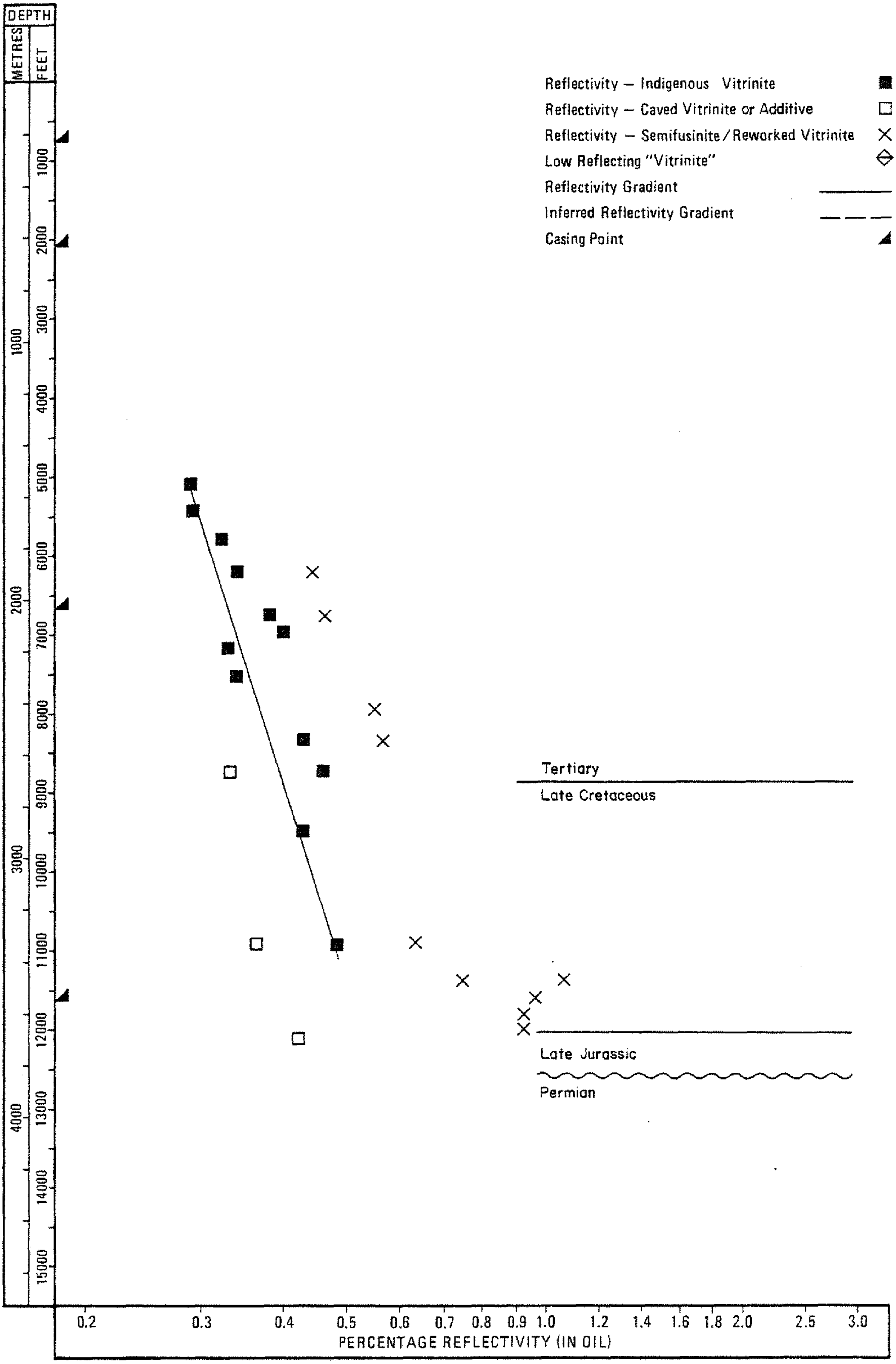



FIGURE 2 Vitrinite Reflectivity against Depth

COMPANY: NORSK HYDRO    WELL: 15/5-3    LOCATION: NORWEGIAN NORTH SEA

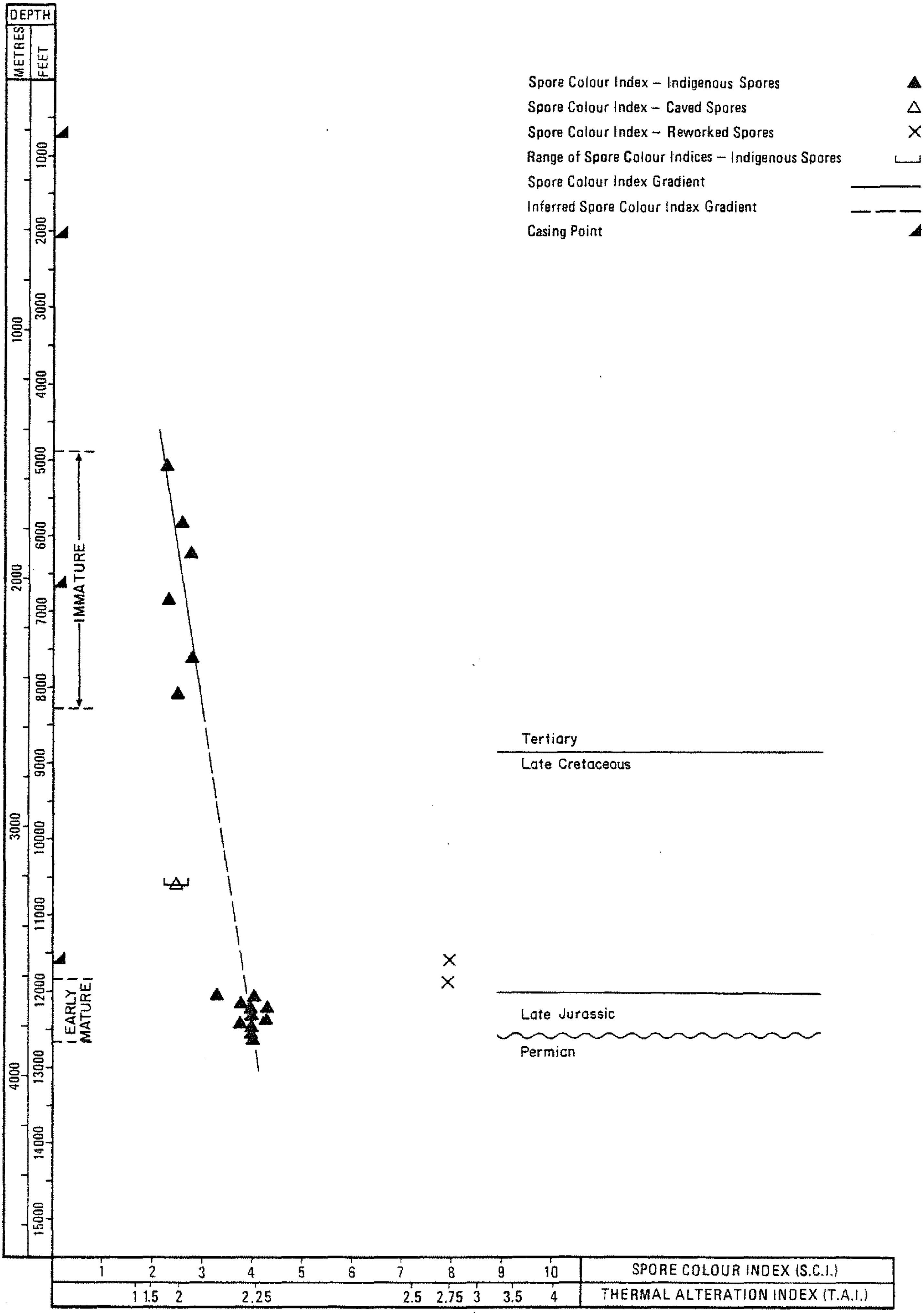



FIGURE 3 Spore Colour Indices against Depth

FIG. 4 WELL 15/5-3
2070m

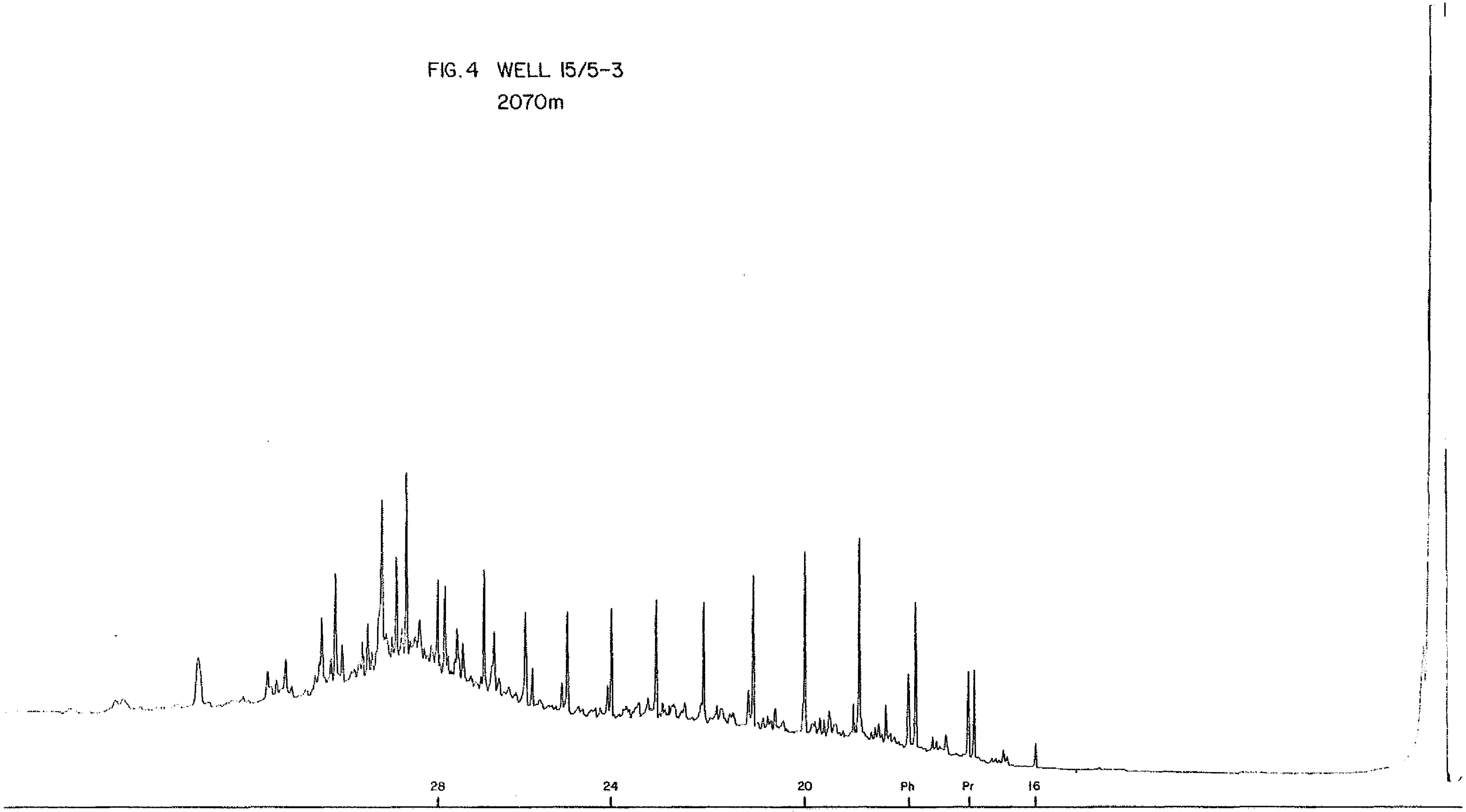


