

280001

SOURCE ROCK EVALUATION, KOORKAH-1
T-18-P, BASS BASIN *R17a/86*

Amoco Australia Petroleum Company

F3/786/0-F6416/86(Part5) July 1986

OR-288



The Australian
Mineral Development
Laboratories

1700 Kingston Street, Frewville,
South Australia 5063
Telephone Adelaide (08) 79 1662
Telex AA82520

Please address all
correspondence to
P.O. Box 114 Eastwood
SA 5063
In reply quote:

280002

amdel



24 July 1986

F 3/786/0
F 6416/86 - Part 5

Amoco Australia Petroleum Company
15 Blue Street
NORTH SYDNEY NSW 2060

Attention: C.W. Waring
K. Grant

REPORT F 6416/86 - Part 5

YOUR REFERENCE: LPO 1259

TITLE: Source rock evaluation, Koorkah-1,
T-18-P, Bass Basin

MATERIAL: Canned cuttings (84 samples). Sidewall
cores (11 samples).

LOCALITY: KOORKAH-1

IDENTIFICATION: As in Tables 1 and 3 of report

DATE RECEIVED: 8 April 1986

WORK REQUIRED: Headspace gas analysis (84 samples).
Total organic carbon (34 samples).
Rock-Eval pyrolysis (31 samples).
Solvent extraction and GC of total
extract/hydrocarbons (6 samples).
Isolation and pyrolysis-GC of kerogen
(7 samples). Interpretation.

Investigation and Report by: Dr David McKirdy

Manager-Petroleum Services Section: Dr Brian G. Steveson

for Dr William G. Spencer
General Manager
Applied Sciences Group

cap

Head Office:
1700 Kingston Street, Frewville
South Australia 5063
Telephone (08) 79 1662
Telex: Amdel AA82520
Pilot Plant:
Osman Place
Thebarton, S.A.
Telephone (08) 43 5733
Telex: Amdel AA82725
Branch Laboratories:
Melbourne, Vic.
Telephone (03) 645 3093
Perth, W.A.
Telephone (09) 325 7311
Telex: Amdel AA94893
Sydney, N.S.W.
Telephone (02) 439 7735
Telex: Amdel AA20053
Townsville
Queensland 4814
Telephone (077) 75 1377

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1. INTRODUCTION

A suite of canned cuttings (84 samples) and sidewall cores (11 samples) from Koorkah-1 was submitted for organic geochemical analysis.

The aims of the investigation were twofold:

- (1) to assess the hydrocarbon source potential of the Eastern View Coal Measures in Koorkah-1; and
- (2) to evaluate the possible presence of migrated hydrocarbons or residual oil in the well section between 1780 and 2730 metres depth.

A previous study of Koorkah-1 (Watson, 1986) provided vitrinite reflectance data and descriptions of the dispersed organic matter (DOM) in selected samples from the interval 1520-3126 metres depth.

Headspace gas, total organic carbon and Rock-Eval pyrolysis data on Koorkah-1 were facsimiled to S. Bane/G. Kjellgren on 15, 16, 18 April and 8 May 1986, and formally presented in an interim report (McKirdy, 1986). These geochemical data are collated and interpreted in the present report.

2. ANALYTICAL PROCEDURE

Details of the analytical methods are given in Appendix 1.

3. RESULTS

Analytical data are summarised and presented herein as follows:

| | <u>Table</u> | <u>Figure</u> | <u>Appendix</u> |
|--|--------------|---------------|-----------------|
| Headspace gas | 1,2 | 1-4 | - |
| Total organic carbon (TOC) | 3-5 | - | - |
| Rock-Eval pyrolysis | 4,5 | 5-7 | - |
| C ₁₅₊ extract (EOM, total hydrocarbons) | 6 | 8-13 | - |
| Kerogen pyrolysis-GC | 7 | 14-20 | - |
| Vitrinite reflectance | - | - | 2 |

4. DISCUSSION

4.1 Maturity

The vitrinite reflectance versus depth profile for Koorkah-1 (Appendix 2) indicates that the Eocene section above 2000 metres depth is thermally immature (VR < 0.5%). Liquid hydrocarbon generation from sediments of such low rank can be expected only where the DOM is rich in resinite (Snowdon and Powell, 1982; Powell, 1985). This is not the case in Koorkah-1 (Watson, 1986).

Apart from a localised zone of elevated rank immediately adjacent to the dolerite sill (2095-2129 metres depth), Eocene, Paleocene and Cretaceous sediments within the interval 2000-2950 metres depth are marginally mature (VR = 0.5-0.7%). The rank threshold for significant gas generation from terrestrial (woody-herbaceous) organic matter (VR = 0.6%: Monnier *et al.*, 1983) occurs at 2730 metres depth in the Cretaceous sequence.

Oil generation from resinite-poor terrestrial organic matter commences at VR = 0.7% (Powell, 1985). Thus, the top of the oil window in Koorkah-1 is located at approximately 2950 metres depth, in the Cretaceous section of the Eastern View Coal Measures.

Rock-Eval Tmax values are in good agreement with measured vitrinite reflectance (Figs. 5-7).

Rock-Eval production index, another maturity-dependent parameter, displays a less well defined trend of increasing values with depth in Koorkah-1 (Tables 4 and 5). Values increase from PI = 0.07 at the top of the Eastern View Coal Measures to PI = 0.21 at the base. The anomalously high production indices (PI = 0.31-0.50), and related very low S₂, PC and HI values, of cuttings samples from immediately above the sill are the result of local heating caused by its intrusion into the basal part of the Eocene sequence. Other positive excursions in the production index *versus* depth profile for Koorkah-1 (Table 6) were investigated (section 4.4) to see if they represented zones of migrated hydrocarbons.

Headspace gas data also have the potential to delineate maturation trends (see e.g. Alexander *et al.*, 1983; Monnier *et al.*, 1983). In the Koorkah-1 well section, a clearly defined maximum in the total gas (C₁-C₄) profile (Fig. 1) coincides with the dolerite sill. The *i*-C₄/*n*-C₄ profile (Fig. 3) is as would be expected for the maturity range documented by VR data (cf. Alexander *et al.*, 1983, fig. 1). This isomeric ratio decreases to less than unity at the anticipated onset of significant gas generation (VR = 0.6%, 2750 metres depth).

Percent wet gas (Fig. 2) and *i*-C₅/*n*-C₅ (Fig. 4) display no obvious relationship with increasing depth and/or maturity. In samples with significant gas yields (C₁-C₄ > 10000 ppm), wet gas values greater than 50% occur *above* 2750 metres depth (Fig. 2B). This may indicate extensive upward migration of C₂-C₄ hydrocarbons from within the underlying gas generation window.

4.2 Source Richness

Cuttings gas (C₁-C₄) yields below 1600 metres depth in Koorkah-1 are mostly *fair* (1000-10000 ppm), although intervals with *good to very good* gas richness (10000-100000+ ppm) are reasonably common throughout the Eastern View Coal Measures (Fig. 1). Wet gas (C₅+) yields, however, are uniformly poor (<1000 ppm) throughout (Table 2).

Total organic values (Tables 3-5) decrease with increasing depth in the Eastern View Coal Measures, thus:

| | TOC | | n |
|------------|------------|--------|-----|
| | Range % | Mean % | |
| Eocene | 0.61-10.9 | 3.19 | 11* |
| Paleocene | 1.35- 2.16 | 1.83 | 4 |
| Cretaceous | 0.43- 6.45 | 1.35 | 17 |

*Excludes 2 samples which come from the same depth as the sill and therefore represent cavings.

Source richness is mostly *poor to fair* as indicated by potential hydrocarbon yields (oil and gas) in the range $S_1+S_2 = 0.3-5$ kg/tonne (Tables 4 and 5). However, the following samples display *good to very good* source richness for petroleum hydrocarbons.

| Age | Depth m | $S_1 + S_2$ mg h'c/g | PC % | TOC % |
|------------|------------|-------------------------|---------|----------|
| Eocene | 1780-89 | 36.5 | 3.04 | 10.9 |
| | 1924-33 | 24.7 | 2.05 | 4.85 |
| | 1978-87 | 13.3 | 1.10 | 5.45 |
| | 1996-05 | 7.2 | 0.59 | 3.40 |
| Paleocene | 2284-93 | 7.5 | 0.62 | 2.10 |
| | 2392-01 | 6.9 | 0.57 | 2.16 |
| Cretaceous | 2728 | 15.1 | 1.25 | 6.45 |

4.3 Source Quality and Kerogen Type

Hydrogen index values (HI = 60-450 mg S_2 /g TOC; Tables 4 and 5) suggest the presence of organic matter which ranges in composition from oil and gas-prone Type II-III kerogen to gas-prone Type III kerogen (Figs. 5-7). The best quality organic matter (albeit immature) occurs in the Eocene and Paleocene sections of the Eastern View Coal Measures. Samples with hydrogen index values greater than HI = 200 are considered to have significant liquid hydrocarbon source potential.

Very low hydrogen index values (HI < 50) characterise thermally altered Eocene sediments immediately overlying the sill (Fig. 5). [Note: Tmax values in these samples are unreliable because of the small, ill-defined S_2 peaks in their Rock-Eval pyrograms].

Organic petrological examination of another suite of cuttings and sidewall core samples from Koorkah-1 (Watson, 1986) confirms the presence of woody-herbaceous DDM rich in inertinite and vitrinite. High vitrinite contents ($V = 50-70\%$ of DDM) are reasonably common in Eocene shales and siltstones, whereas the Paleocene and Cretaceous DDM tends to be predominantly inertinitic. Exinite contents are uniformly low throughout ($E = 5-10\%$ of DDM).

In order to more rigorously assess their liquids-generation potential, seven samples (4 Eocene, 2 Paleocene, 1 Cretaceous) were selected for kerogen isolation and pyrolysis-GC (PGC : Table 7). [Note: A contaminant compound of unknown origin coelutes with the C_{16} *n*-alkane peak in all but one of these PGC traces. The true concentration of $n-C_{16:0}$ in these pyrograms has been estimated from the adjacent C_{15} and C_{17} *n*-alkene/*n*-alkane pairs, and an appropriate correction made to the relevant parameters in Table 7 (viz. $\% C_{11+}$, C_1-C_4/C_{5+}). Fortunately, this contamination does not obscure the overall character of the kerogen pyrolysate].

Inspection of the PGC traces (Figs. 14-20) reveals kerogen pyrolysates of remarkably similar composition, notwithstanding the range of hydrogen index values represented ($HI = 196-444$). The Cretaceous kerogen (2728 metres depth) is obviously gas-prone (Fig. 20), being the most aromatic (toluene/ $n-C_{7:1} = 3.8$; *m* + *p*-xylene/ $n-C_{8:1} = 2.5$) and having the highest "gas/oil ratio" ($C_1-C_4/C_{5+} = 1.58$) (Table 7). Samples from 1924-33 metres (Eocene) and 2284-93 metres (Paleocene) have the lowest "gas/oil ratios" ($C_1-C_4/C_{5+} < 1$: Table 7) but even these kerogens are, at best, potential sources of only gas-condensate.

4.4 Residual Oil Analysis

Of the six samples selected for residual oil analysis (Table 6), only two gave EOM/total hydrocarbon GC traces that resemble those of an oil or condensate (viz. 2032-43 metres, Eocene, and 2284-93 metres, Paleocene : Figs. 11 and 12). The migrated hydrocarbons which stain both these intervals are characterised by high pristane/phytane and pristane/*n*-heptadecane ratios ($pr/ph \approx 4$; $pr/n-C_{17} > 1$). The latter feature suggests relative immaturity. Immature condensate (MPI-derived source $VR = 0.7\%$) recovered from the Eocene in Pelican-5 (RFT 3, 2788.2 metres) has a similarly high pristane/*n*-heptadecane ratio.

The remaining extracts represent indigenous immature source-rock bitumen (Figs. 8-10, 13).

5. CONCLUSIONS

1. Non-marine sediments of the Eastern View Coal Measures above 2000 metres depth in Koorkah-1 are thermally immature ($VR < 0.5\%$).
2. Intrusion of a 34 metre thick dolerite sill into the basal part of the Eocene section has produced a zone of elevated maturity which is clearly evident on the vitrinite reflectance profile for Koorkah-1 between 1900 and 2400 metres depth.

3. The rank thresholds for the onset of hydrocarbon generation from resinite-poor terrestrial organic matter are located within the Cretaceous sequence as follows:

| <u>Threshold</u> | <u>VR</u> % | <u>Depth</u> m |
|-------------------|----------------|-------------------|
| top of gas window | 0.60 | 2730 |
| top of oil window | 0.70 | 2950 |

Optimum maturity for oil generation is approached only at T.D. in this well (VR = 0.95% at 3148 metres).

4. The richest potential source rocks in Koorkah-1 occur between 1780 and 2005 metres depth in the Eocene section of the Eastern View Coal Measures (TOC = 3-11%; S₁+S₂ = 7-37 kg h'cs/tonnes). These sediments contain gas/condensate-prone Type II-III kerogen which, although immature at Koorkah-1, may well be generative elsewhere in the permit area.
5. Although less abundant and still only marginally mature (VR = 0.5-0.6%), dispersed organic matter of similar quality is present in the Paleocene section of the Koorkah-1 well (notably at 2284-2401 metres depth). The Cretaceous sequence is essentially gas-prone.
6. Migrated oil/condensate appears to have stained cuttings from at least two intervals in Koorkah-1 (viz. 2032-2043 metres, Eocene; 2284-2293 metres, Paleocene).

6. REFERENCES

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AMDEL HEADSPACE GAS ANALYSIS

Client AMOCO
Well KOORKAH 1

| DEPTH (m) | METHANE | ETHANE | PROPANE | I-BUTANE | N-BUTANE | I-PENTANE | N-PENTANE | HEXANE | HEPTANES+ |
|--------------|---------|--------|---------|----------|----------|-----------|-----------|--------|-----------|
| 1618-27 | 7 | 16 | 38 | 17 | 11 | 8 | 5 | 0 | 0 |
| 1636-45 | 614 | 103 | 97 | 50 | 28 | 24 | 9 | 26 | 21 |
| 1654-63 | 63 | 7 | 44 | 24 | 16 | 12 | 7 | 14 | 8 |
| 1672-81 | 757 | 212 | 195 | 71 | 33 | 22 | 7 | 18 | 10 |
| 1690-99 | 2581 | 992 | 443 | 127 | 42 | 29 | 8 | 18 | 8 |
| 1708-17 | 1823 | 261 | 207 | 87 | 27 | 24 | 6 | 17 | 8 |
| 1726-35 | 39 | 74 | 67 | 36 | 13 | 15 | 5 | 19 | 26 |
| 1744-53 | 8 | 9 | 17 | 12 | 5 | 7 | 0 | 8 | 5 |
| 1762-71 | 215 | 38 | 42 | 37 | 17 | 26 | 7 | 37 | 51 |
| 1780-89 | 15121 | 4275 | 1256 | 341 | 97 | 74 | 14 | 55 | 44 |
| 1798-07 | 5 | 2 | 11 | 9 | 4 | 6 | 2 | 11 | 12 |
| 1816-25 | 5 | 14 | 29 | 15 | 8 | 9 | 4 | 15 | 16 |
| 1834-43 | 260 | 0 | 7 | 10 | 5 | 8 | 3 | 15 | 18 |
| 1852-61 | 11179 | 69 | 99 | 44 | 26 | 19 | 8 | 25 | 39 |
| 1870-79 | 362 | 210 | 202 | 100 | 42 | 44 | 13 | 45 | 65 |
| 1888-97 | 6 | 0 | 18 | 11 | 16 | 7 | 5 | 10 | 19 |
| 1906-15 | 3 | 0 | 11 | 5 | 16 | 4 | 4 | 7 | 11 |
| 1924-33 | 18538 | 20 | 71 | 51 | 48 | 21 | 9 | 17 | 15 |
| 1942-51 | 4629 | 3132 | 1464 | 730 | 426 | 169 | 45 | 76 | 56 |
| 1960-69 | 3072 | 2116 | 1034 | 515 | 306 | 98 | 25 | 53 | 43 |
| 1978-87 | 30182 | 7849 | 2647 | 883 | 537 | 127 | 34 | 48 | 33 |
| 1996-05 | 8980 | 3951 | 1951 | 801 | 489 | 213 | 57 | 85 | 43 |
| 2014-23 | 26456 | 6838 | 3123 | 941 | 525 | 356 | 183 | 239 | 90 |
| 2032-43 | 11305 | 6632 | 4148 | 1146 | 610 | 443 | 230 | 484 | 209 |
| 2050-59 | 72997 | 1546 | 1269 | 375 | 192 | 126 | 54 | 103 | 47 |
| 2068-77 | 102469 | 1089 | 1123 | 326 | 174 | 121 | 55 | 145 | 81 |
| 2086-95 | 100367 | 2059 | 1325 | 452 | 229 | 165 | 123 | 128 | 47 |
| 2104-13 | 48062 | 581 | 291 | 86 | 49 | 35 | 28 | 37 | 17 |
| 2122-31 | 71112 | 203 | 189 | 67 | 42 | 32 | 26 | 44 | 22 |
| 2140-49 | 43871 | 1195 | 1034 | 275 | 126 | 80 | 32 | 65 | 35 |
| 2158-67 | 511 | 38 | 45 | 21 | 14 | 17 | 9 | 25 | 18 |
| 2176-85 | 4130 | 813 | 775 | 218 | 122 | 89 | 31 | 60 | 31 |
| 2194-03 | 76600 | 1129 | 1004 | 279 | 151 | 114 | 37 | 77 | 38 |
| 2212-21 | 11491 | 475 | 513 | 168 | 98 | 78 | 29 | 60 | 30 |
| 2230-39 | 11066 | 546 | 559 | 195 | 134 | 76 | 38 | 54 | 29 |
| 2266-75 | 2011 | 512 | 1337 | 715 | 387 | 206 | 68 | 84 | 29 |
| 2284-93 | 18000 | 471 | 991 | 379 | 220 | 95 | 35 | 56 | 30 |
| 2302-11 | 562 | 283 | 582 | 226 | 134 | 68 | 29 | 56 | 41 |
| 2320-29 | 22 | 0 | 5 | 3 | 2 | 1 | 1 | 1 | 1 |
| 2338-47 | 3777 | 2282 | 2753 | 946 | 316 | 115 | 45 | 44 | 17 |
| 2356-65 | 3904 | 1734 | 1841 | 501 | 204 | 89 | 36 | 48 | 31 |
| 2374-83 | 7666 | 3976 | 2858 | 724 | 266 | 125 | 39 | 63 | 36 |
| 2392-01 | 15775 | 4471 | 2055 | 468 | 205 | 109 | 37 | 70 | 49 |
| 2410-19 | 4781 | 2864 | 2111 | 498 | 224 | 108 | 35 | 65 | 43 |
| 2428-37 | 866 | 497 | 484 | 89 | 64 | 30 | 14 | 29 | 35 |
| 2446-55 | 103 | 52 | 35 | 8 | 6 | 3 | 2 | 3 | 0 |
| 2464-73 | 198 | 107 | 136 | 37 | 26 | 12 | 8 | 12 | 8 |
| 2482-91 | 1 | 0 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| 2500-09 | 2197 | 92 | 187 | 46 | 32 | 11 | 11 | 12 | 8 |
| 2518-27 | 37840 | 1172 | 1133 | 178 | 108 | 31 | 24 | 23 | 13 |

AMDEL HEADSPACE GAS ANALYSIS

Client AMOCO
Well KOORKAH 1

| DEPTH (m) | METHANE | ETHANE | PROPANE | I-BUTANE | N-BUTANE | I-PENTANE | N-PENTANE | HEXANE | HEPTANES+ |
|--------------|---------|--------|---------|----------|----------|-----------|-----------|--------|-----------|
| 2536-45 | 1435 | 1169 | 1226 | 205 | 131 | 38 | 30 | 27 | 14 |
| 2554-63 | 29082 | 1760 | 1685 | 249 | 171 | 43 | 33 | 30 | 14 |
| 2572-81 | 1561 | 1328 | 1461 | 232 | 173 | 48 | 32 | 33 | 0 |
| 2590-99 | 18287 | 3051 | 2014 | 273 | 187 | 56 | 30 | 40 | 22 |
| 2608-17 | 3964 | 1582 | 1512 | 257 | 182 | 57 | 34 | 41 | 23 |
| 2626-35 | 1172 | 2054 | 1920 | 251 | 172 | 40 | 28 | 28 | 16 |
| 2644-53 | 1398 | 1732 | 2012 | 309 | 190 | 45 | 31 | 31 | 18 |
| 2662-71 | 1482 | 1491 | 1715 | 247 | 178 | 42 | 29 | 28 | 23 |
| 2680-89 | 2565 | 2342 | 2182 | 375 | 318 | 92 | 53 | 66 | 41 |
| 2698-07 | 5 | 27 | 92 | 22 | 18 | 7 | 4 | 8 | 9 |
| 2716-25 | 4171 | 3117 | 2288 | 310 | 277 | 73 | 39 | 46 | 26 |
| 2734-43 | 376 | 714 | 1104 | 178 | 158 | 50 | 28 | 34 | 20 |
| 2752-61 | 1216 | 899 | 728 | 94 | 92 | 30 | 17 | 25 | 17 |
| 2770-79 | 1080 | 564 | 511 | 73 | 80 | 27 | 17 | 28 | 22 |
| 2788-97 | 531 | 198 | 189 | 31 | 32 | 12 | 7 | 9 | 5 |
| 2806-15 | 1201 | 547 | 471 | 65 | 73 | 22 | 13 | 16 | 12 |
| 2824-33 | 174 | 140 | 198 | 40 | 44 | 17 | 12 | 19 | 11 |
| 2842-51 | 732 | 0 | 14 | 6 | 9 | 4 | 2 | 5 | 8 |
| 2860-69 | 1520 | 1231 | 1732 | 340 | 340 | 117 | 62 | 85 | 52 |
| 2878-87 | 30052 | 220 | 332 | 62 | 74 | 29 | 19 | 29 | 31 |
| 2896-05 | 2813 | 2410 | 2463 | 337 | 421 | 104 | 61 | 69 | 42 |
| 2914-23 | 1722 | 818 | 791 | 178 | 131 | 58 | 30 | 46 | 27 |
| 2932-41 | 2810 | 2441 | 2481 | 450 | 470 | 161 | 93 | 129 | 85 |
| 2950-59 | 14 | 16 | 45 | 13 | 18 | 8 | 8 | 16 | 26 |
| 2968-77 | 63 | 54 | 87 | 15 | 22 | 7 | 6 | 10 | 14 |
| 2986-95 | 3657 | 2790 | 2014 | 267 | 355 | 112 | 68 | 84 | 51 |
| 3004-13 | 434 | 611 | 518 | 56 | 83 | 27 | 20 | 32 | 29 |
| 3022-31 | 366 | 320 | 312 | 49 | 78 | 31 | 26 | 41 | 35 |
| 3040-49 | 178 | 117 | 274 | 43 | 76 | 30 | 21 | 34 | 36 |
| 3058-67 | 6500 | 87 | 150 | 27 | 48 | 22 | 15 | 29 | 30 |
| 3076-85 | 1005 | 714 | 867 | 102 | 169 | 59 | 35 | 52 | 40 |
| 3094-03 | 17673 | 78 | 237 | 45 | 80 | 38 | 25 | 45 | 40 |
| 3112-21 | 70381 | 1181 | 1615 | 293 | 443 | 196 | 98 | 142 | 97 |
| 3130-39 | 16791 | 90 | 145 | 28 | 40 | 18 | 12 | 18 | 15 |