FIG. 5 WELL 15/5-3

2190m

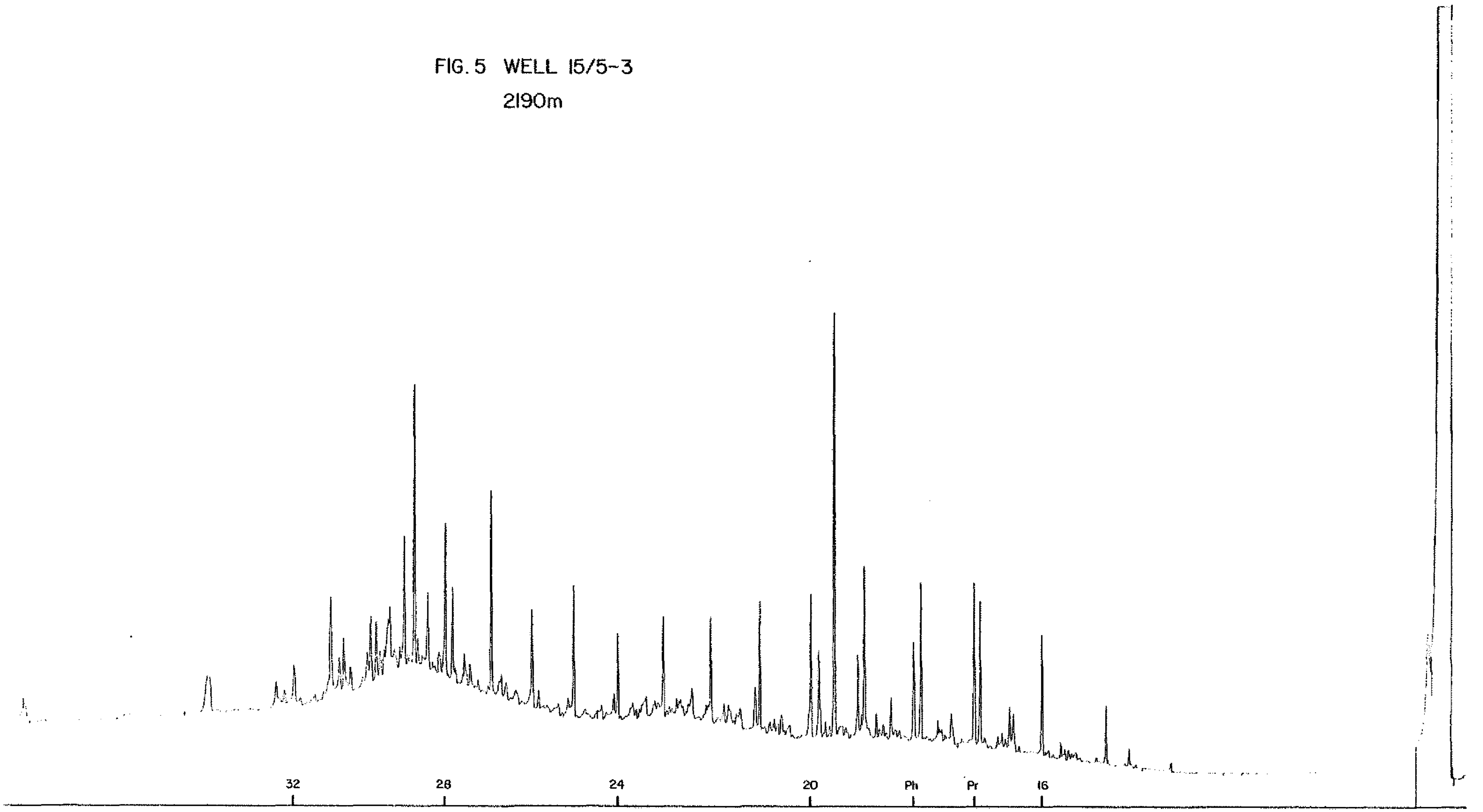


FIG. 6 WELL 15/5-3

2310 m

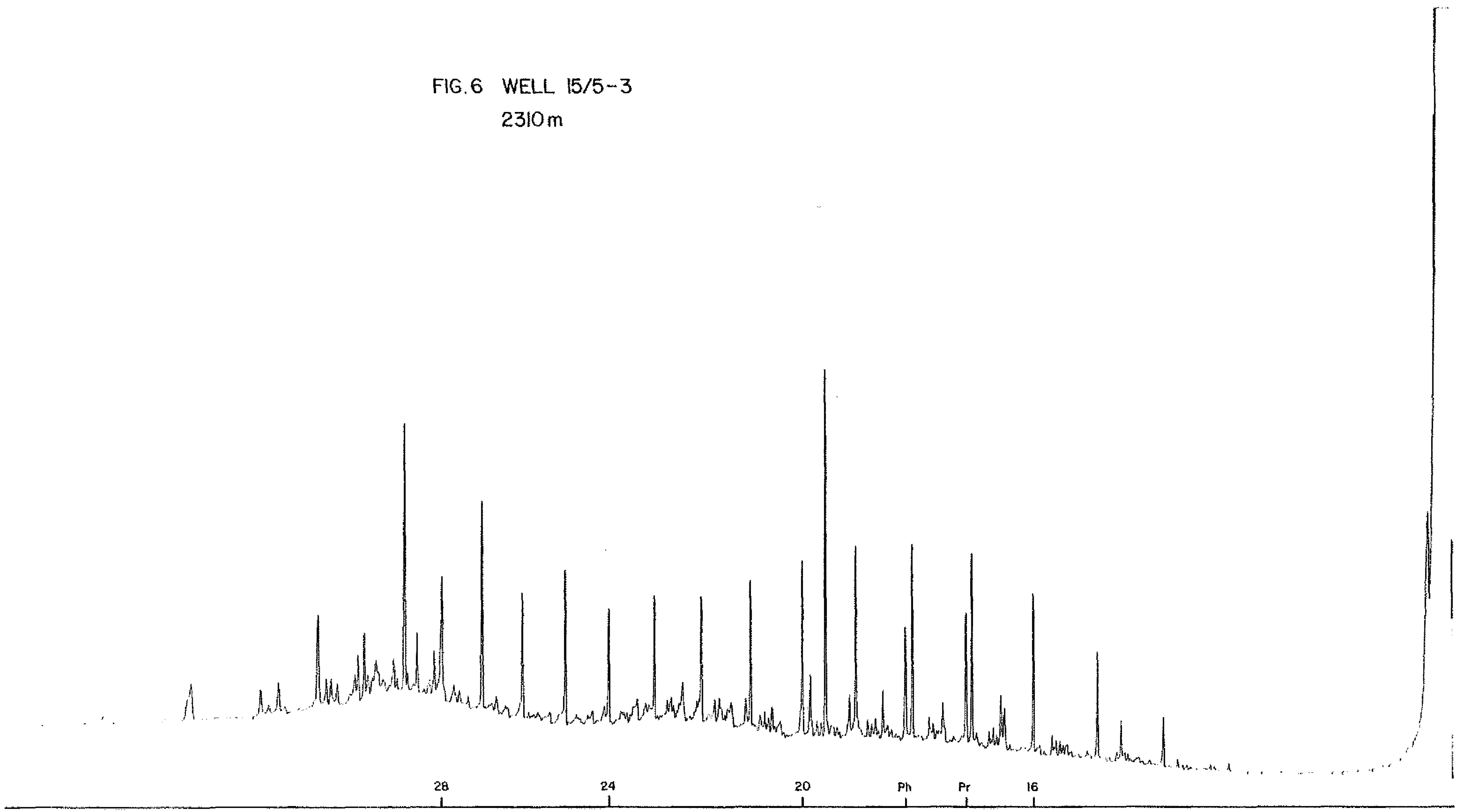


FIG. 7 WELL 15/5-3

2310m

Hand Picked Shale

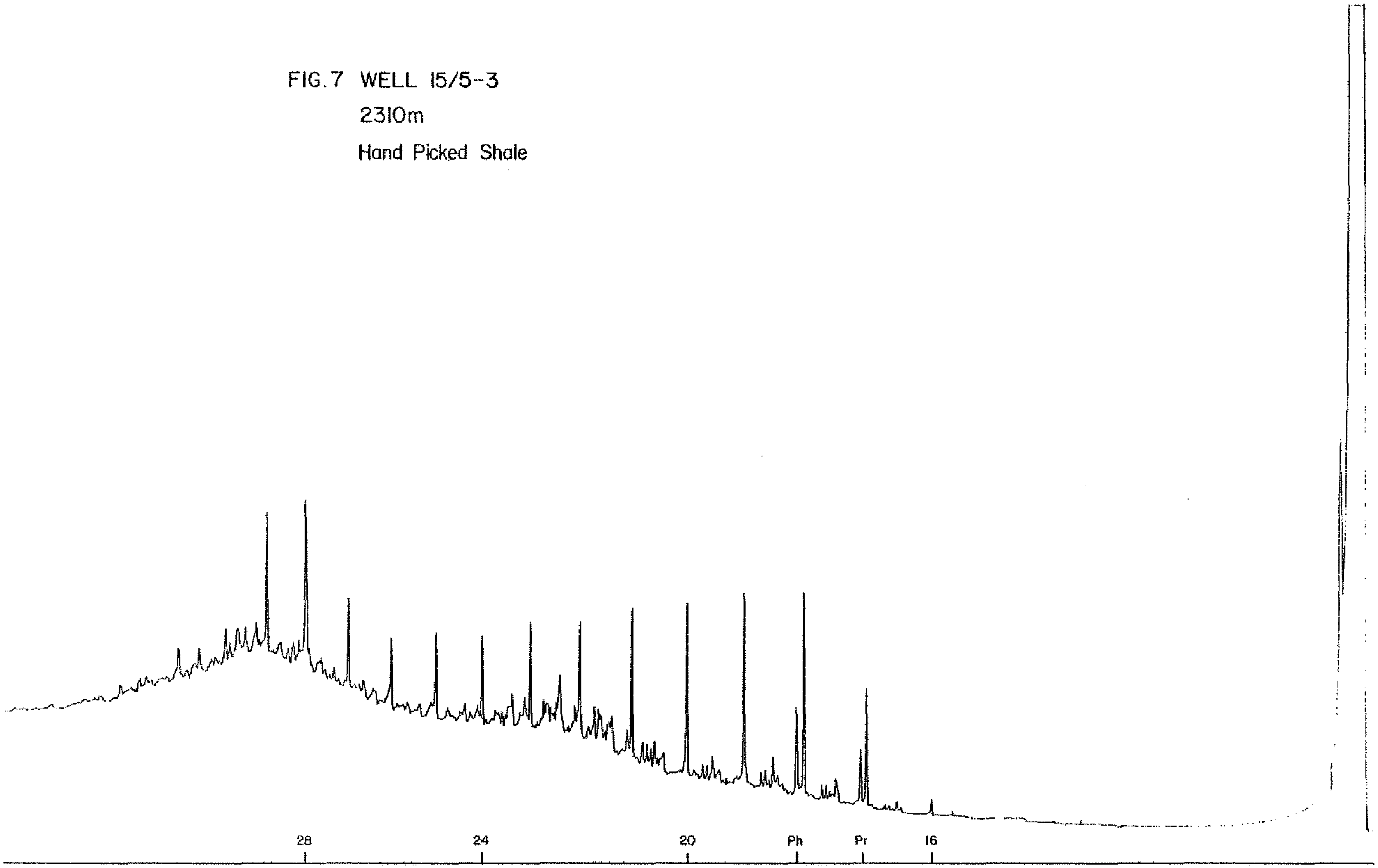


FIG. 8 WELL 15/5-3
3150m

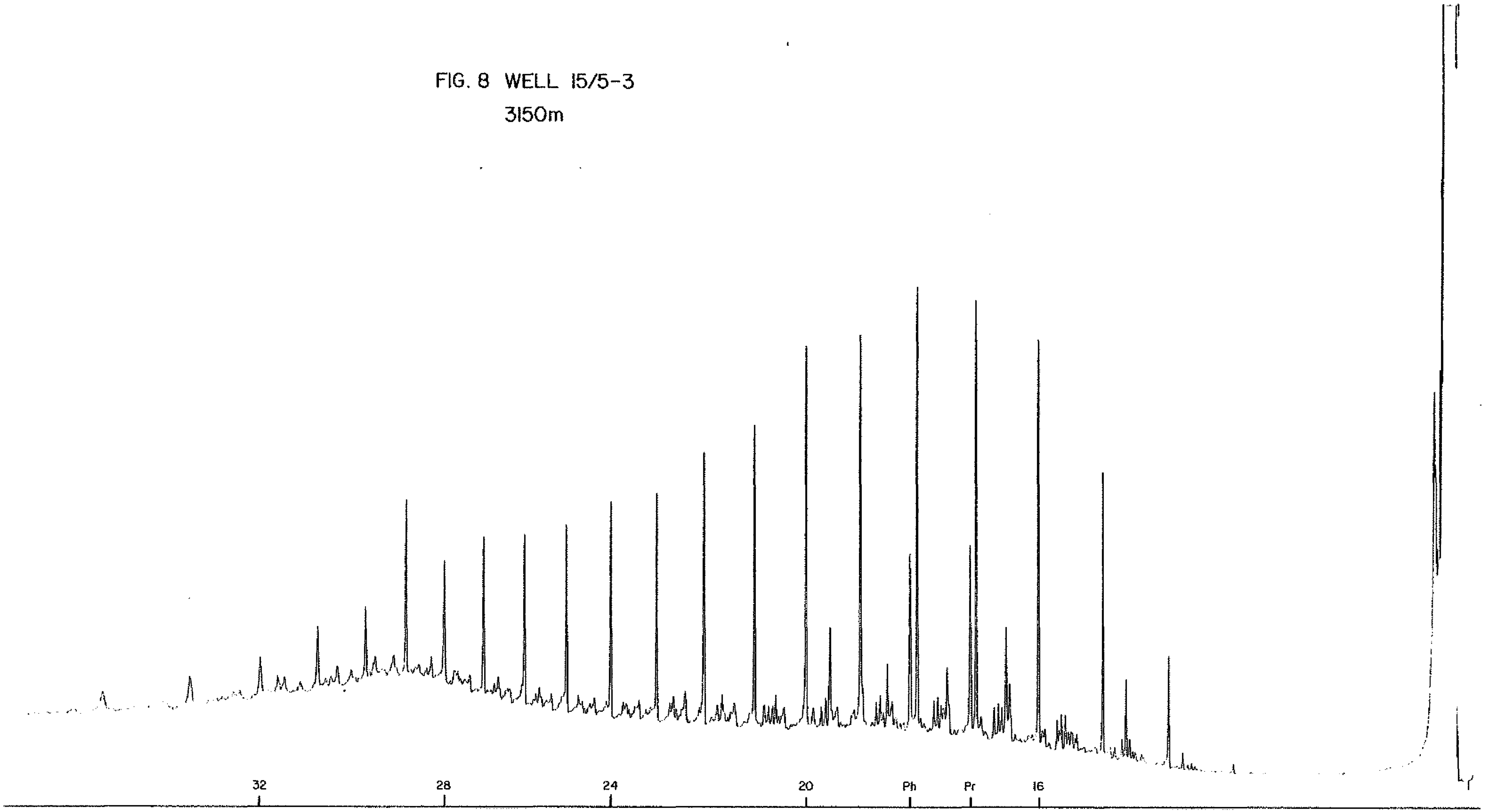