TABLE 2

AMDEL HEADSPACE GAS ANALYSIS

Client AMOCO
Well KOORKAH 1

| DEPTH m | WET GAS (%) | iC4/nC4 | iC5/nC5 | C1-C4 ppm | C5+ ppm |
|------------|----------------|---------|---------|--------------|------------|
| 1618-27 | 92.0 | 1.52 | 1.36 | 89 | 13 |
| 1636-45 | 31.2 | 1.79 | 1.18 | 892 | 79 |
| 1654-63 | 59.3 | 1.53 | 1.28 | 154 | 41 |
| 1672-81 | 40.3 | 2.15 | 1.52 | 1269 | 57 |
| 1690-99 | 38.3 | 3.05 | 1.42 | 4184 | 63 |
| 1708-17 | 24.2 | 3.26 | 1.11 | 2404 | 56 |
| 1726-35 | 83.1 | 2.73 | 0.88 | 229 | 66 |
| 1744-53 | 84.3 | 2.31 | 0.73 | 50 | 20 |
| 1762-71 | 38.3 | 2.26 | 0.64 | 348 | 121 |
| 1780-89 | 28.3 | 3.52 | 1.32 | 21090 | 188 |
| 1798-07 | 84.5 | 2.34 | 0.62 | 31 | 31 |
| 1816-25 | 93.5 | 2.00 | 0.85 | 71 | 44 |
| 1834-43 | 7.9 | 1.85 | 0.64 | 282 | 44 |
| 1852-61 | 2.1 | 1.71 | 1.36 | 11417 | 90 |
| 1870-79 | 60.5 | 2.42 | 0.95 | 916 | 167 |
| 1888-97 | 89.2 | 0.71 | 2.36 | 51 | 40 |
| 1906-15 | 91.7 | 0.34 | 3.93 | 35 | 27 |
| 1924-33 | 1.0 | 1.07 | 2.31 | 18728 | 62 |
| 1942-51 | 55.4 | 1.71 | 2.52 | 10381 | 346 |
| 1960-69 | 56.4 | 1.68 | 3.12 | 7043 | 219 |
| 1978-87 | 28.3 | 1.64 | 4.21 | 42097 | 243 |
| 1996-05 | 44.5 | 1.64 | 2.29 | 16172 | 399 |
| 2014-23 | 30.2 | 1.79 | 1.47 | 37883 | 868 |
| 2032-43 | 52.6 | 1.88 | 1.38 | 23840 | 1366 |
| 2050-59 | 4.4 | 1.95 | 1.52 | 76379 | 330 |
| 2068-77 | 2.6 | 1.88 | 1.44 | 105181 | 402 |
| 2086-95 | 3.9 | 1.97 | 1.39 | 104433 | 462 |
| 2104-13 | 2.1 | 1.75 | 1.41 | 49068 | 117 |
| 2122-31 | 0.7 | 1.59 | 1.31 | 71613 | 124 |
| 2140-49 | 5.7 | 2.18 | 1.59 | 46503 | 211 |
| 2158-67 | 18.6 | 1.50 | 0.82 | 628 | 69 |
| 2176-85 | 31.8 | 1.79 | 1.37 | 6058 | 212 |
| 2194-03 | 3.2 | 1.84 | 1.32 | 79163 | 266 |
| 2212-21 | 9.8 | 1.73 | 1.26 | 12744 | 196 |
| 2230-39 | 11.5 | 1.45 | 1.77 | 12501 | 196 |
| 2266-75 | 59.5 | 1.85 | 1.88 | 4963 | 387 |
| 2284-93 | 10.3 | 1.73 | 2.32 | 20062 | 216 |
| 2302-11 | 68.5 | 1.69 | 1.96 | 1787 | 194 |
| 2320-29 | 32.2 | 1.13 | 2.37 | 32 | 4 |
| 2338-47 | 62.5 | 2.99 | 2.76 | 10074 | 221 |
| 2356-65 | 52.3 | 2.45 | 2.30 | 8184 | 203 |
| 2374-83 | 50.5 | 2.72 | 2.12 | 15491 | 263 |
| 2392-01 | 31.3 | 2.29 | 1.88 | 22974 | 265 |
| 2410-19 | 54.4 | 2.23 | 2.07 | 10479 | 252 |
| 2428-37 | 56.7 | 1.39 | 2.15 | 2000 | 108 |
| 2446-55 | 49.8 | 1.42 | 1.98 | 204 | 7 |
| 2464-73 | 60.8 | 1.39 | 2.11 | 504 | 41 |
| 2482-91 | 71.0 | 0.94 | 0.79 | 5 | 1 |
| 2500-09 | 14.0 | 1.43 | 2.79 | 2554 | 42 |

TABLE 2 contd.

AMDEL HEADSPACE GAS ANALYSIS

Client AMOCO
Well KOORKAH 1

| DEPTH ■ | WET GAS (%) | iC4/nC4 | iC5/nC5 | C1-C4 ppm | C5+ ppm |
|------------|----------------|---------|---------|--------------|------------|
| 2518-27 | 6.4 | 1.65 | 3.51 | 40432 | 91 |
| 2536-45 | 65.6 | 1.56 | 3.46 | 4167 | 109 |
| 2554-63 | 11.7 | 1.46 | 4.01 | 32947 | 120 |
| 2572-81 | 67.2 | 1.33 | 3.61 | 4755 | 114 |
| 2590-99 | 23.2 | 1.46 | 3.36 | 23812 | 147 |
| 2608-17 | 47.1 | 1.41 | 3.20 | 7497 | 155 |
| 2626-35 | 79.0 | 1.46 | 4.33 | 5569 | 111 |
| 2644-53 | 75.2 | 1.62 | 4.21 | 5641 | 125 |
| 2662-71 | 71.0 | 1.39 | 4.28 | 5114 | 122 |
| 2680-89 | 67.0 | 1.18 | 3.45 | 7782 | 252 |
| 2698-07 | 96.7 | 1.21 | 2.41 | 164 | 28 |
| 2716-25 | 59.0 | 1.12 | 3.81 | 10163 | 183 |
| 2734-43 | 85.1 | 1.13 | 3.17 | 2531 | 130 |
| 2752-61 | 59.9 | 1.02 | 3.11 | 3029 | 88 |
| 2770-79 | 53.2 | 0.90 | 2.93 | 2308 | 94 |
| 2788-97 | 45.9 | 0.98 | 2.76 | 982 | 32 |
| 2806-15 | 49.1 | 0.89 | 3.26 | 2356 | 64 |
| 2824-33 | 70.9 | 0.93 | 2.55 | 595 | 58 |
| 2842-51 | 3.8 | 0.62 | 2.20 | 761 | 20 |
| 2860-69 | 70.6 | 1.00 | 2.90 | 5164 | 317 |
| 2878-87 | 2.2 | 0.84 | 2.59 | 30740 | 108 |
| 2896-05 | 66.7 | 0.80 | 4.06 | 8444 | 275 |
| 2914-23 | 52.7 | 1.36 | 2.26 | 3641 | 161 |
| 2932-41 | 67.5 | 0.96 | 2.92 | 8652 | 468 |
| 2950-59 | 86.8 | 0.72 | 2.07 | 106 | 58 |
| 2968-77 | 73.8 | 0.67 | 2.98 | 242 | 37 |
| 2986-95 | 59.7 | 0.75 | 3.16 | 9083 | 316 |
| 3004-13 | 74.5 | 0.67 | 3.07 | 1701 | 108 |
| 3022-31 | 67.5 | 0.63 | 2.53 | 1124 | 133 |
| 3040-49 | 74.1 | 0.56 | 2.57 | 690 | 120 |
| 3058-67 | 4.6 | 0.56 | 2.19 | 6811 | 97 |
| 3076-85 | 64.8 | 0.60 | 2.85 | 2858 | 186 |
| 3094-03 | 2.4 | 0.56 | 2.10 | 18113 | 148 |
| 3112-21 | 4.8 | 0.66 | 2.26 | 73913 | 533 |
| 3130-39 | 1.8 | 0.70 | 2.20 | 17094 | 64 |

TABLE 3: TOTAL ORGANIC CARBON CONTENTS OF SIDEWALL CORES,
KOORKAH-1

| SWC No. | Depth m | TOC % |
|---------|------------|----------|
| 25 | 2465.5 | 1.73* |
| 24 | 2555 | 1.26* |
| 20 | 2676 | 1.03* |
| 19 | 2728 | 6.45* |
| 17 | 2763.5 | 1.12* |
| 13 | 2884 | 0.45 |
| 12 | 2929 | 1.20* |
| 10 | 2959.5 | 0.90 |
| 7 | 3030 | 1.20* |
| 6 | 3062 | 0.65 |
| 2 | 3126 | 1.27* |

*Selected for Rock Eval pyrolysis (Table 4).

TABLE 4

280014

AMDEL

ROCK-EVAL PYROLYSIS

06/03/86

Client AMOCO

Well KOORKAH-1 Sidewall Cores

| DEPTH | T MAX | S1 | S2 | S3 | S1+S2 | PI | S2/S3 | PC | TOC | HI | OI |
|---------|-------|------|-------|------|-------|------|-------|------|------|-----|----|
| 2465.50 | 438 | 0.25 | 2.60 | 0.36 | 2.85 | 0.09 | 7.22 | 0.23 | 1.73 | 150 | 20 |
| 2555.00 | 440 | 0.17 | 1.48 | 0.25 | 1.65 | 0.10 | 5.92 | 0.13 | 1.26 | 117 | 19 |
| 2676.00 | 443 | 0.16 | 0.65 | 0.51 | 0.81 | 0.19 | 1.27 | 0.06 | 1.03 | 63 | 49 |
| 2728.00 | 439 | 2.04 | 13.05 | 1.42 | 15.09 | 0.14 | 31.07 | 1.25 | 6.45 | 202 | 6 |
| 2763.50 | 441 | 0.29 | 1.77 | 0.12 | 2.06 | 0.14 | 14.75 | 0.17 | 1.12 | 158 | 10 |
| 2929.00 | 441 | 0.35 | 1.55 | 0.92 | 1.90 | 0.18 | 1.68 | 0.15 | 1.20 | 129 | 76 |
| 3030.00 | 448 | 0.21 | 0.78 | 0.48 | 0.99 | 0.20 | 1.62 | 0.08 | 1.20 | 65 | 40 |
| 3126.00 | 445 | 0.36 | 1.33 | 0.13 | 1.69 | 0.21 | 10.23 | 0.16 | 1.27 | 104 | 10 |

TABLE 5

280015

AMDEL

ROCK-EVAL PYROLYSIS

08/05/86

| Client | AMOCO | | | | | | | | | | |
|--------------|-------------------------|------|-------|------|-------|------|-------|------|-------|-----|-----|
| Well | KOORKAH-1 Cuttings | | | | | | | | | | |
| DEPTH (m) | T MAX | S1 | S2 | S3 | S1+S2 | PI | S2/S3 | PC | TOC | HI | OI |
| 1780-89 | 426 | 2.48 | 34.06 | 0.87 | 36.54 | 0.07 | 39.14 | 3.04 | 10.90 | 312 | 8 |
| 1924-33 | 431 | 3.16 | 21.55 | 1.17 | 24.71 | 0.13 | 18.41 | 2.05 | 4.85 | 444 | 24 |
| 1978-87 | 431 | 0.91 | 12.40 | 1.08 | 13.31 | 0.07 | 11.48 | 1.10 | 5.45 | 228 | 20 |
| 1996-05 | 431 | 0.51 | 6.66 | 1.21 | 7.17 | 0.07 | 5.50 | 0.59 | 3.40 | 196 | 36 |
| 2014-23 | 429 | 0.36 | 4.59 | 2.11 | 4.95 | 0.07 | 2.17 | 0.41 | 2.84 | 162 | 74 |
| 2032-43 | 440 | 0.23 | 2.48 | 0.76 | 2.71 | 0.09 | 3.26 | 0.22 | 3.30 | 75 | 23 |
| 2050-59 | 436 | 0.09 | 0.17 | 0.29 | 0.26 | 0.35 | 0.58 | 0.02 | 0.53 | 32 | 54 |
| 2068-77 | 439 | 0.17 | 0.18 | 0.27 | 0.35 | 0.50 | 0.66 | 0.02 | 1.28 | 14 | 21 |
| 2086-95 | 432 | 0.10 | 0.22 | 0.20 | 0.32 | 0.31 | 1.10 | 0.02 | 0.61 | 36 | 32 |
| 2104-13 | 431 | 0.55 | 2.96 | 0.31 | 3.51 | 0.16 | 9.54 | 0.29 | 0.81 | 365 | 38 |
| 2122-31 | 431 | 0.09 | 0.70 | 0.26 | 0.79 | 0.12 | 2.69 | 0.06 | 0.28 | 250 | 93 |
| 2140-49 | 439 | 0.12 | 0.84 | 0.52 | 0.96 | 0.12 | 1.61 | 0.08 | 0.78 | 108 | 67 |
| 2194-03 | 434 | 0.19 | 2.09 | 0.63 | 2.28 | 0.08 | 3.31 | 0.19 | 1.15 | 182 | 55 |
| 2284-93 | 436 | 1.38 | 6.14 | 0.36 | 7.52 | 0.18 | 17.05 | 0.62 | 2.10 | 292 | 17 |
| 2374-83 | 438 | 0.18 | 2.29 | 0.44 | 2.47 | 0.07 | 5.20 | 0.20 | 1.35 | 170 | 33 |
| 2392-01 | 436 | 0.76 | 6.14 | 0.67 | 6.90 | 0.11 | 9.16 | 0.57 | 2.16 | 284 | 31 |
| 2518-27 | 441 | 0.12 | 1.52 | 0.32 | 1.64 | 0.07 | 4.75 | 0.13 | 1.23 | 123 | 26 |
| 2554-63 | 441 | 0.17 | 2.03 | 0.41 | 2.20 | 0.08 | 4.95 | 0.18 | 1.43 | 142 | 29 |
| 2590-99 | 441 | 0.14 | 1.87 | 0.61 | 2.01 | 0.07 | 3.06 | 0.16 | 1.44 | 130 | 42 |
| 2878-87 | 435 | 0.26 | 2.78 | 0.52 | 3.04 | 0.09 | 5.34 | 0.25 | 1.52 | 183 | 34 |
| 3094-03 | 445 | 0.14 | 0.90 | 2.50 | 1.04 | 0.13 | 0.36 | 0.09 | 0.71 | 127 | 352 |
| 3112-21 | 449 | 0.14 | 0.85 | 0.81 | 0.99 | 0.14 | 1.04 | 0.09 | 0.72 | 118 | 113 |
| 3130-39 | 449 | 0.10 | 0.53 | 0.24 | 0.63 | 0.16 | 2.20 | 0.06 | 0.43 | 123 | 56 |

KEY TO ROCK-EVAL PYROLYSIS DATA SHEET

| | <u>PARAMETER</u> | <u>SPECIFICITY</u> |
|---------------------------------|---|--|
| T max | position of S ₂ peak in temperature program (°C) | Maturity/Kerogen type |
| S ₁ | kg hydrocarbons (extractable)/tonne rock | Kerogen type/Maturity/Migrated oil |
| S ₂ | kg hydrocarbons (kerogen pyrolysate)/tonne rock | Kerogen type/Maturity |
| S ₃ | kg CO ₂ (organic)/tonne rock | Kerogen type/Maturity * |
| S ₁ + S ₂ | Potential Yield | Organic richness/Kerogen type |
| PI | Production Index (S ₁ /S ₁ + S ₂) | Maturity/Migrated Oil |
| PC | Pyrolysable Carbon (wt. percent) | Organic richness/Kerogen type/Maturity |
| TOC | Total Organic Carbon (wt. percent) | Organic richness |
| HI | Hydrogen Index (mg h'c (S ₂)/g TOC) | Kerogen type/Maturity |
| OI | Oxygen Index (mg CO ₂ (S ₃)/g TOC) | Kerogen type/Maturity * |

*Also subject to interference by CO₂ from decomposition of carbonate minerals.

280016

TABLE 6: SAMPLES SELECTED FOR RESIDUAL OIL ANALYSIS, KOORKAH-1

| Depth m | Sample Type | Wt Sample g | EDM ppm | Total Hydrocarbons % EDM |
|------------|-------------|----------------|------------|-----------------------------|
| 1780-1789 | Cuttings | 19.56 | 6109 | 43.1 |
| 1924-1933 | Cuttings | 33.67 | 169050 | 7.9 |
| 1978-1987 | Cuttings | 20.61 | 6341 | n.d. |
| 2032-2041 | Cuttings | 32.50 | 1772 | 60.0* |
| 2284-2293 | Cuttings | 30.10 | 2943 | 42.8* |
| 2728 | SWC | 13.20 | 924 | n.d. |

n.d. = not determined.

*oil/condensate-like GC trace.

TABLE 7: KEROGEN PYROLYSIS-GC DATA, KOORKAH-1

| Depth m | Age | HI | C ₁ -C ₄ % | C ₅ -C ₁₀ % | C ₁₁₊ % | C ₁ -C ₄ | | m,p-Xyl | |
|------------|------------|-----|-------------------------------------|--------------------------------------|-----------------------|--------------------------------|-----|--------------------|--------------------|
| | | | | | | C ₅₊ | Tol | n-C _{7:1} | n-C _{8:1} |
| 1780-1789 | Eocene | 312 | 52.0 | 27.6 | 20.4 | 1.08 | 2.4 | 1.8 | |
| 1924-1933 | Eocene | 444 | 48.9 | 27.4 | 23.7* | 0.96* | 2.4 | 1.6 | |
| 1978-1987 | Eocene | 228 | 53.5 | 26.8 | 19.7* | 1.15* | 2.3 | 1.6 | |
| 1996-2005 | Eocene | 196 | 52.2 | 28.3 | 19.5* | 1.09* | 2.2 | 1.6 | |
| 2284-2293 | Paleocene | 292 | 49.8 | 30.6 | 19.5* | 0.99* | 2.0 | 1.3 | |
| 2392-2401 | Paleocene | 284 | 59.1 | 25.8 | 15.1* | 1.44* | 2.1 | 1.6 | |
| 2728 | Cretaceous | 202 | 61.3 | 21.8 | 16.9* | 1.58* | 3.8 | 2.5 | |

*Corrected for contaminant peak at n-C_{16:0}

%C₁-C₄, C₅-C₁₀ and C₁₁₊ = percentage of all compounds in the nominated carbon number ranges.

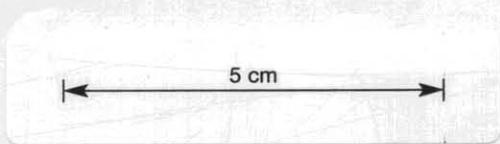
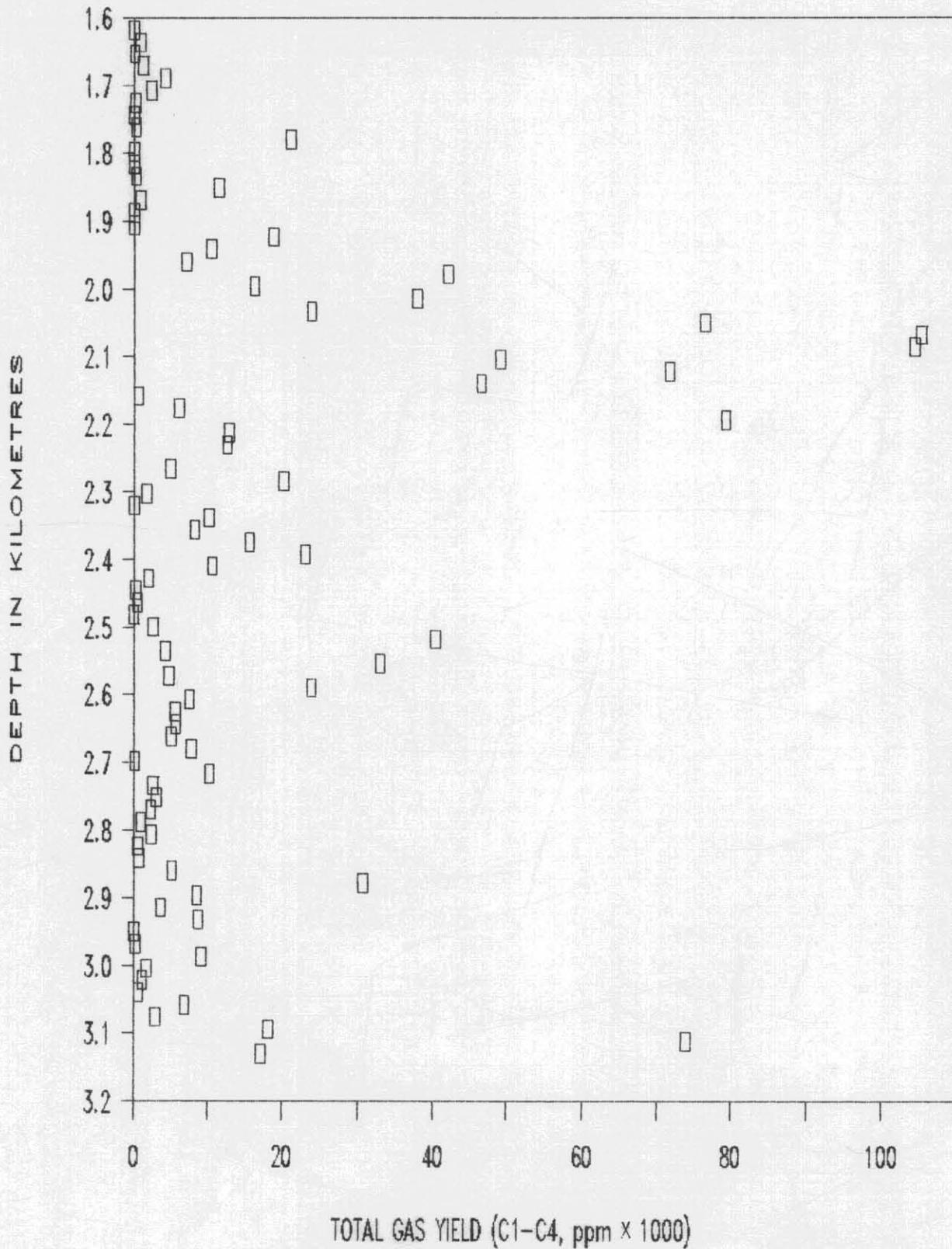
HI = hydrogen index (mg S₂/g TOC)