FIG. 9 WELL 15/5-3
3210m

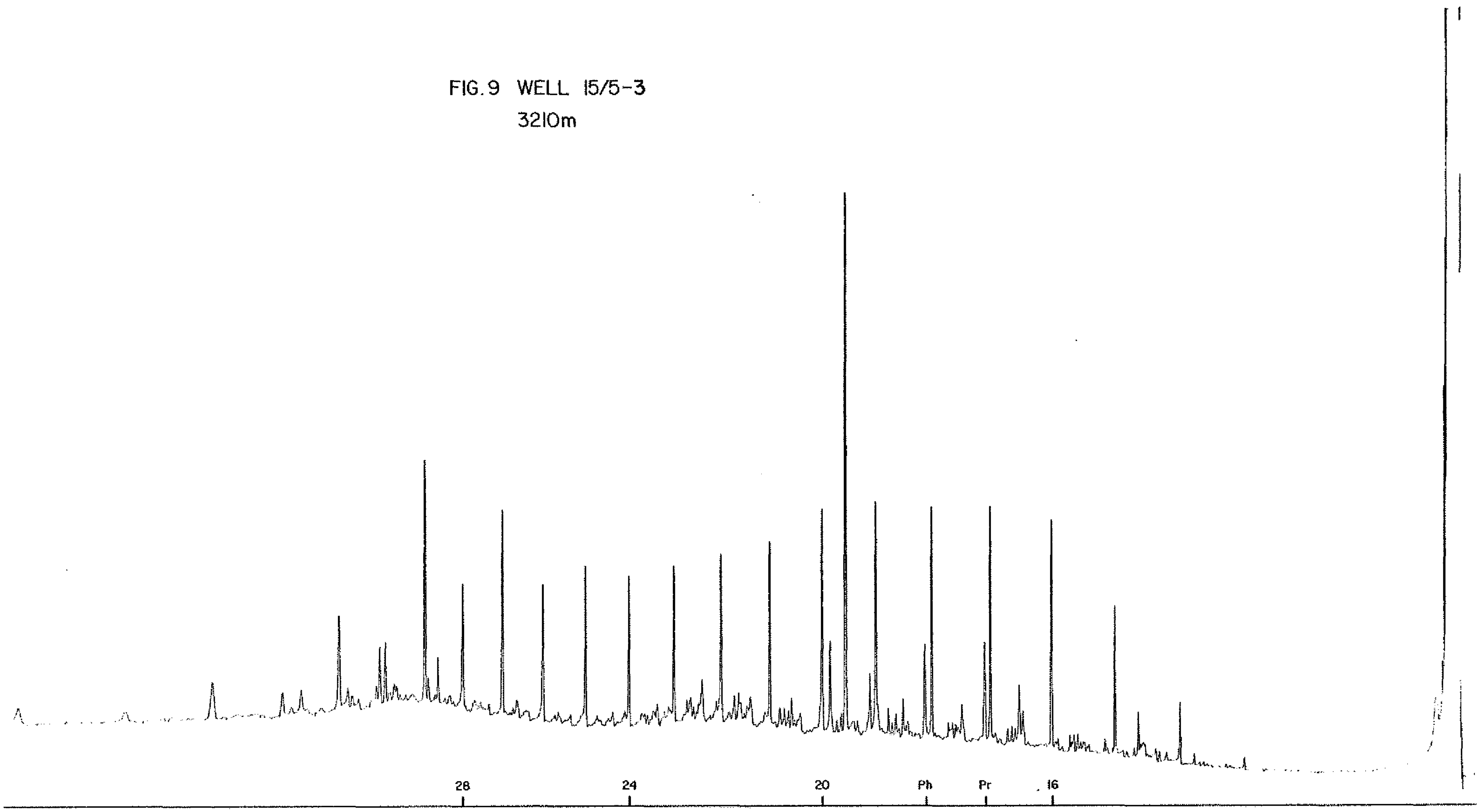


FIG.10 WELL 15/5-3
3330m

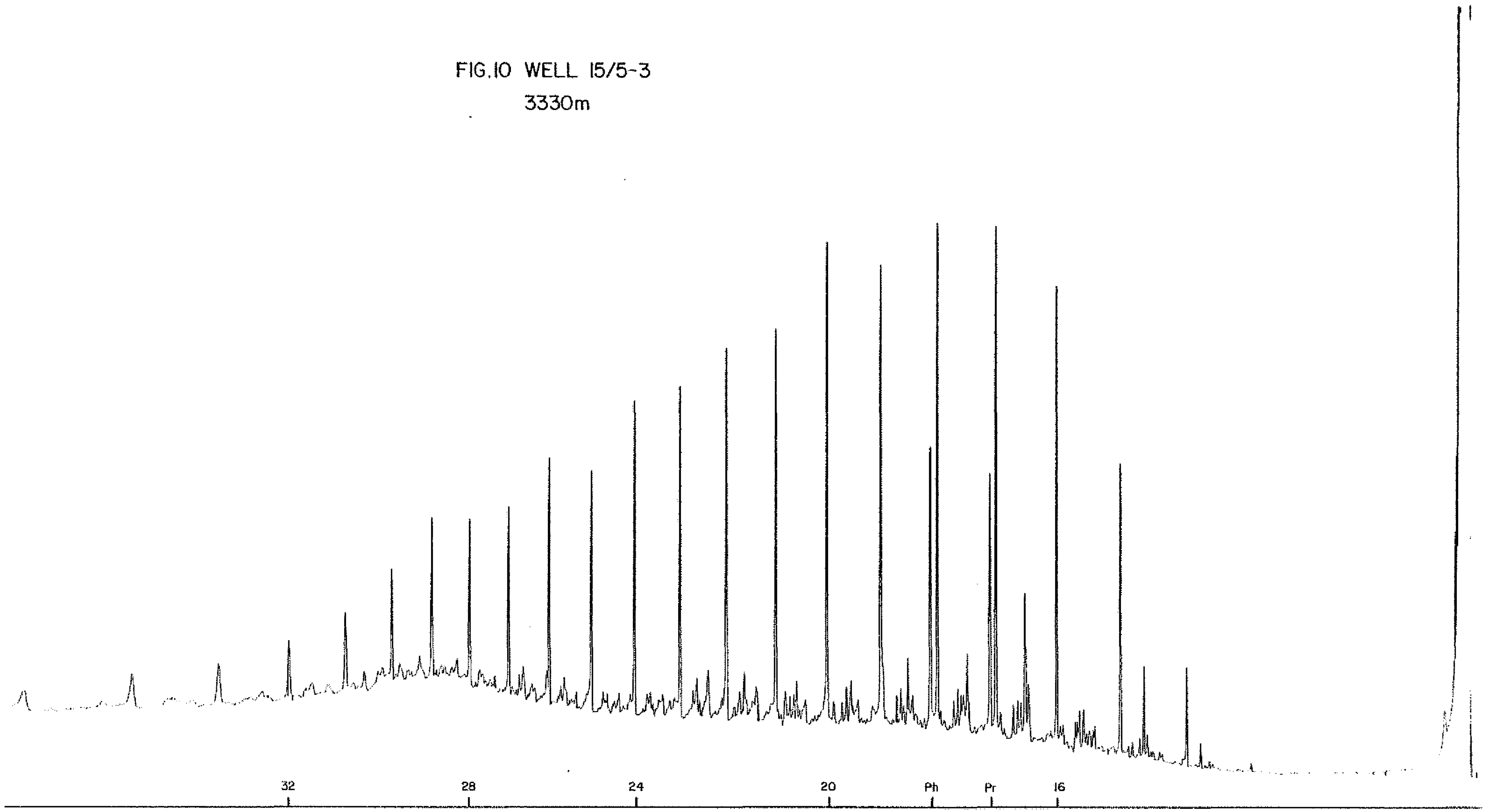


FIG. 11 WELL 15/5-3
3555m

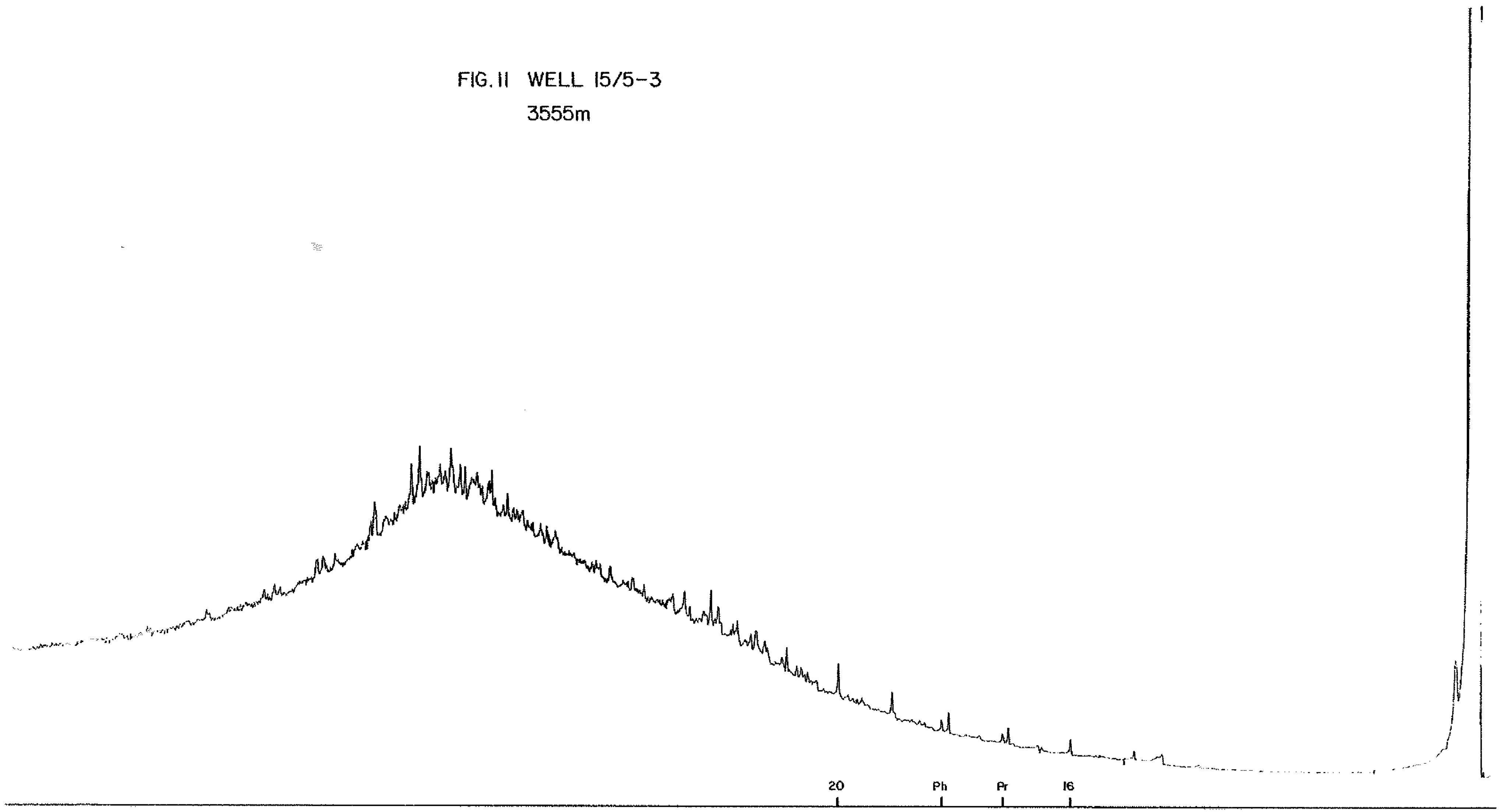


FIG. 12 WELL 15/5-3
3570m

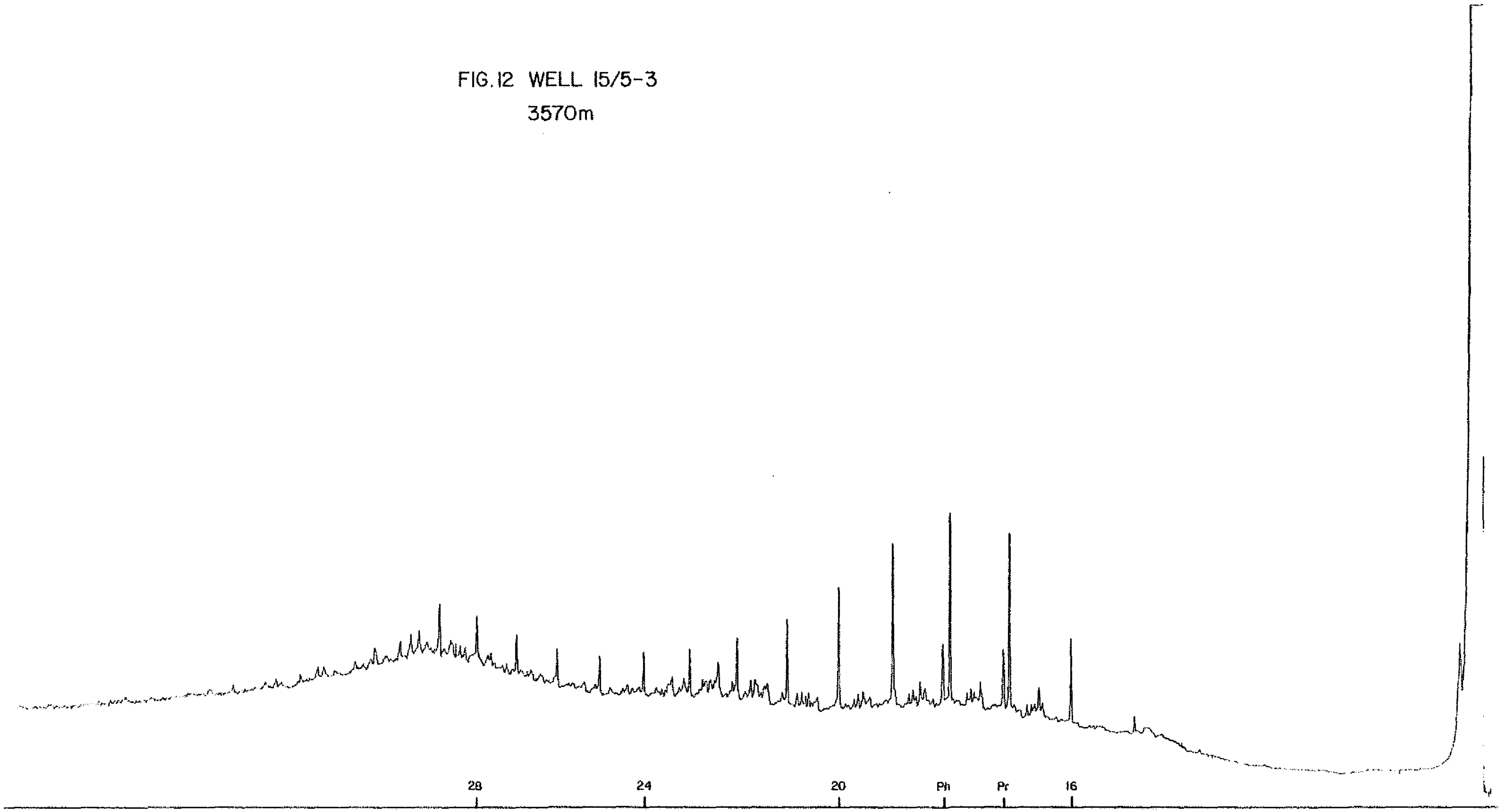


FIG. 13 WELL 15/5-3
3600m