FIGURE 1

280019

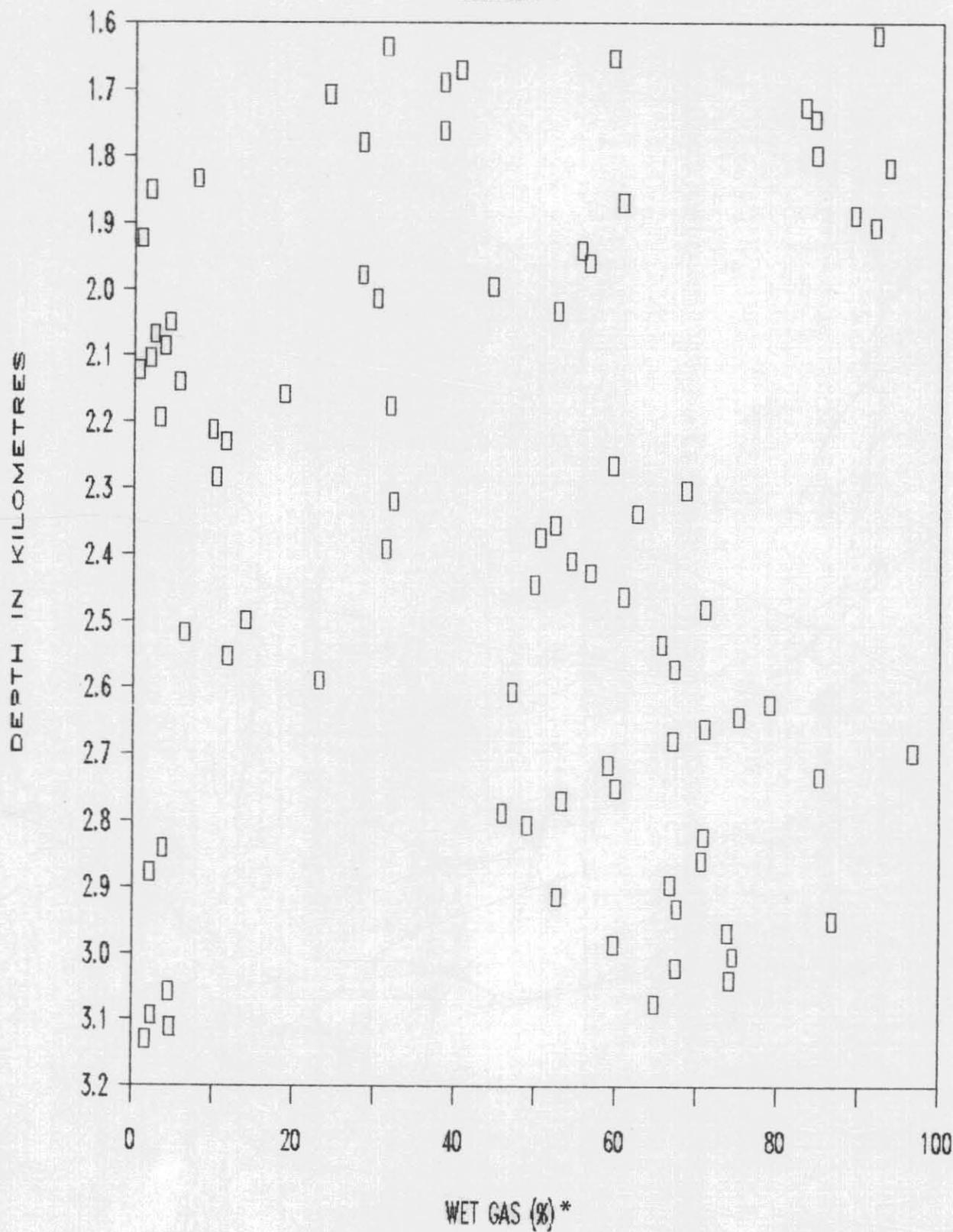
AMOCO

KOORKAH 1

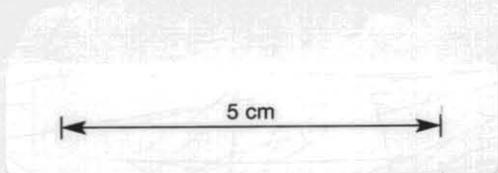


AMOCO

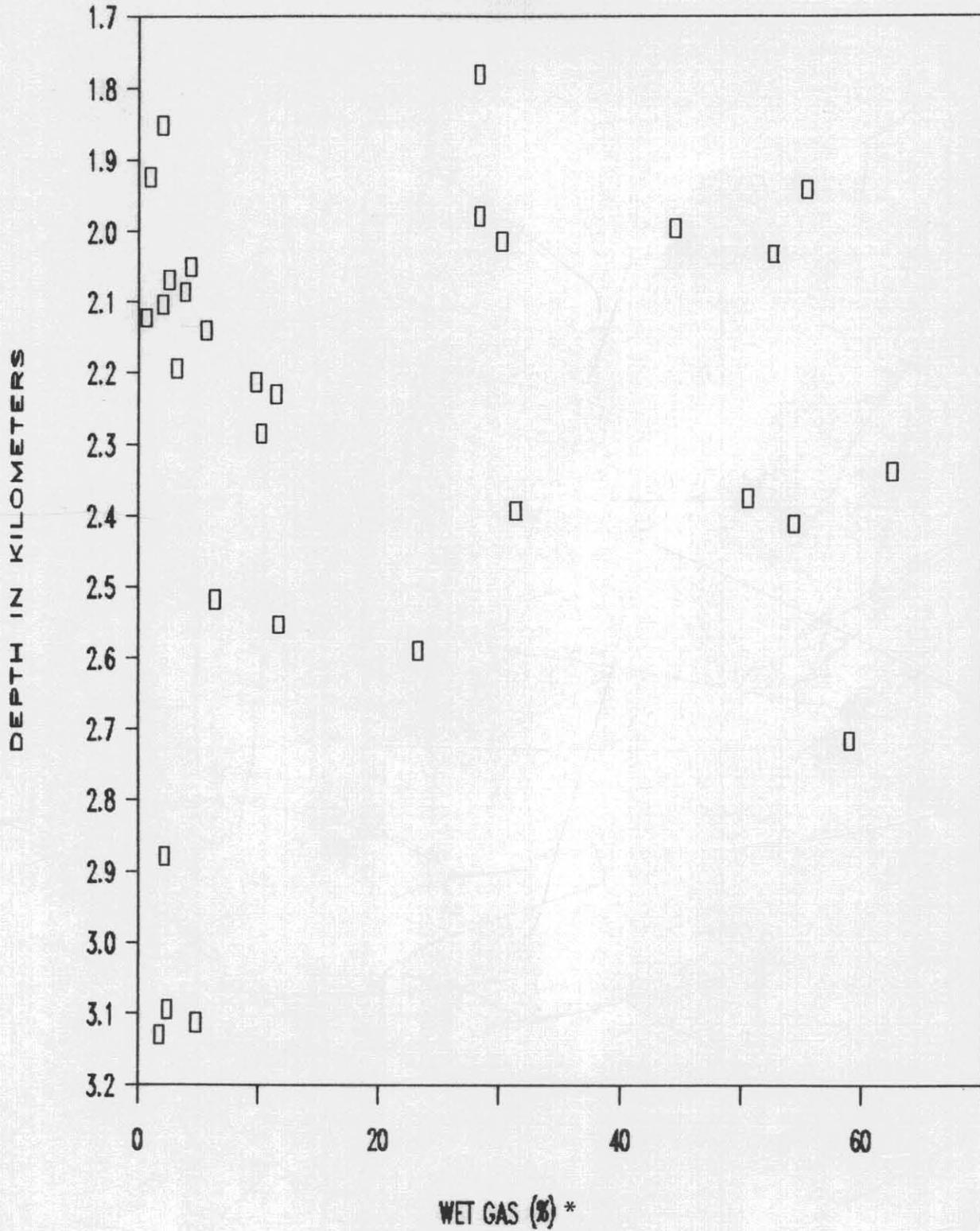
KOORKAH 1



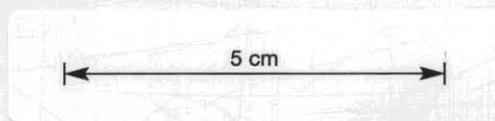
* All samples



AMOCO
KOORKAH 1



* Samples yielding >10,000 ppm C₁-C₄



AMOCO

KOORKAH 1

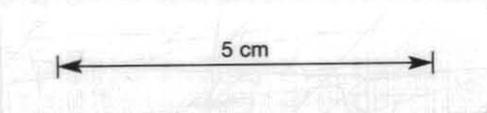
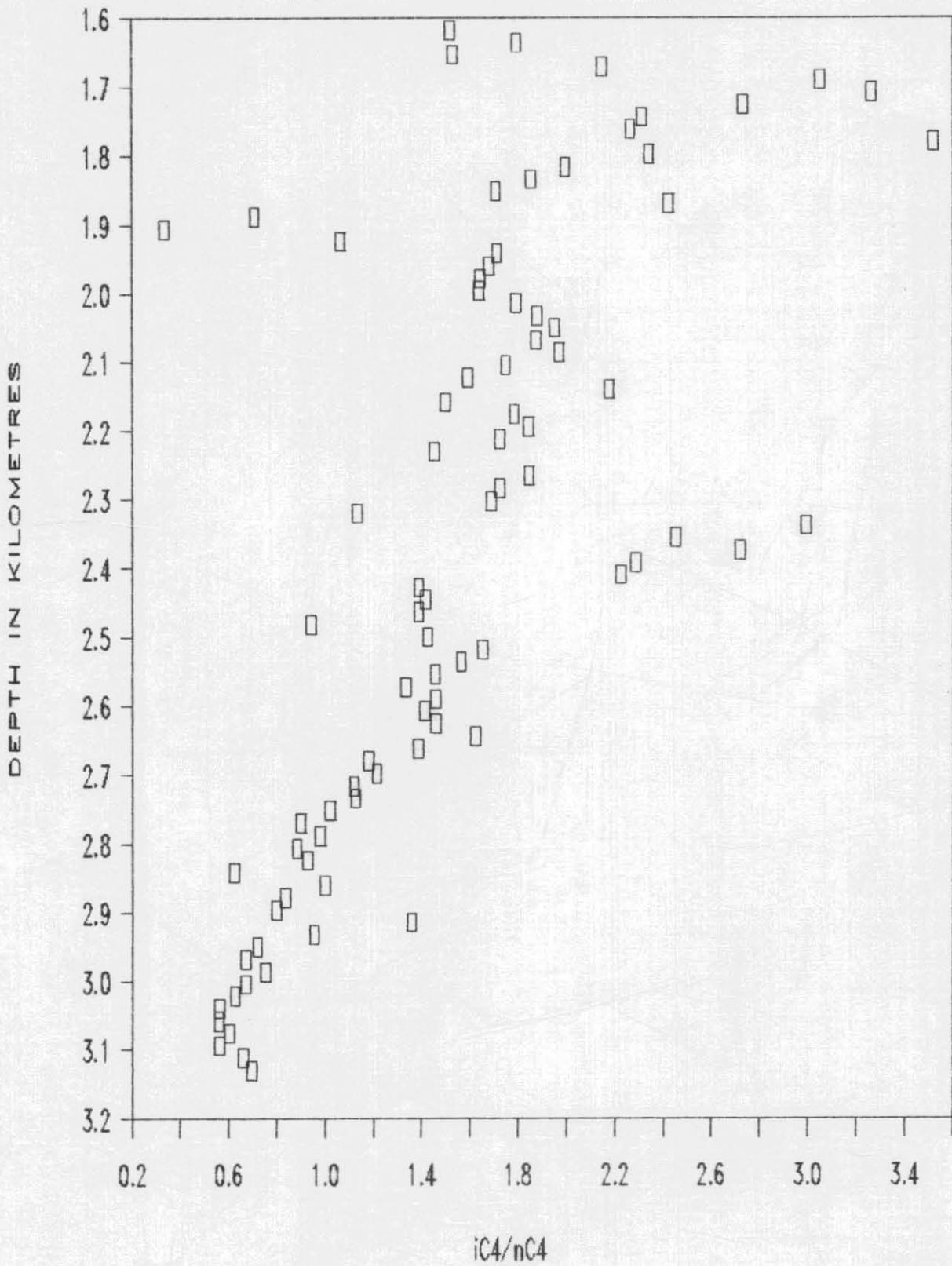
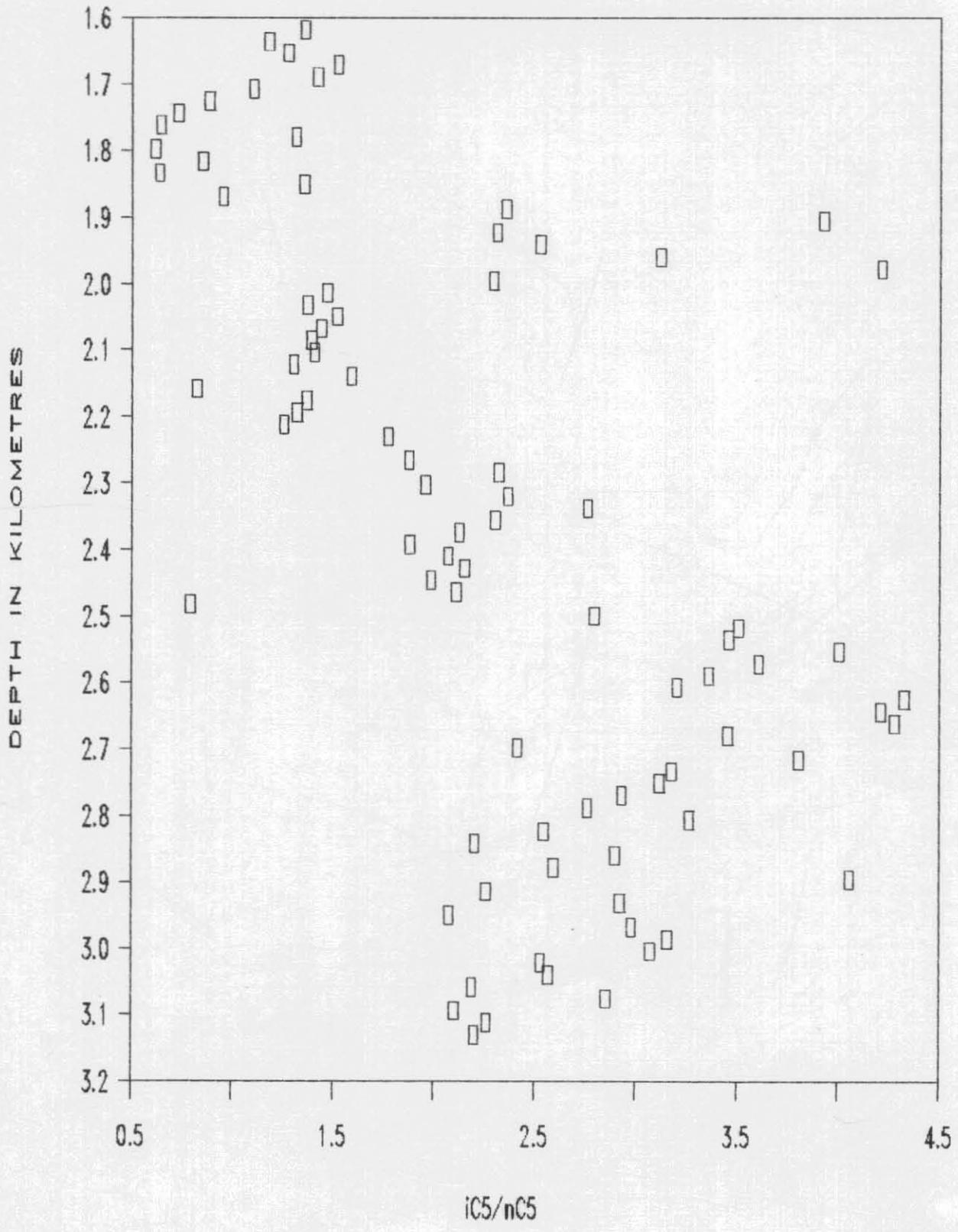