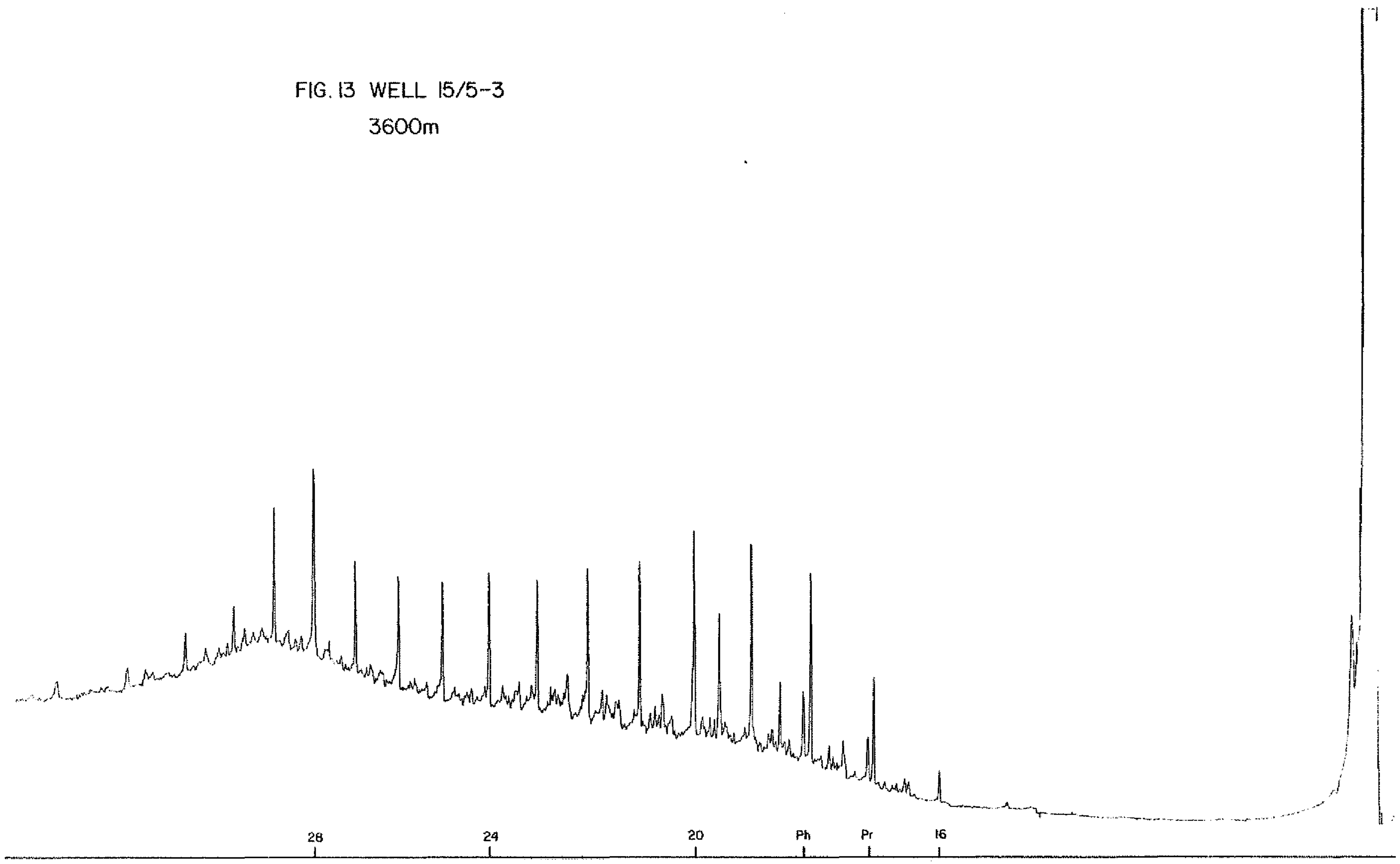


FIG. 14A WELL 15/5-3
3660m

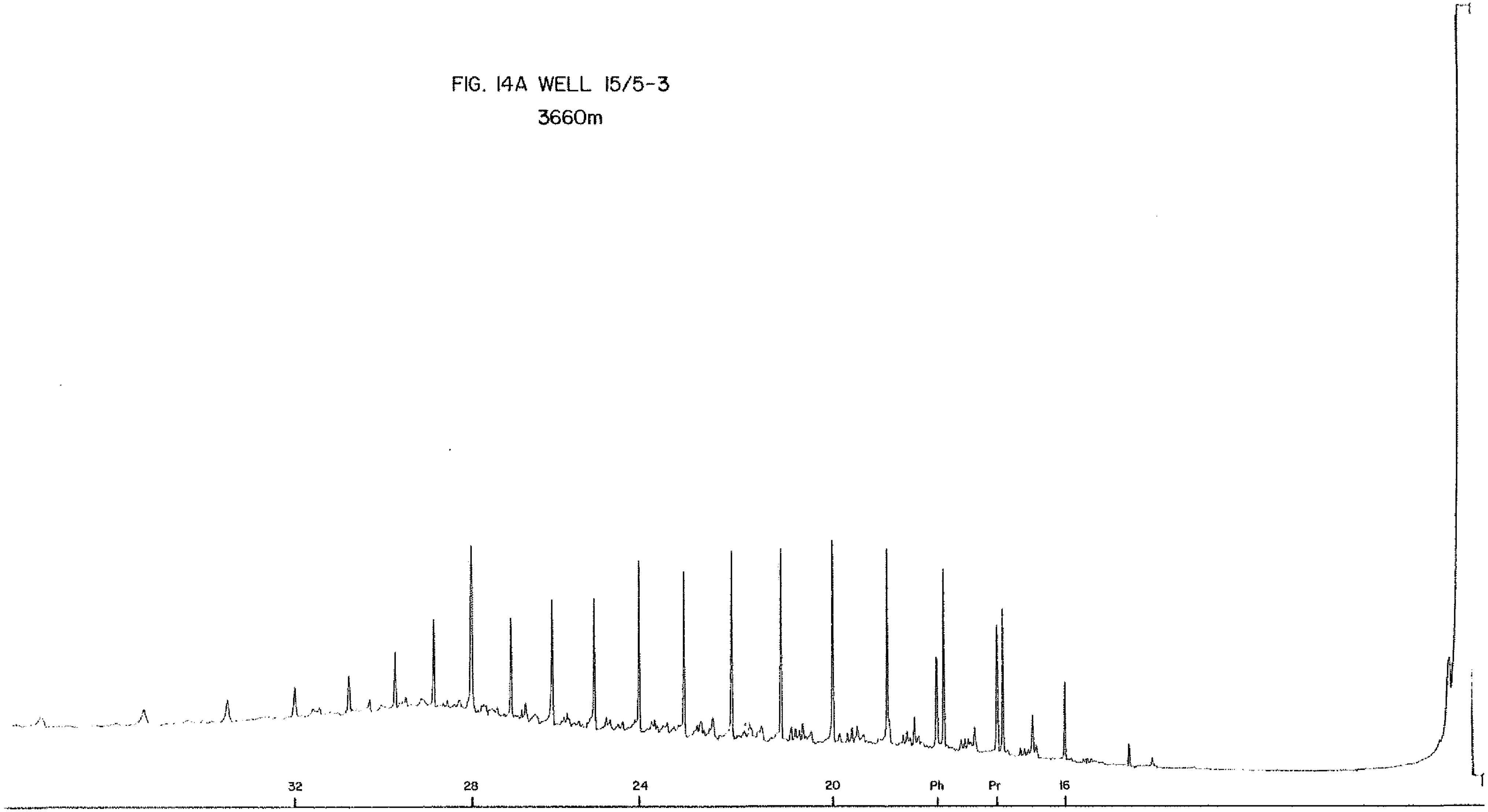


FIG. 14B WELL 15/5-3

3660m

Repeat

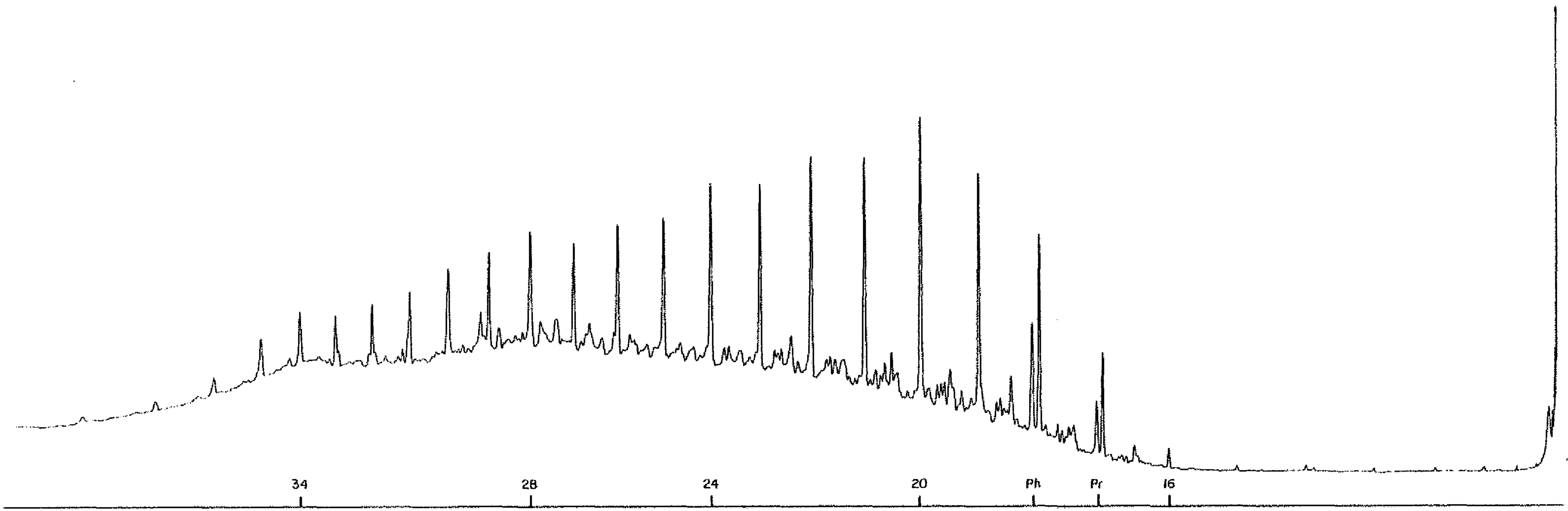


FIG. 15 WELL 15/5-3
3675m

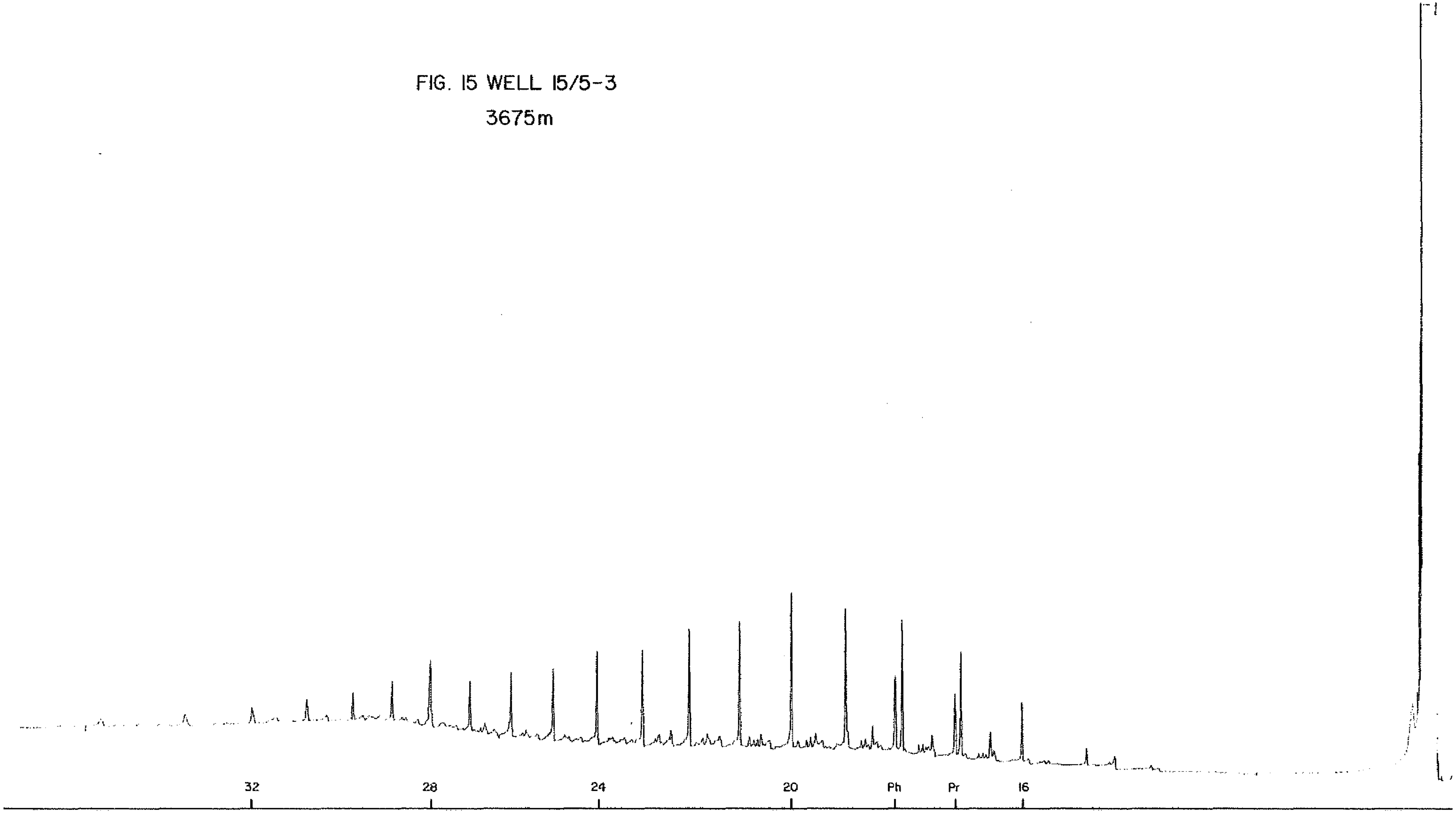


FIG. 16A WELL 15/5-3

3690m

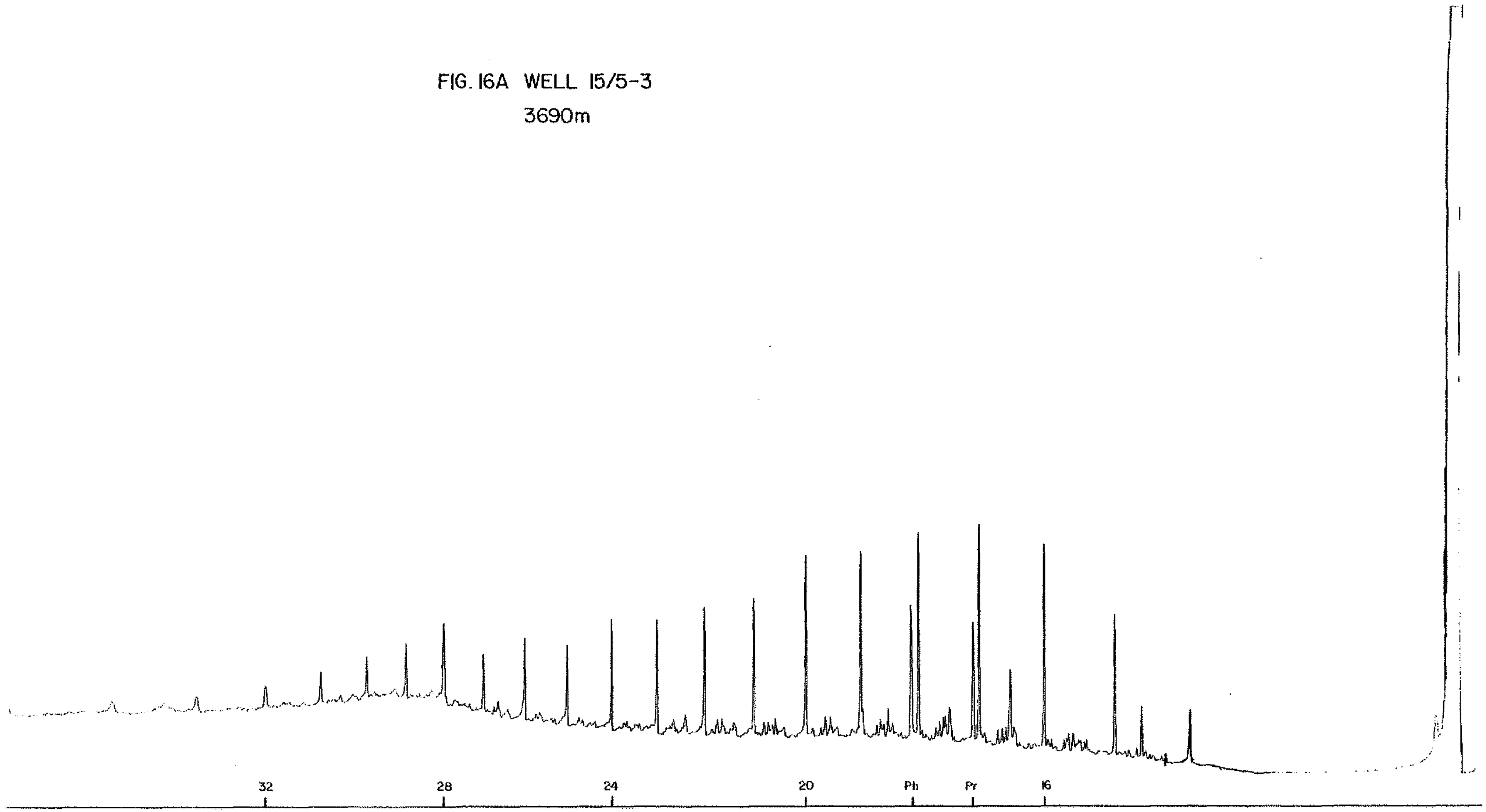


FIG. 16B WELL 15/5-3
3690m - 3705m

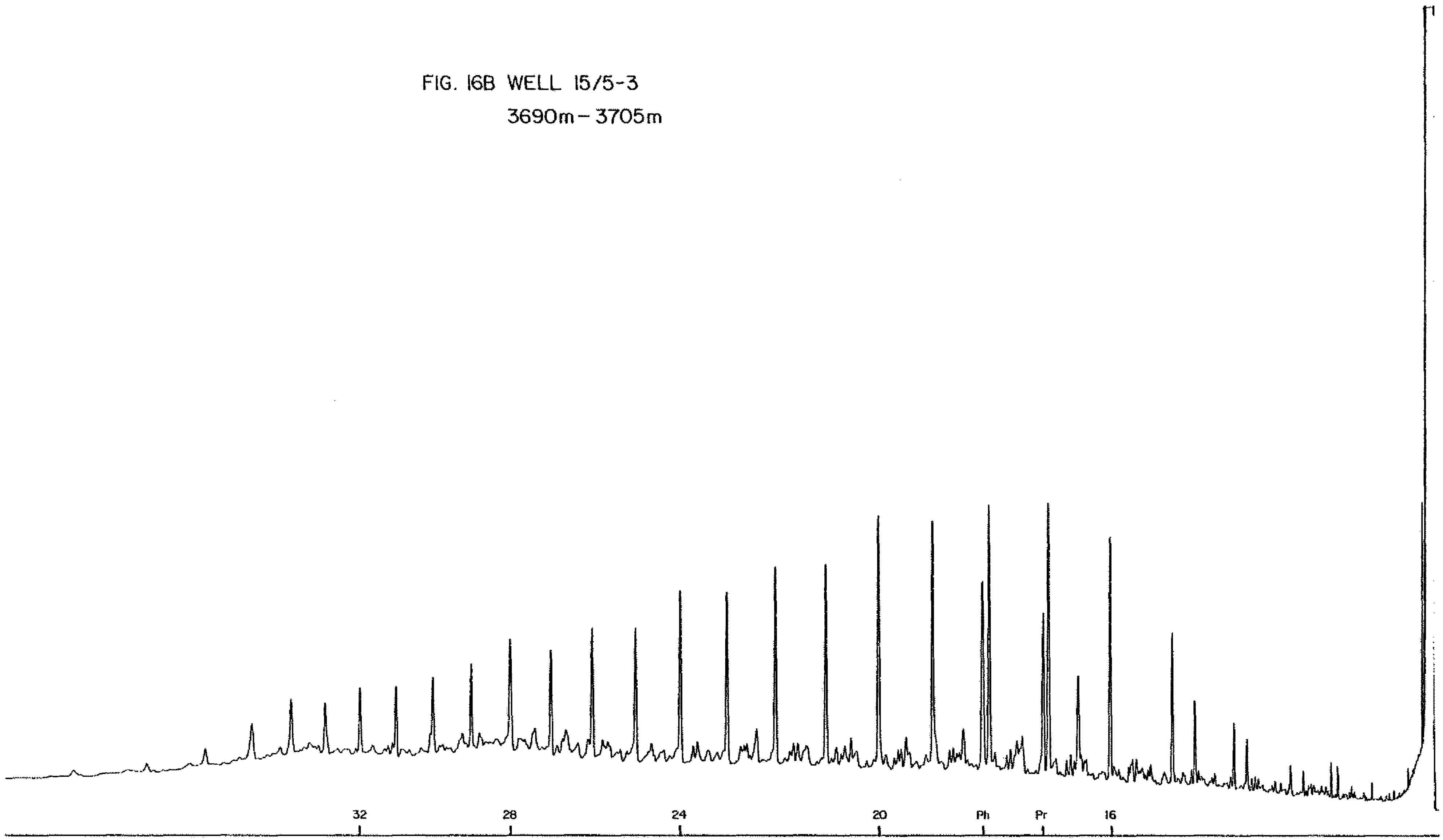


FIG. 17A WELL 15/5-3
3705m

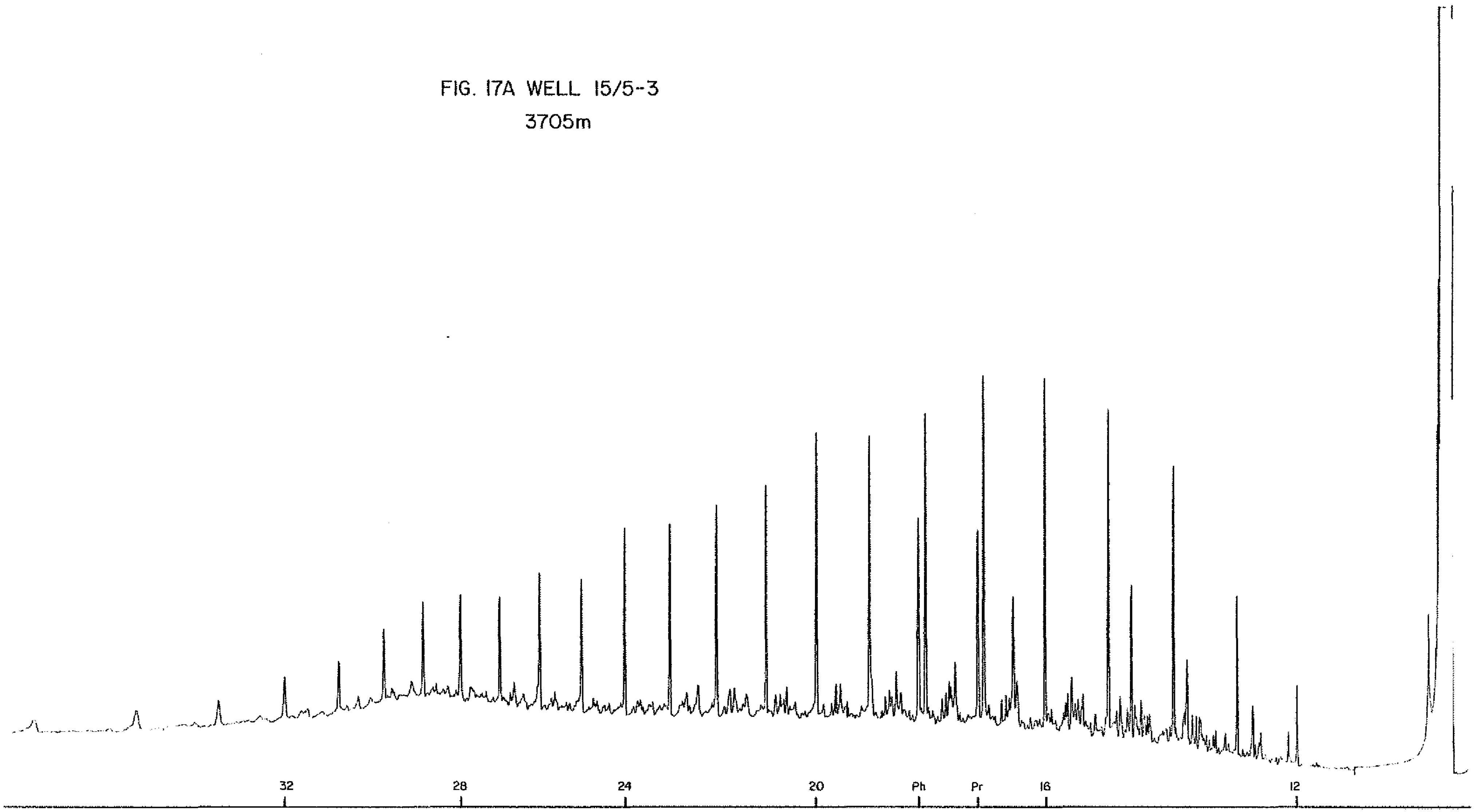


FIG. 17B WELL 15/5-3
3705m-3720m

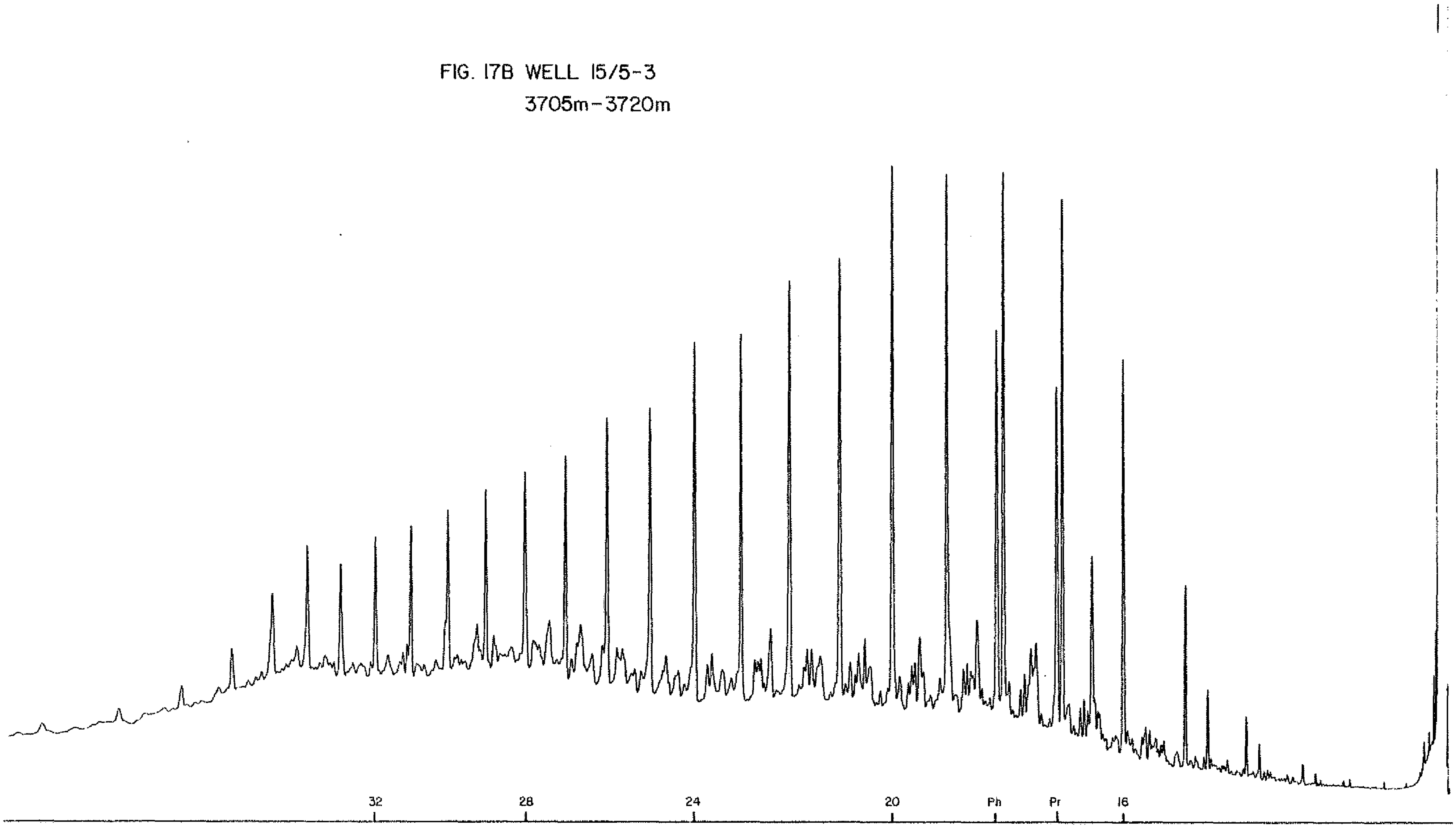


FIG. 18A WELL 15/5-3

3720m

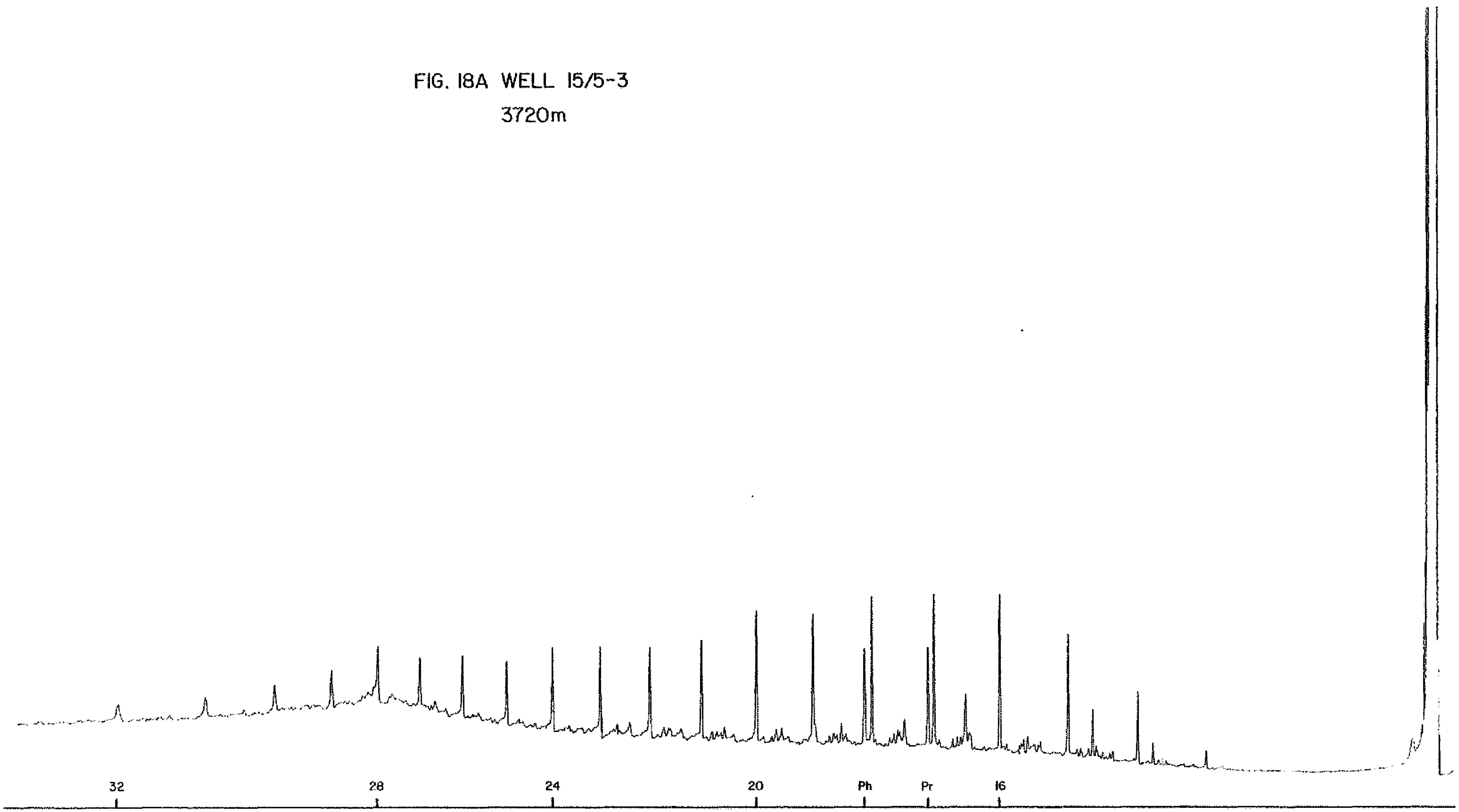