FIGURE 4

280023

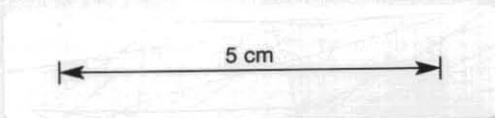
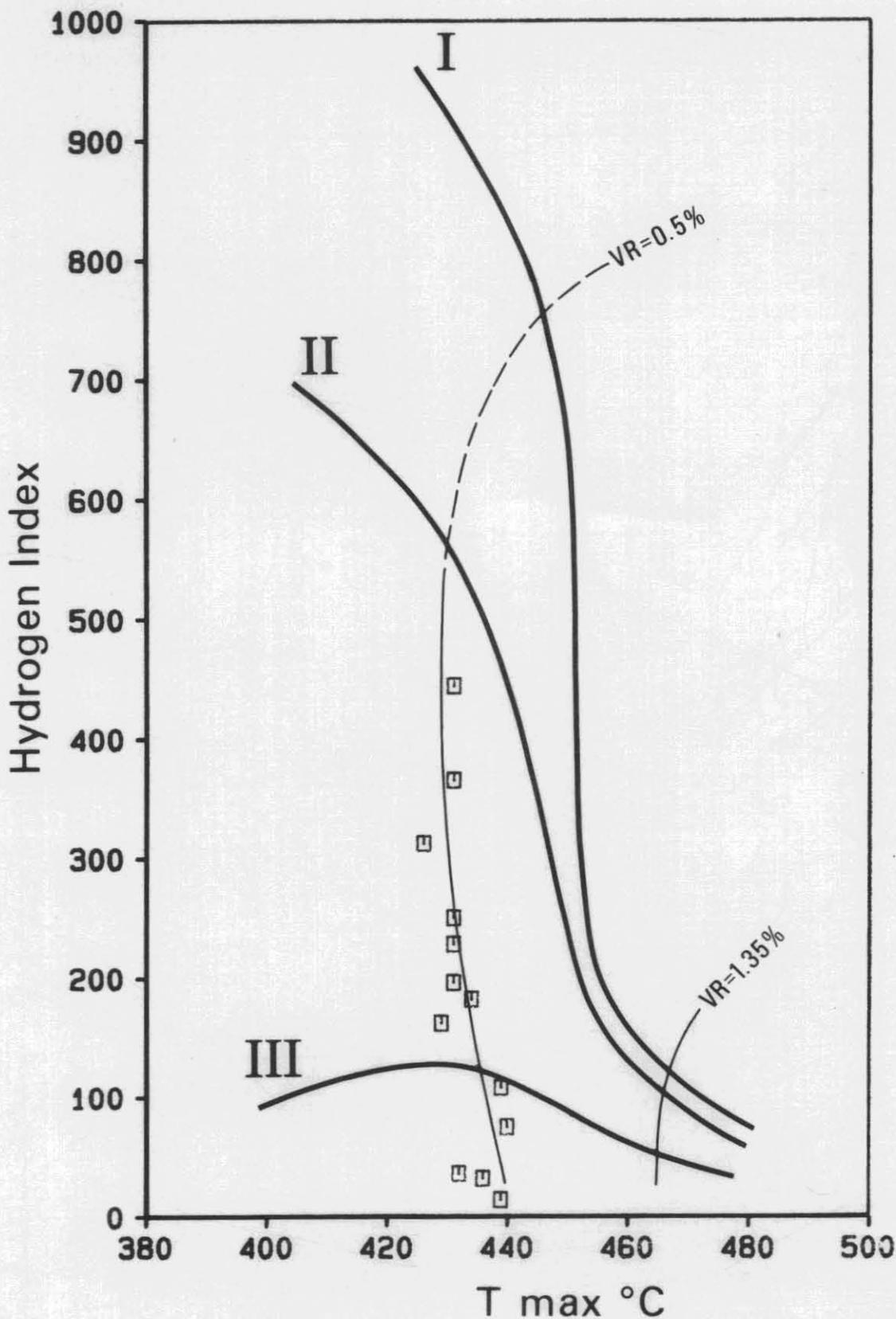
AMOCO

KOORKAH 1



Client : AMOCO
Well name : KOORKAH-1
Interval : EOCENE

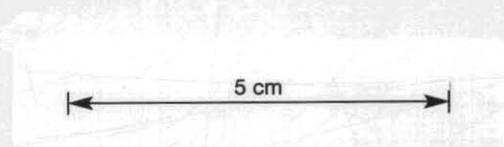
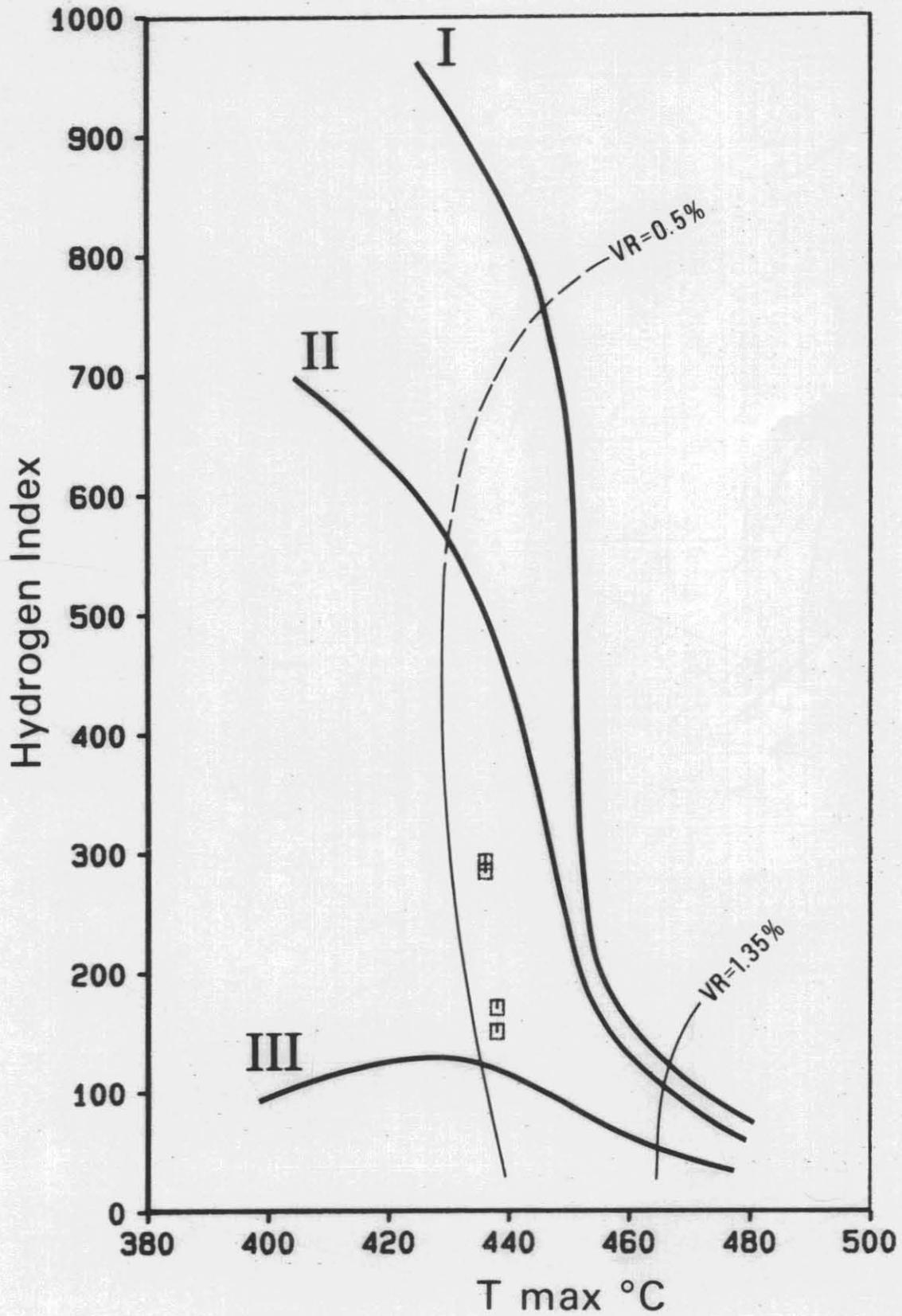
FIGURE 5
280024