FIG. 18B WELL 15/5-3

3720m-3735m

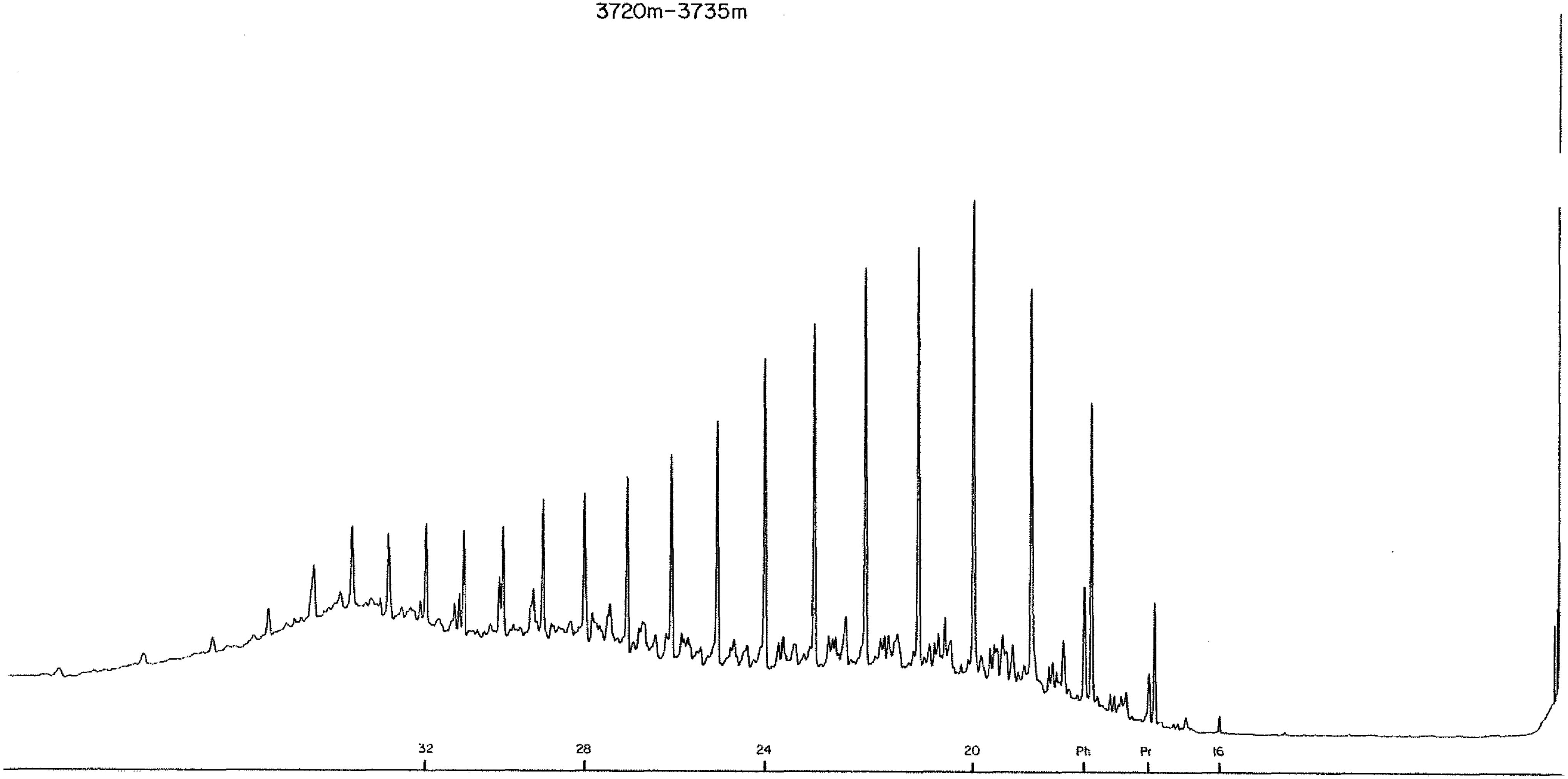


FIG. 19A WELL 15/5-3
3735m

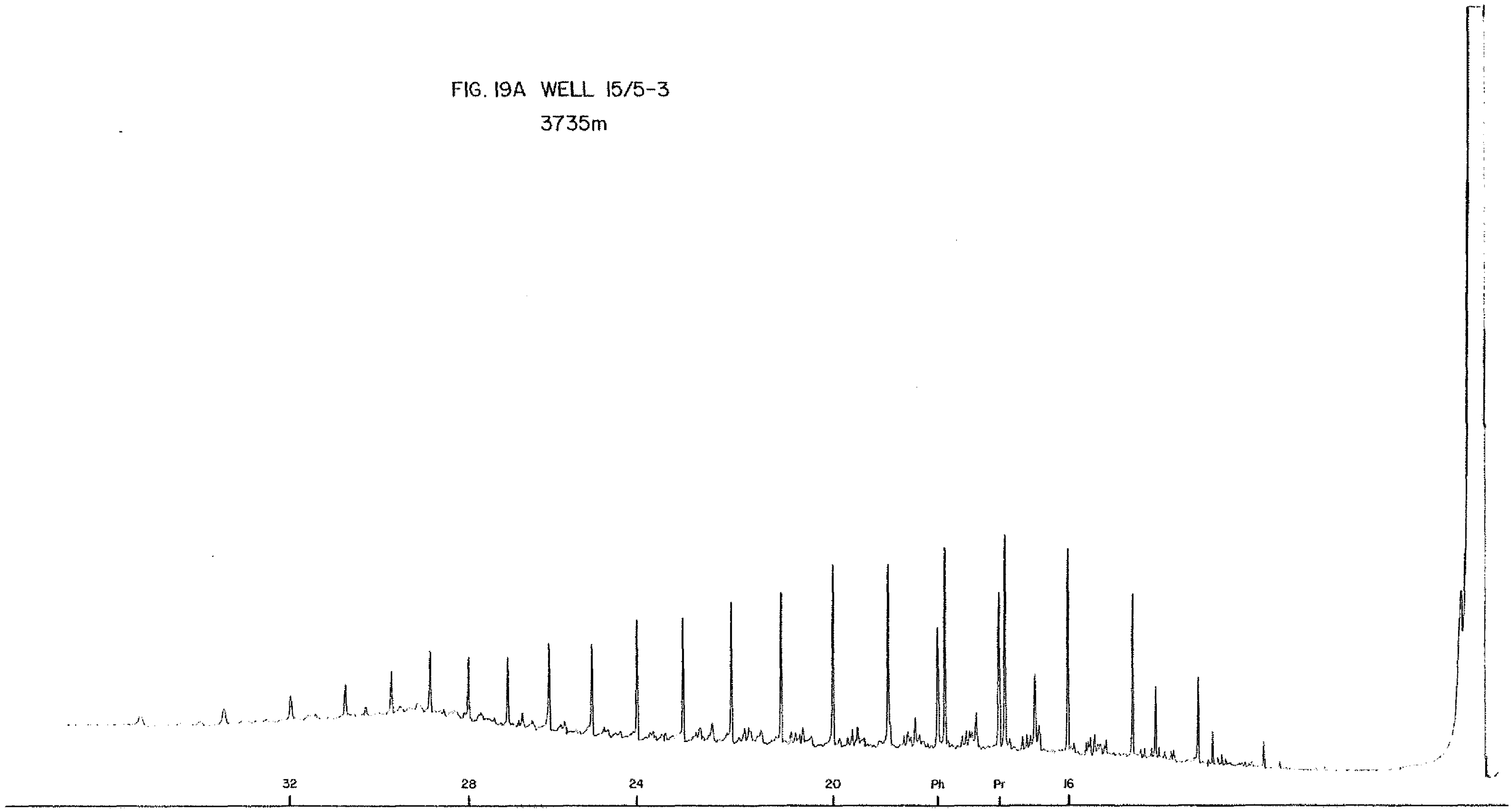


FIG. 19B WELL 15/5-3
3735m-3750m

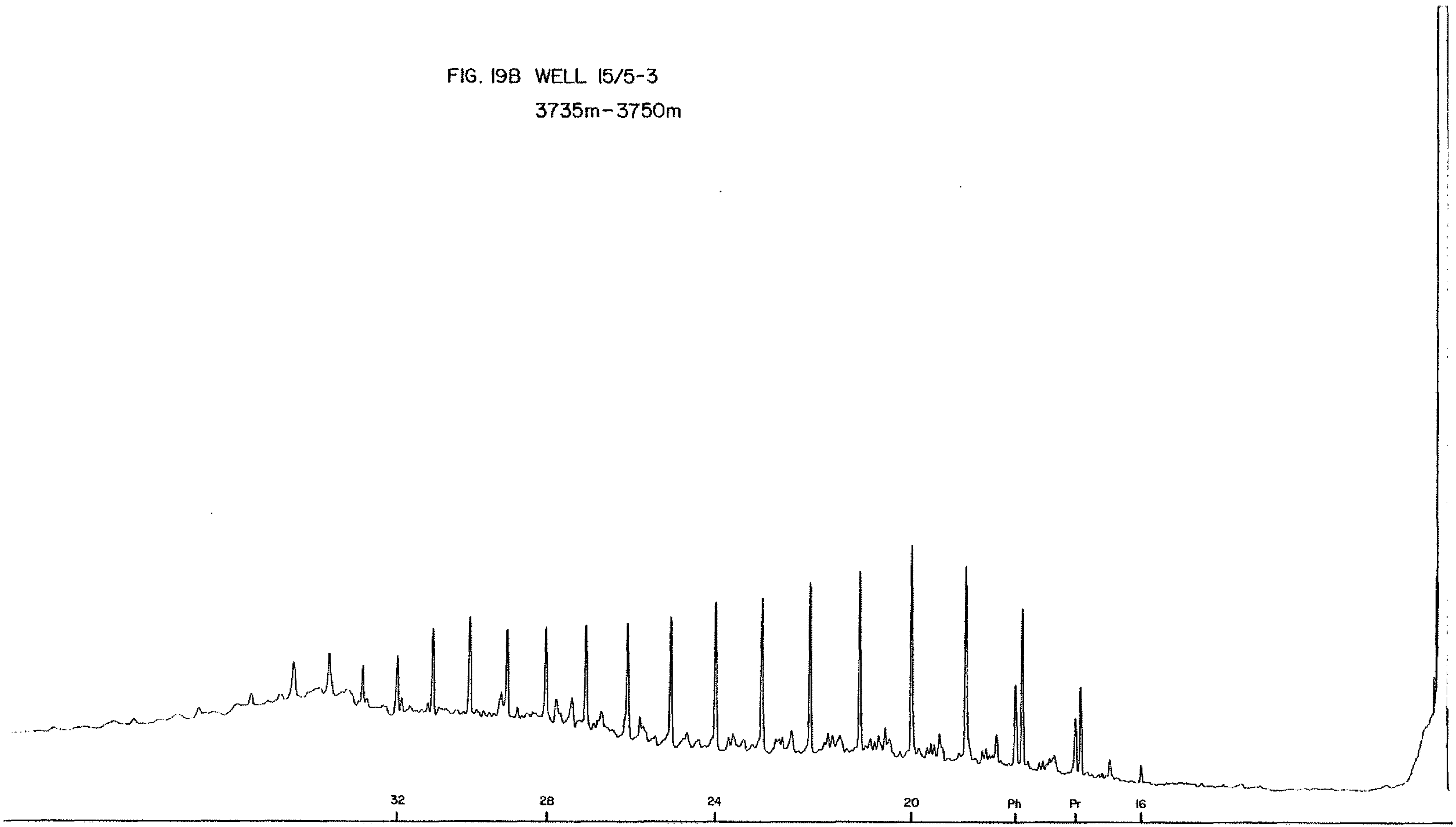


FIG. 20A WELL 15/5-3
3750m

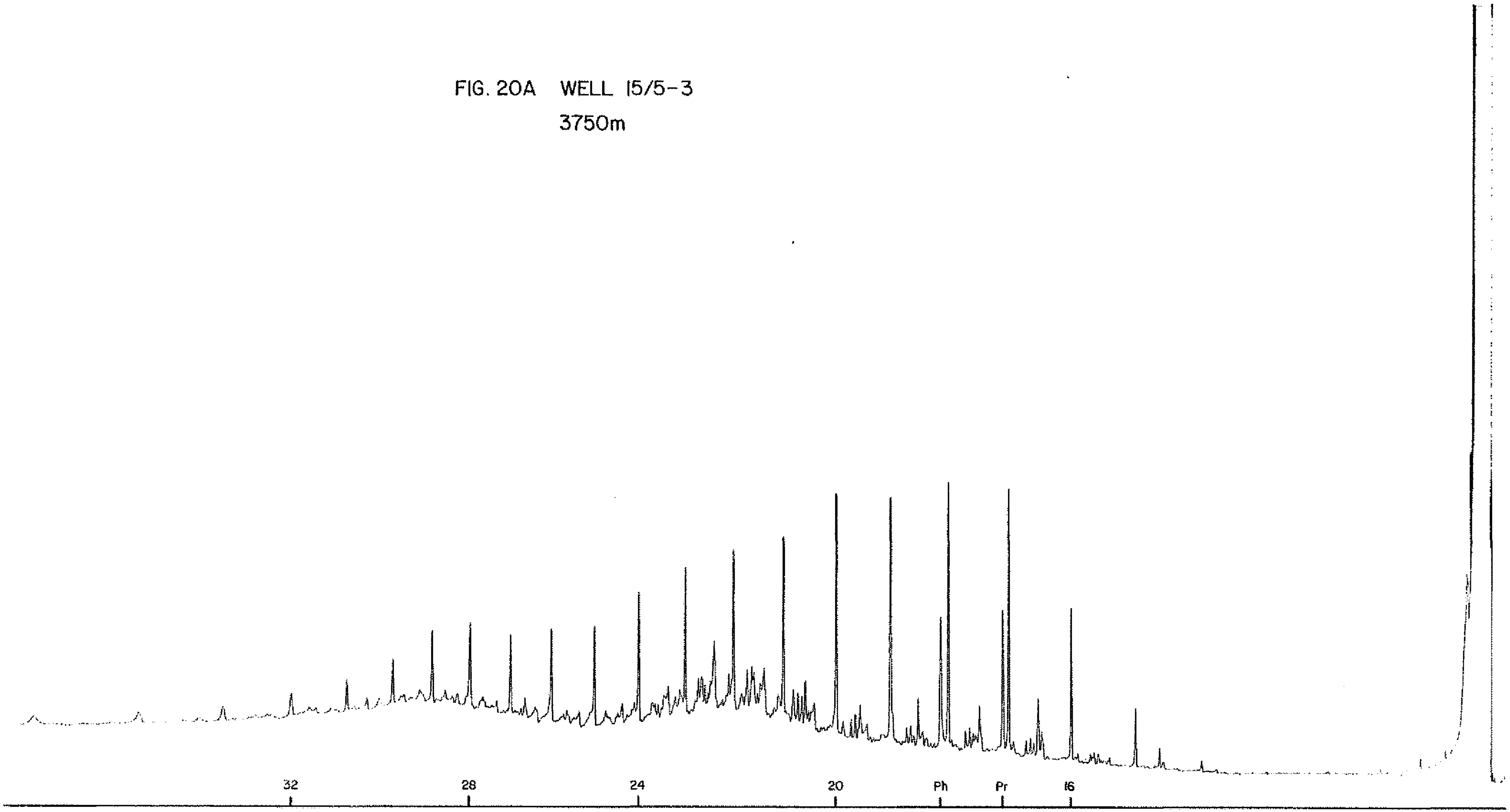