Client : AMOCO
Well name : KOORKAH-1
Interval : PALEOCENE

FIGURE 6

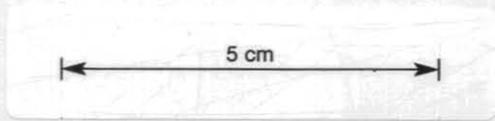
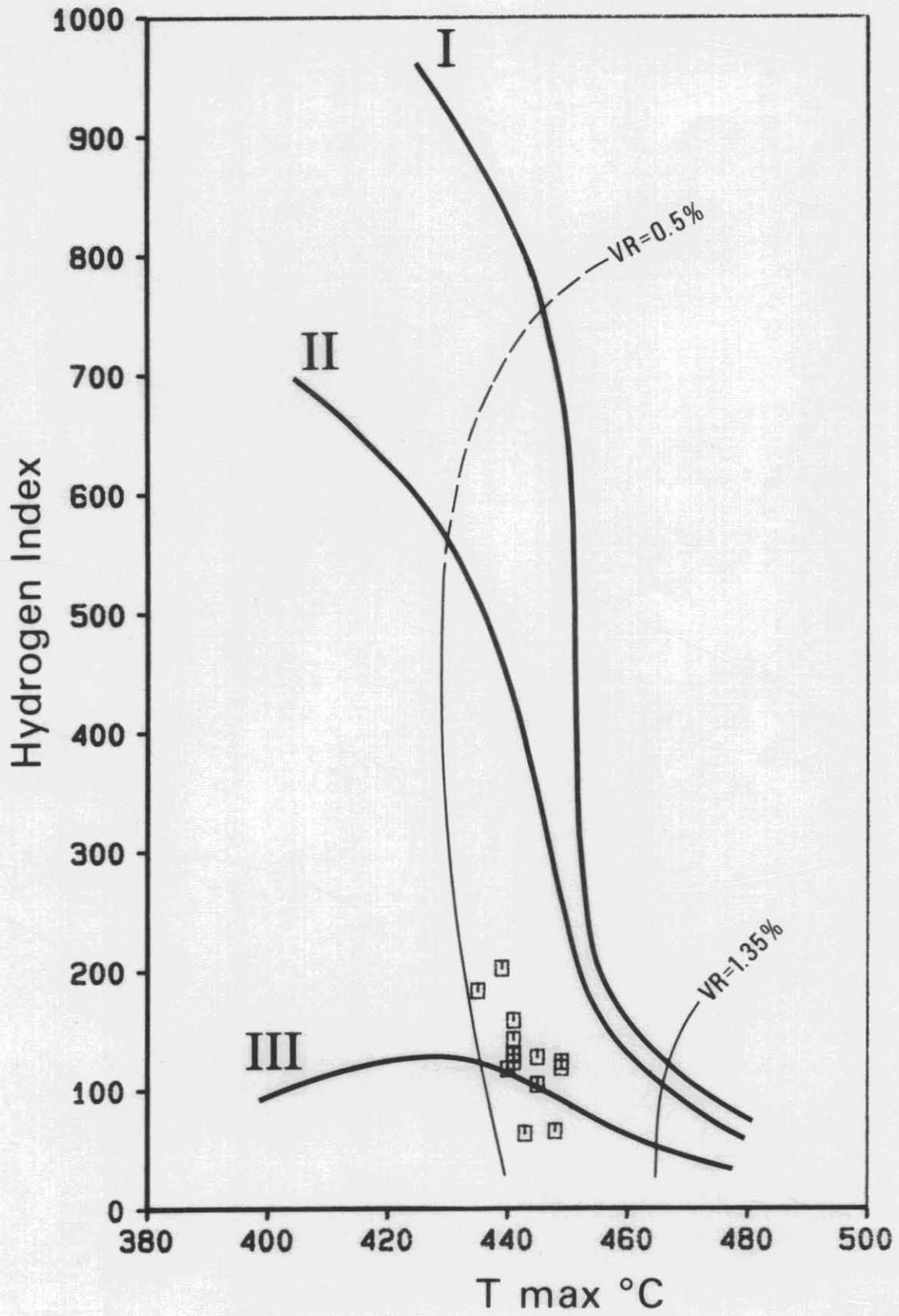
280025



Client : AMOCO
Well name : KOORKAH-1
Interval : CRETACEOUS

FIGURE 7

280026



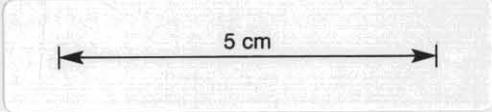
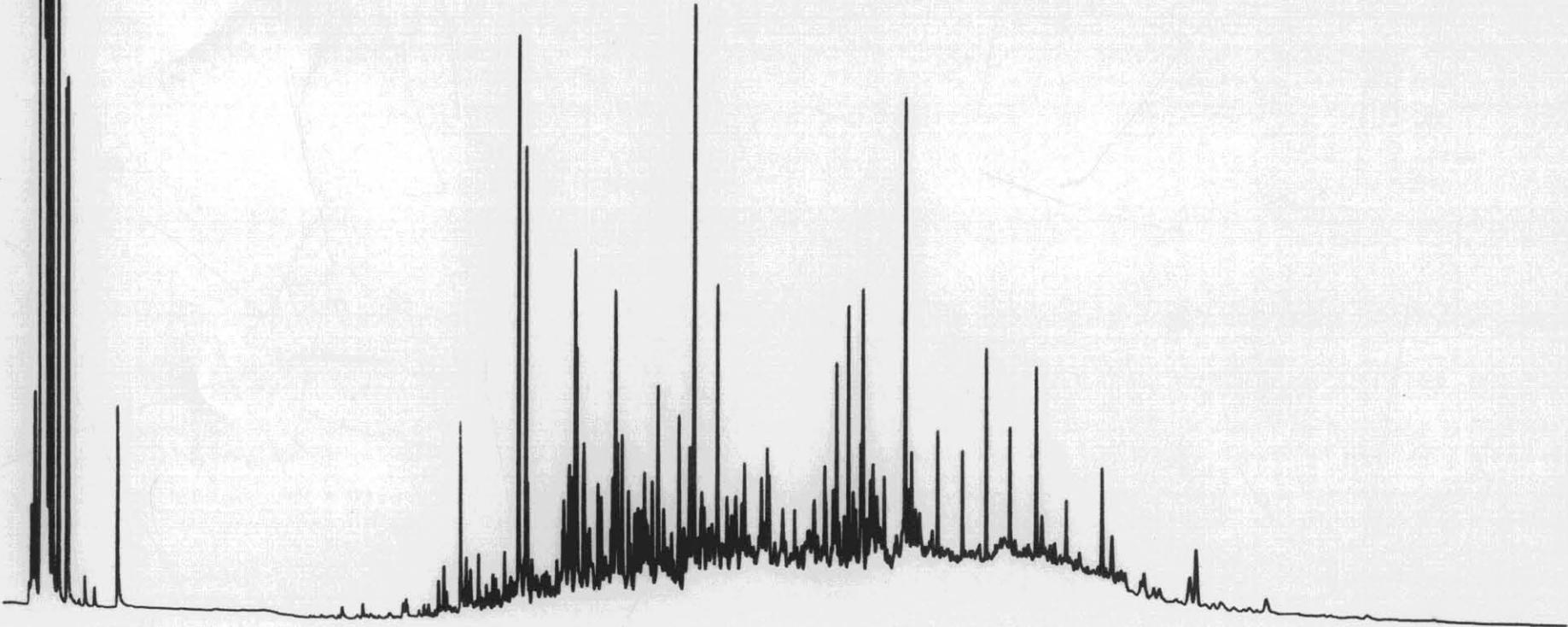