FIG. 20B WELL 15/5-3
3750m – 3765m

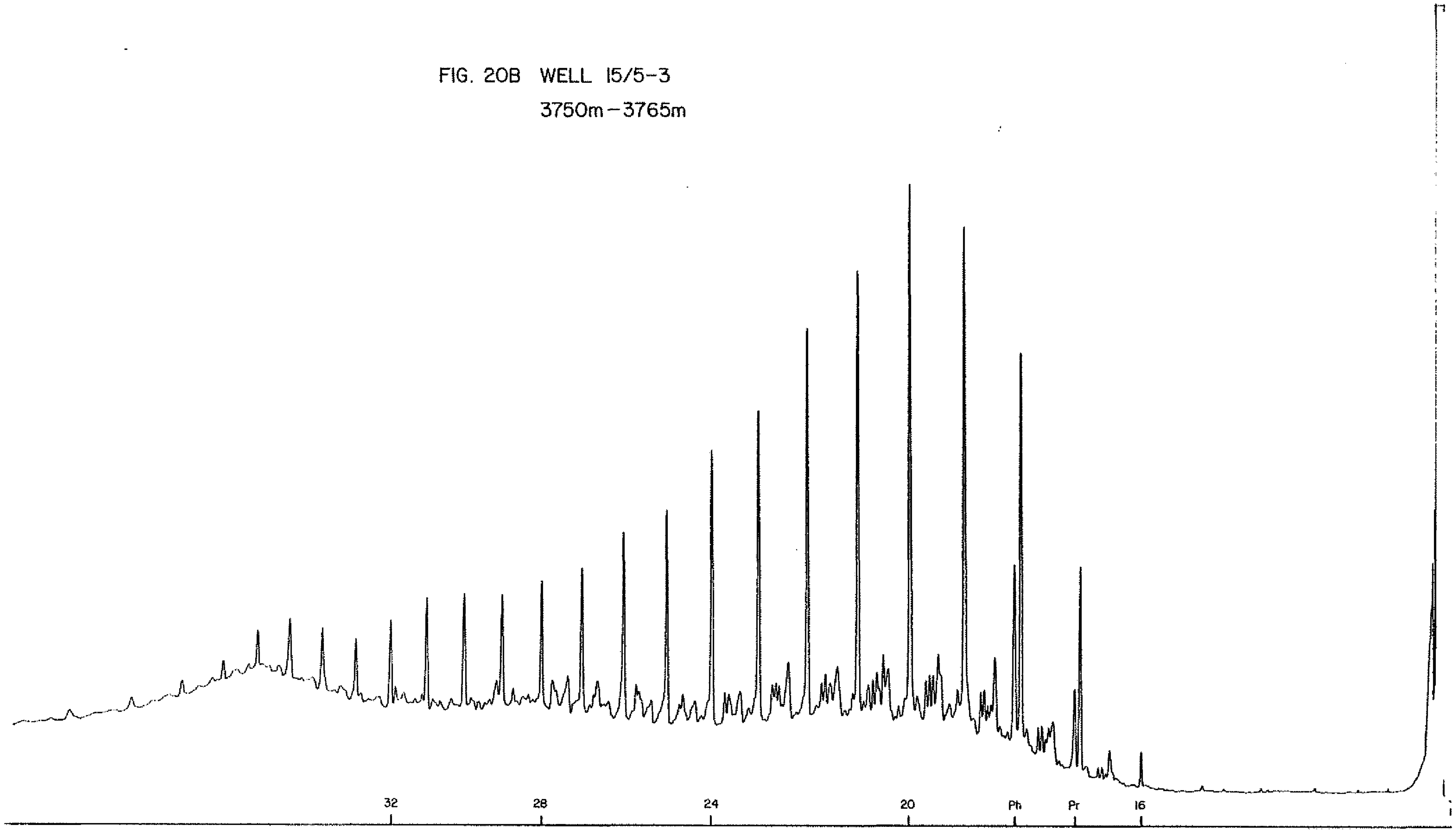


FIG. 21A WELL 15/5-3
3765m

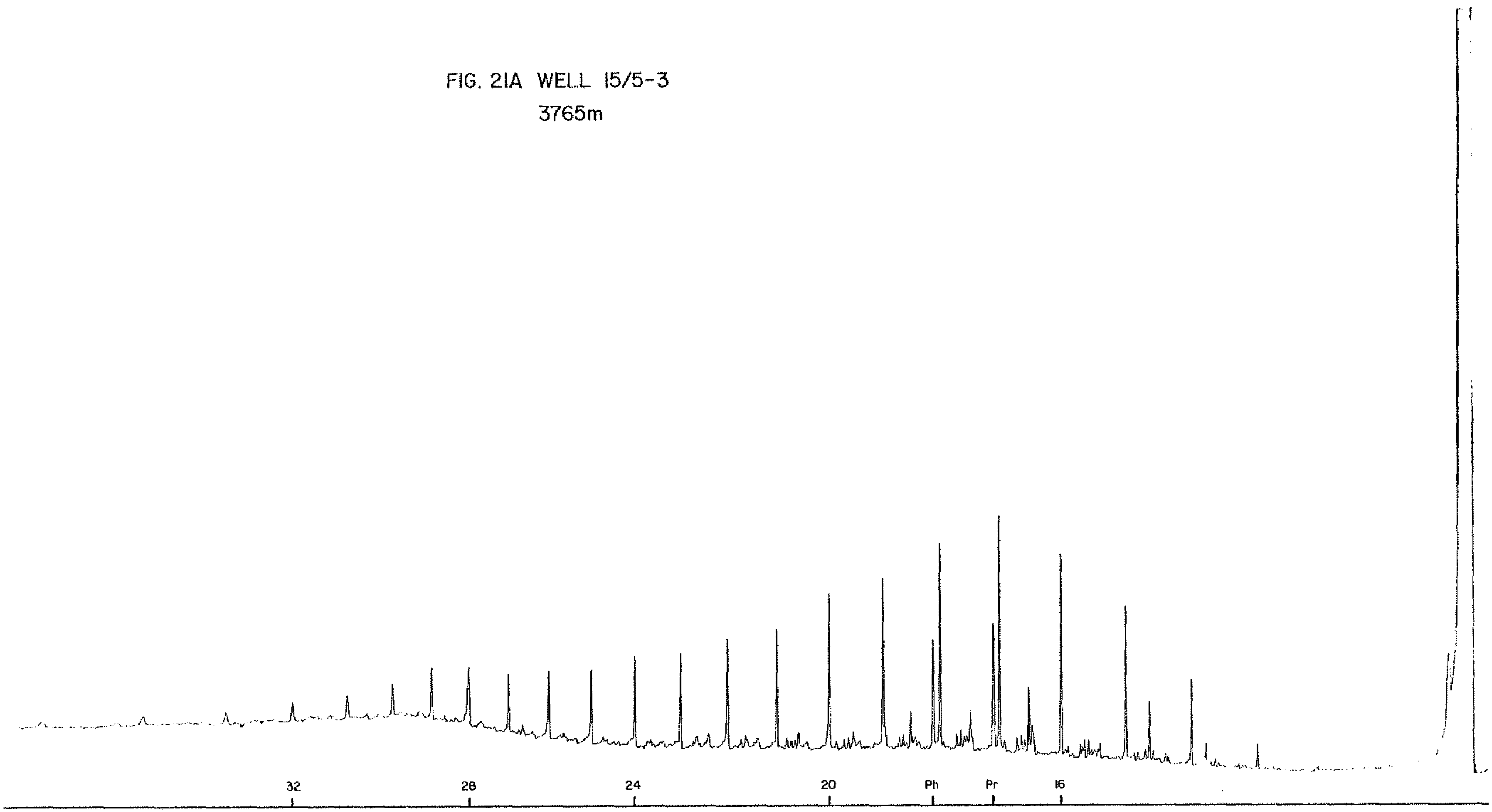


FIG. 21B WELL 15/5-3
3765m-3780m

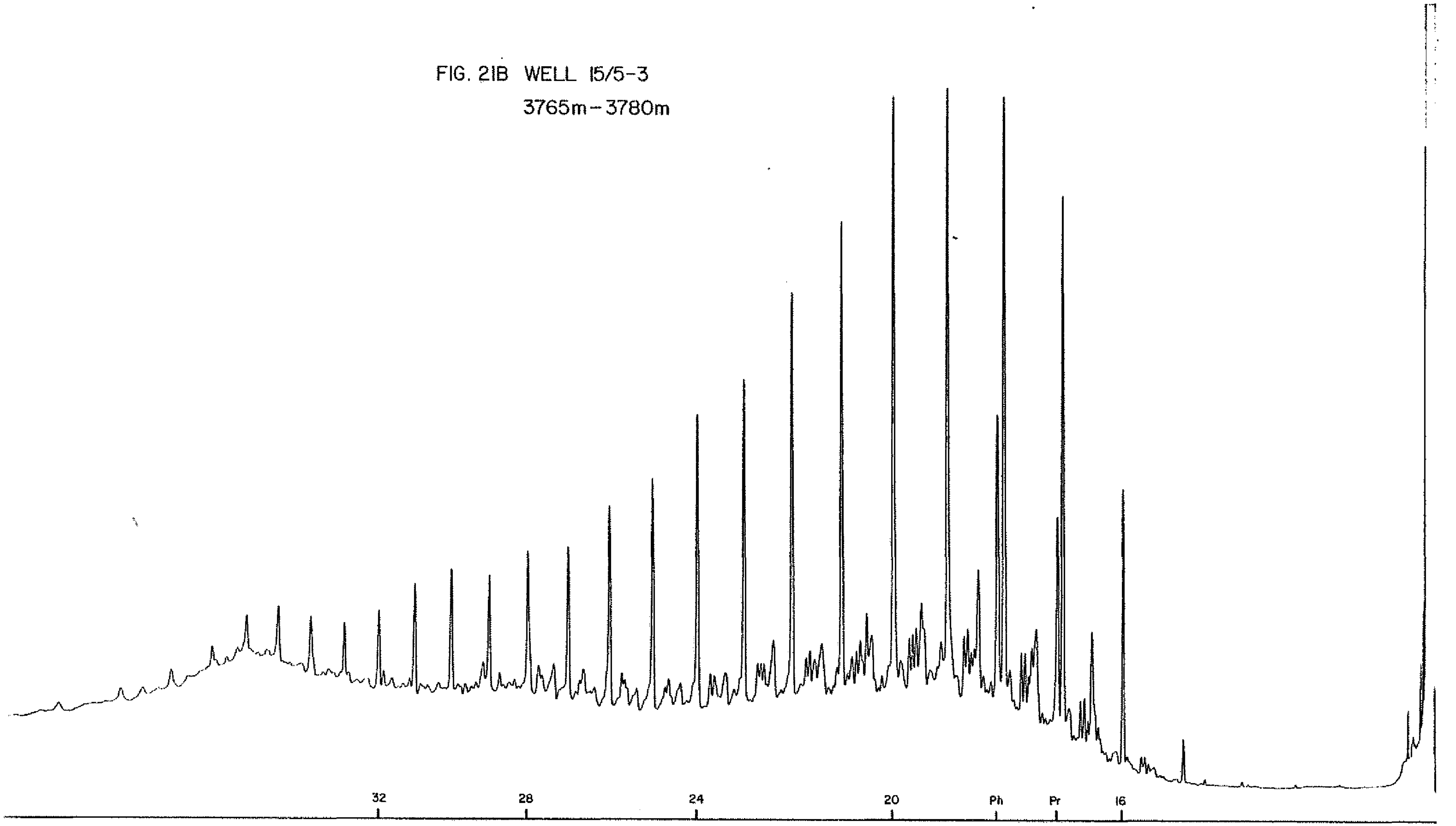


FIG. 22 WELL 15/5-3
3780m

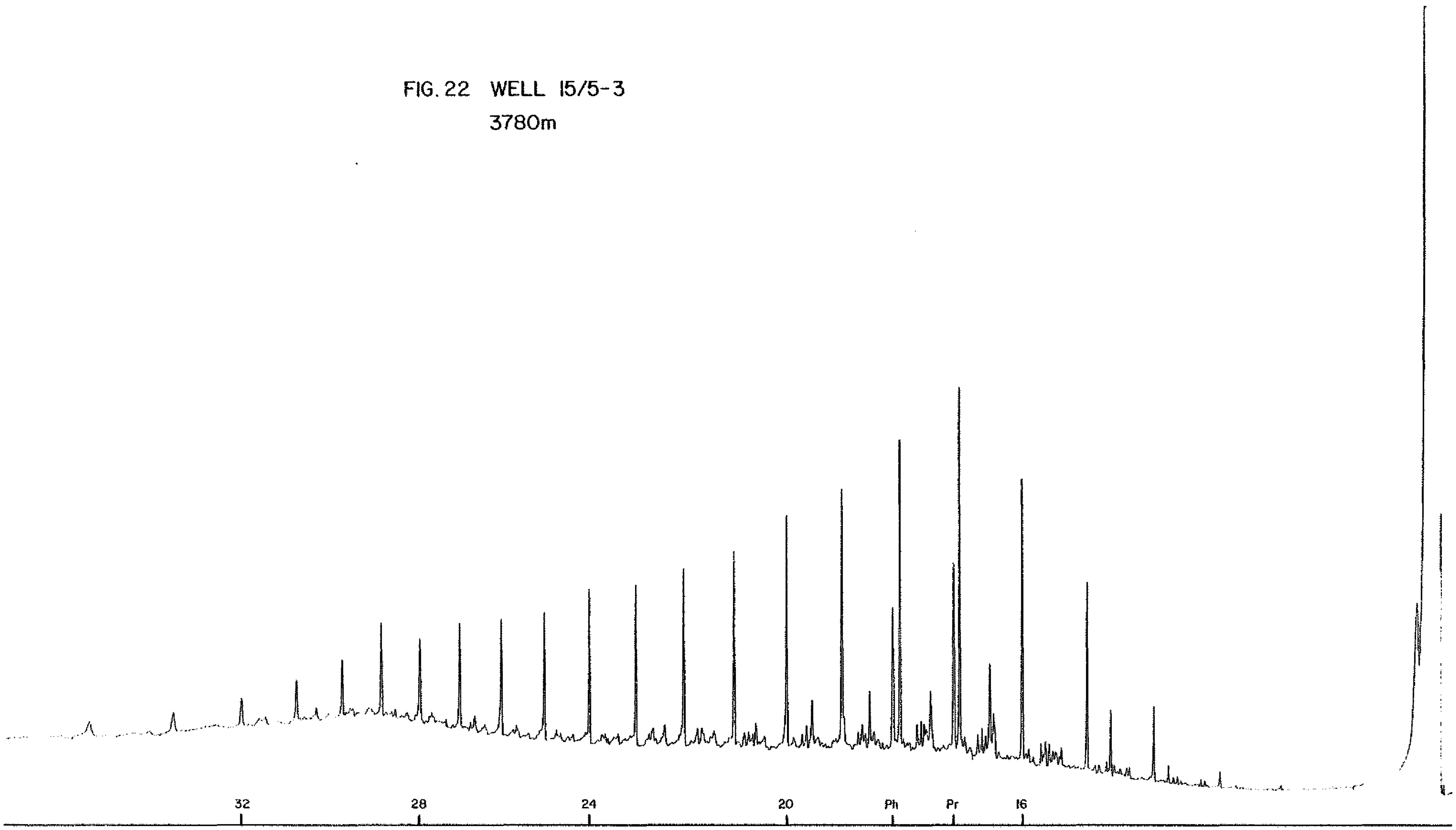


FIG. 23 WELL 15/5-3
3795m

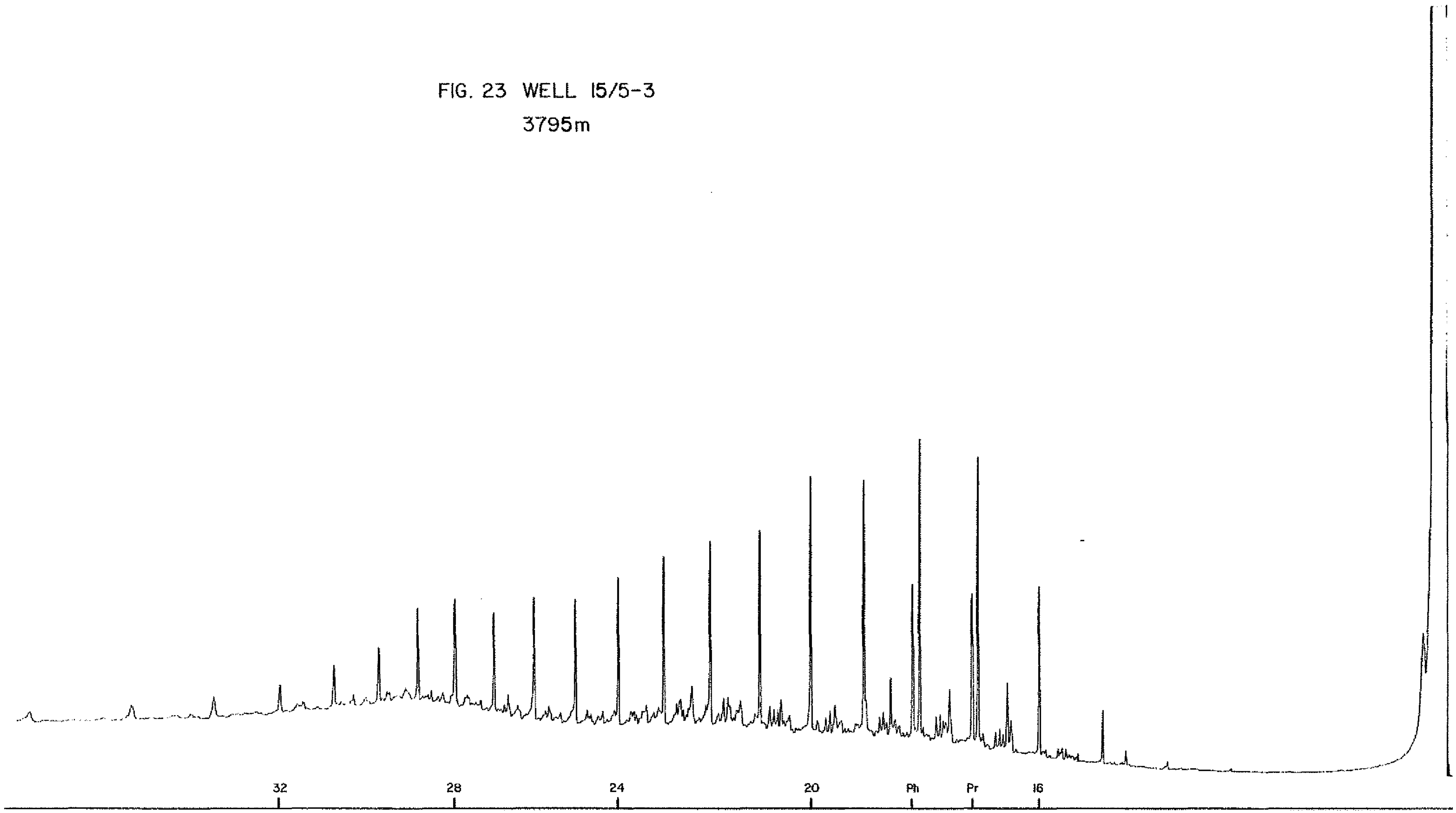


FIG. 24 WELL 15/5-3
3810m

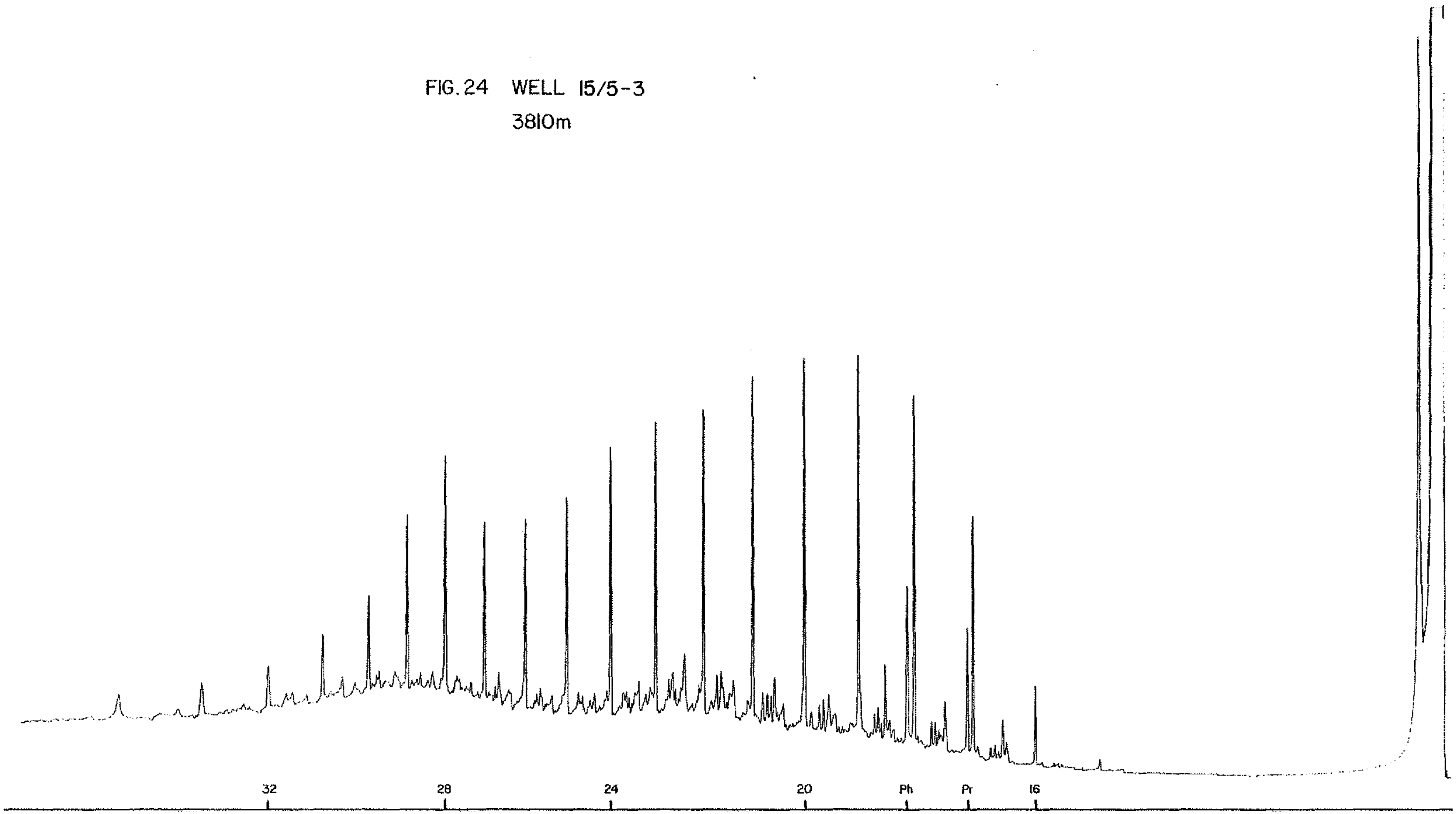
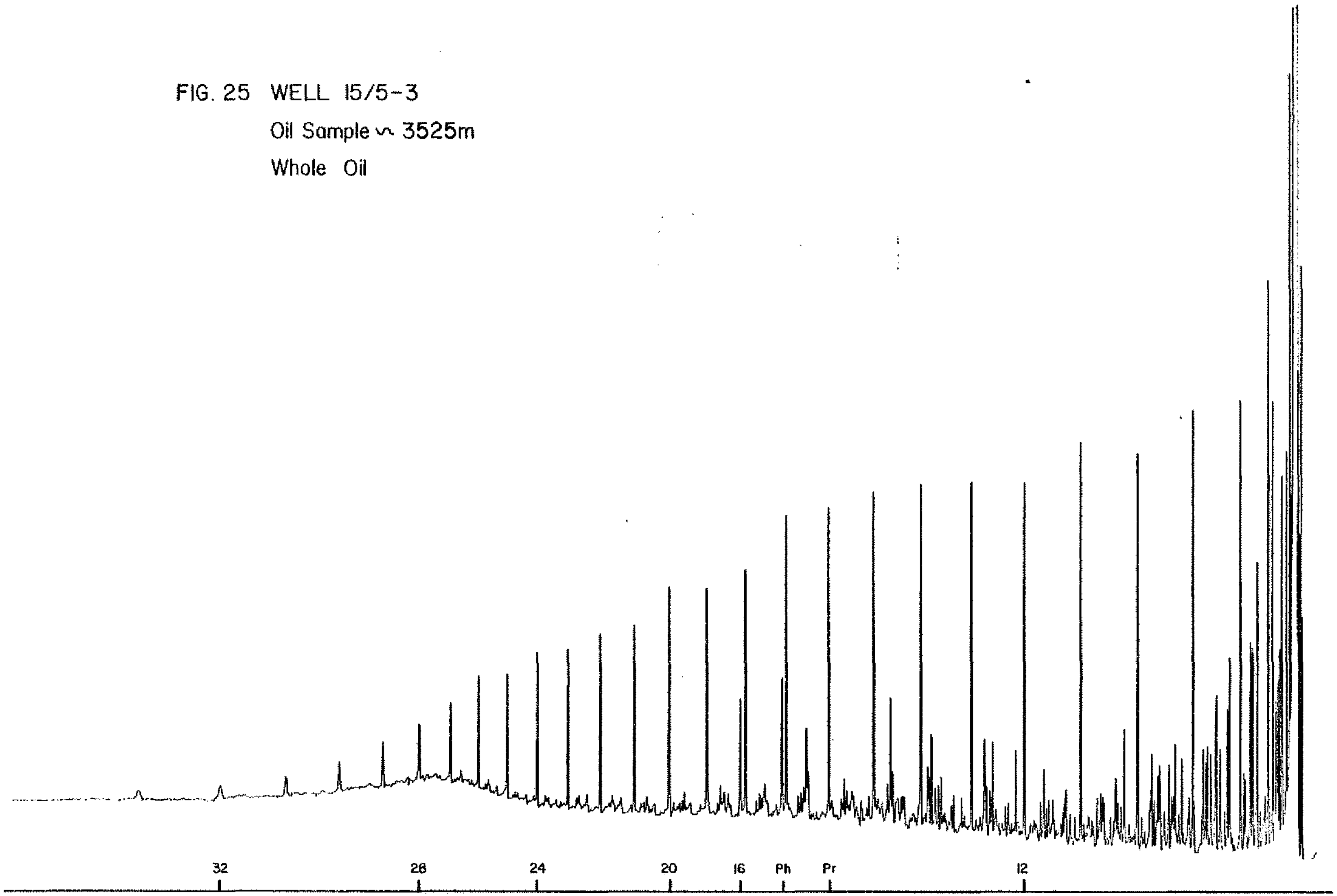


FIG. 25 WELL 15/5-3

Oil Sample ~ 3525m

Whole Oil



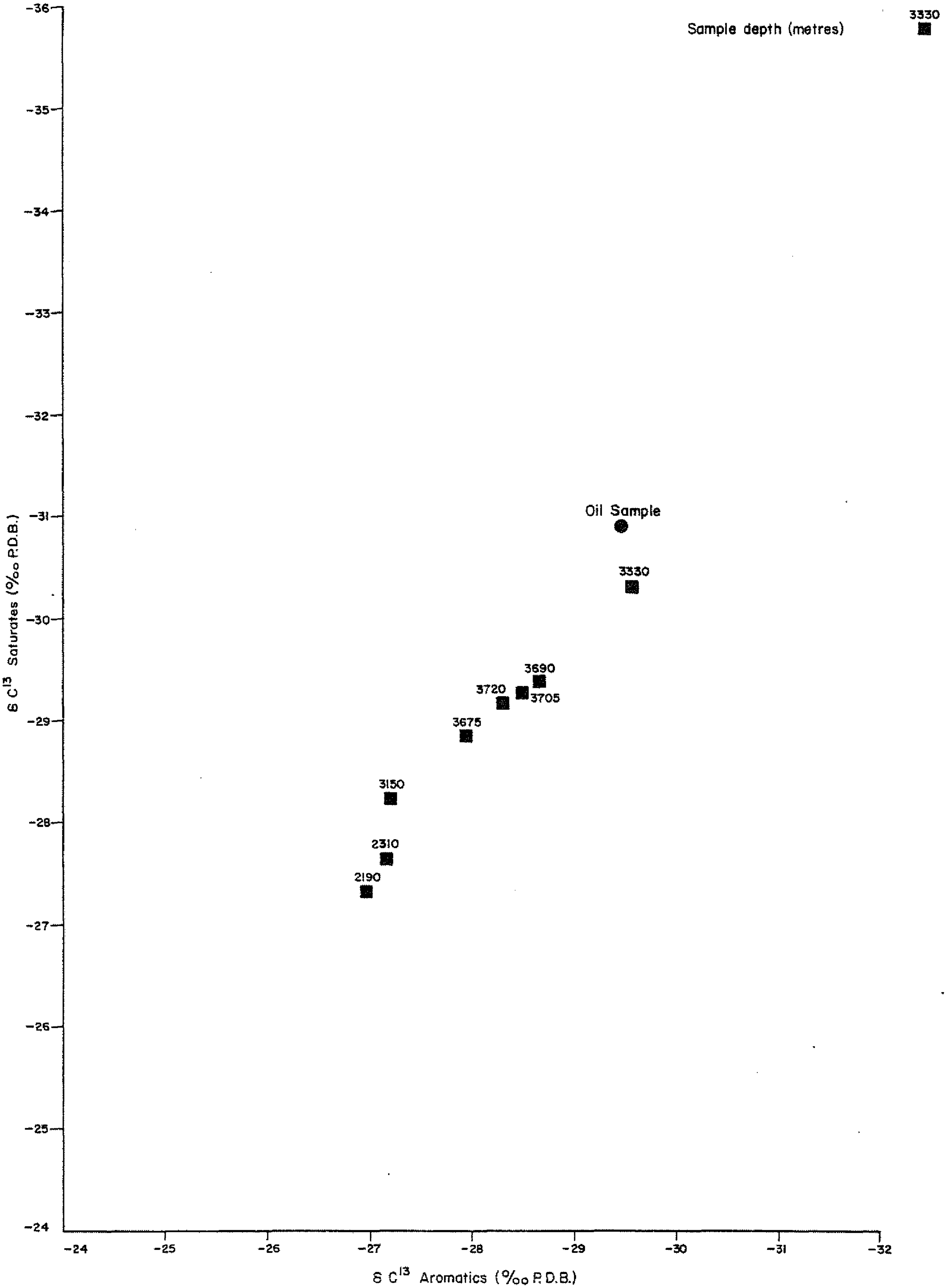



FIGURE 27 Carbon Isotope Data for Rock Extracts and Oil