FIGURE 8

KOORKAH-1 1780-1789 m
Total Hydrocarbons



280027

5 cm

FIGURE 9

KOORKAH-1 1924-1933 m
Total Hydrocarbons

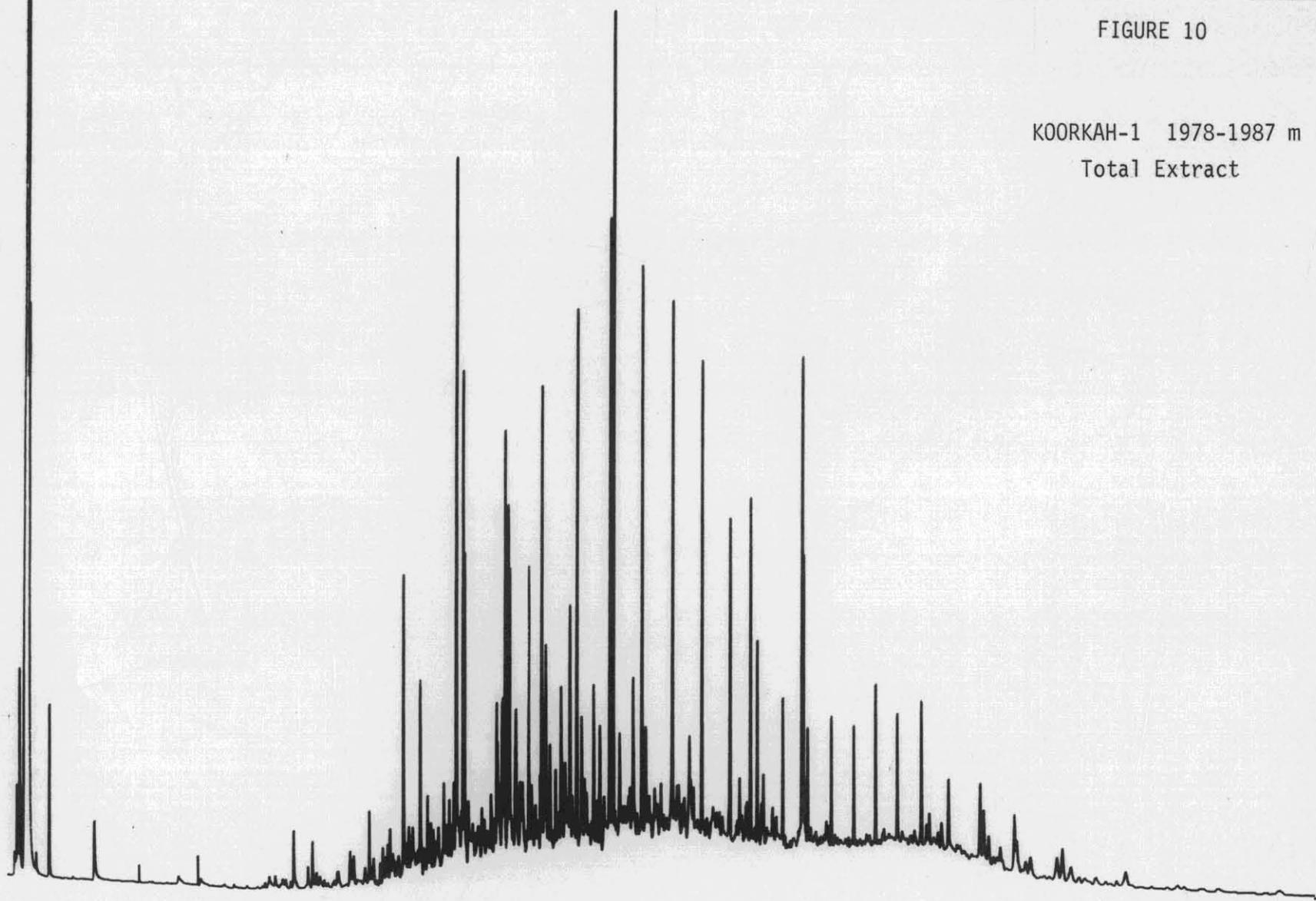
280028



5 cm

FIGURE 10

KOORKAH-1 1978-1987 m
Total Extract

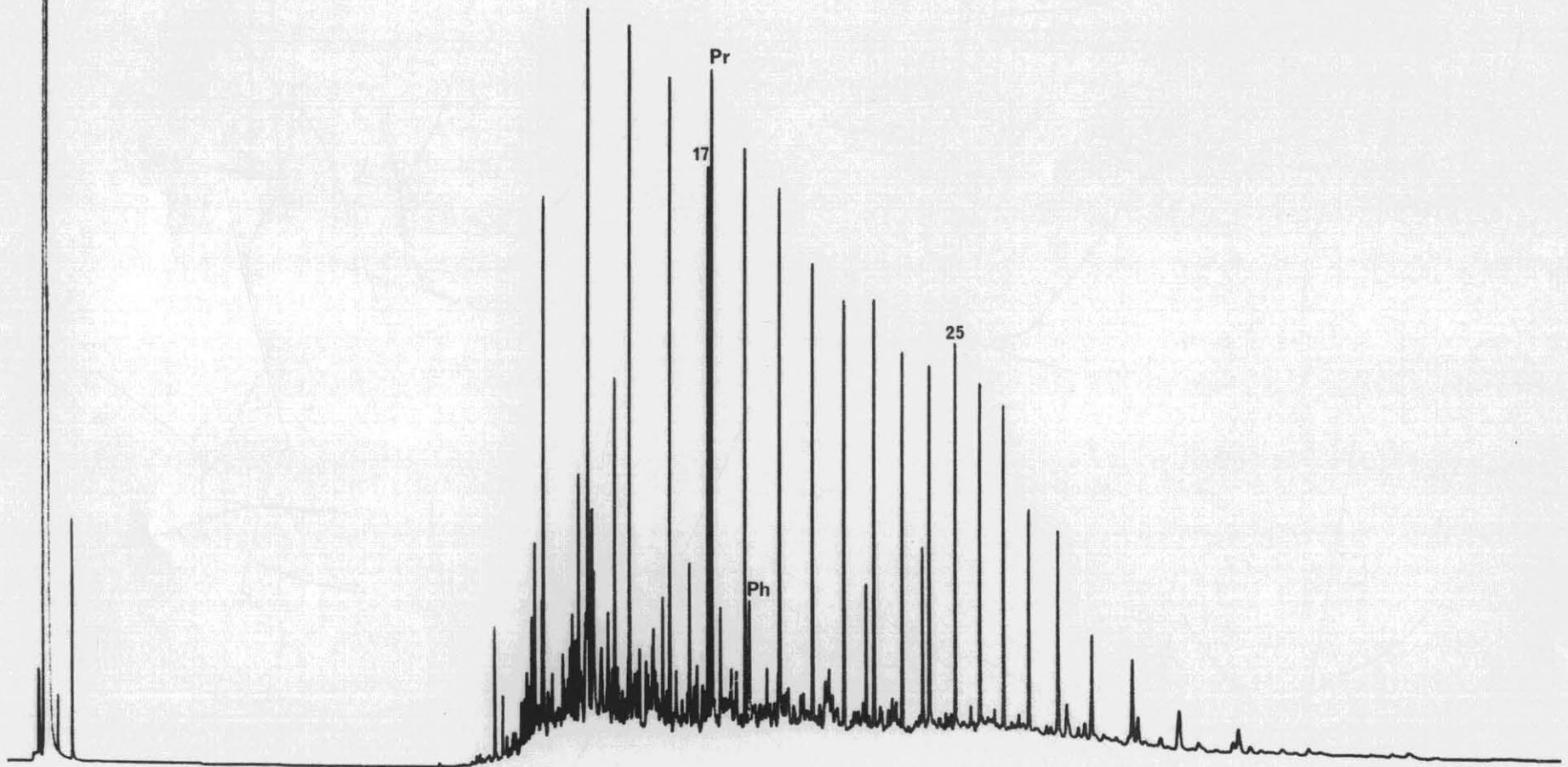


280029

5 cm

FIGURE 11

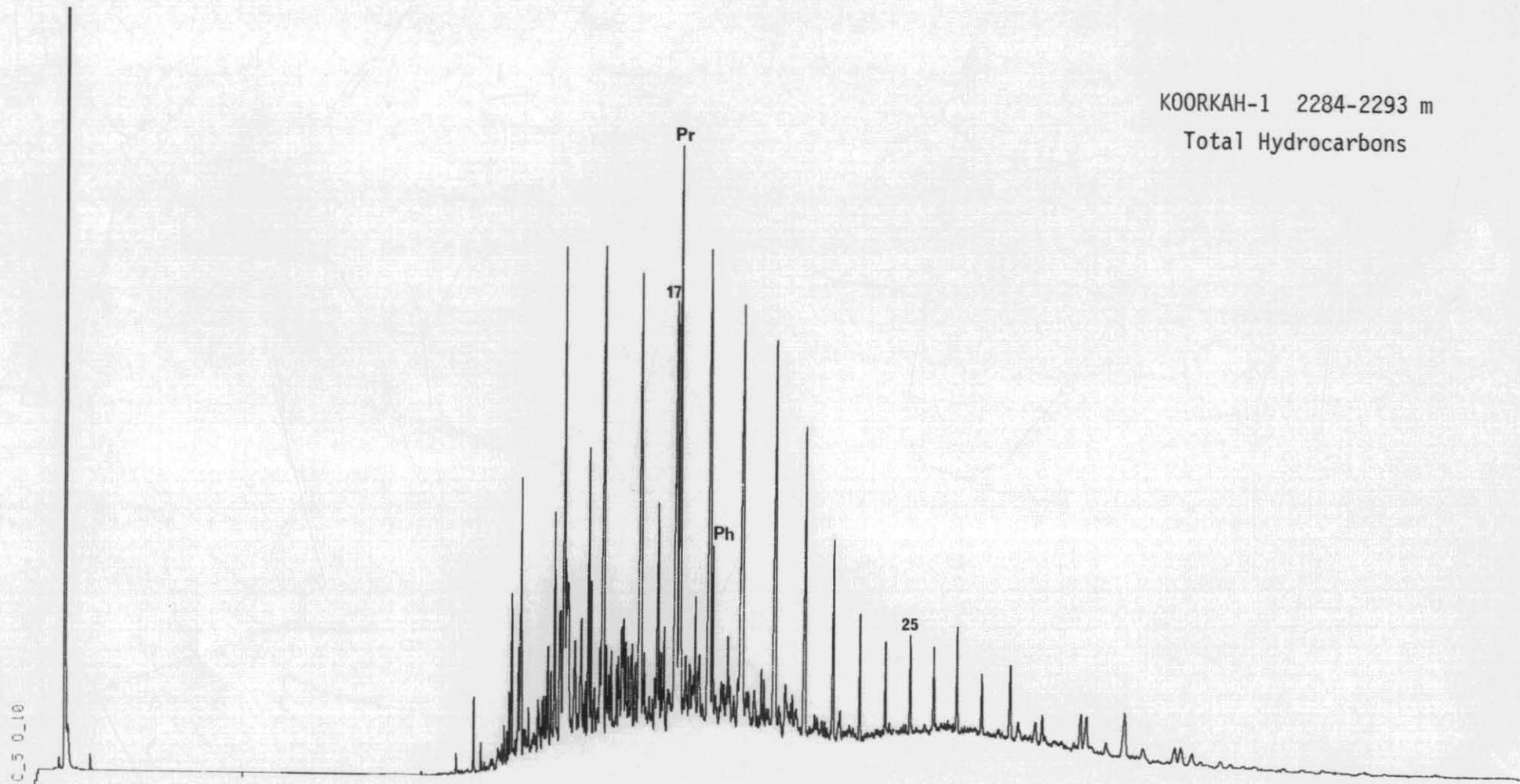
KOORKAH-1 2032-2041 m
Total Hydrocarbons



5 cm

FIGURE 12

KOORKAH-1 2284-2293 m
Total Hydrocarbons

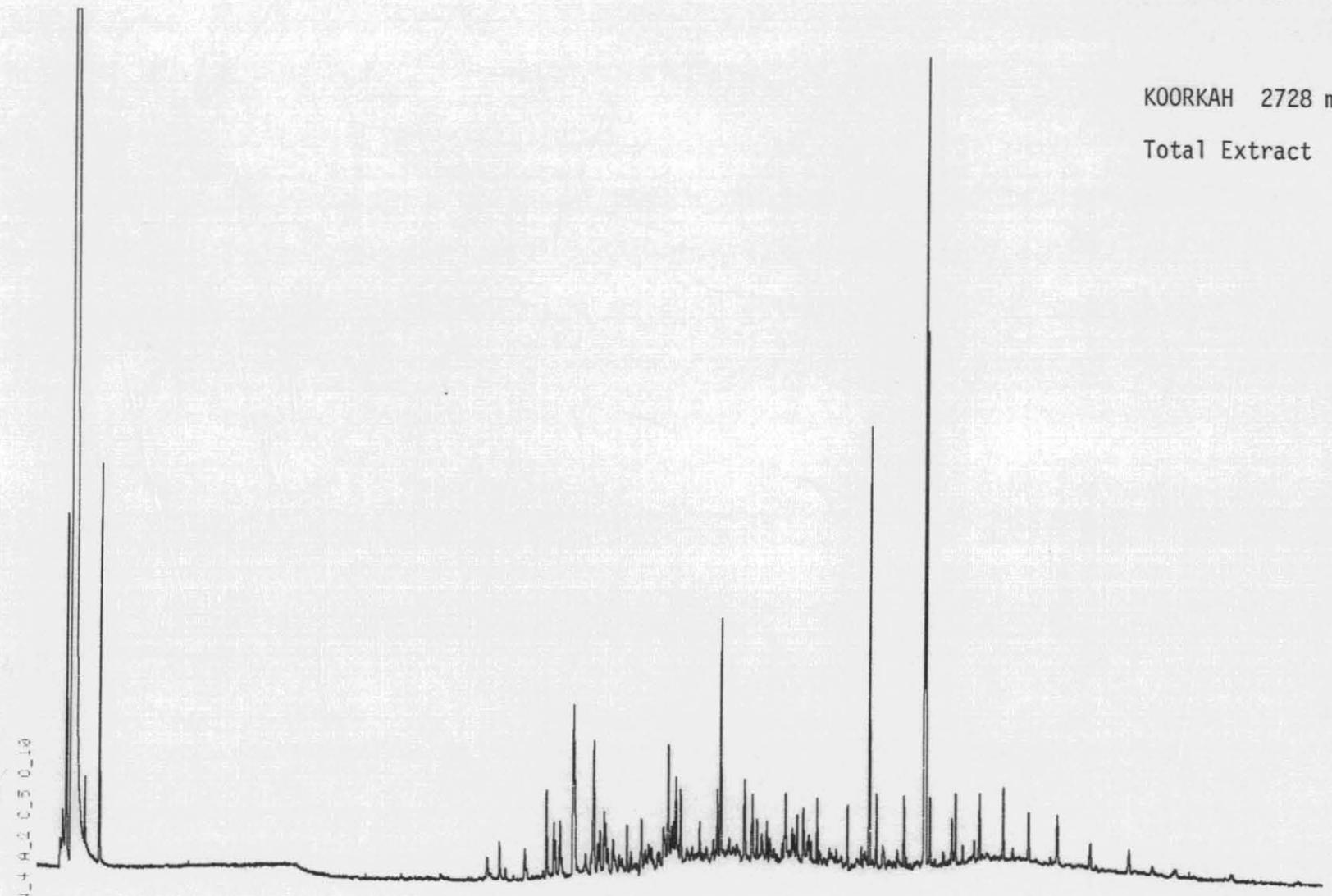


280031

5 cm

FIGURE 13

KOORKAH 2728 m
Total Extract



K_4_A_2_C_5_0_10



280032

FIGURES 14-20

PYROLYSIS-GC TRACES OF KEROGENS FROM EASTERN VIEW
COAL MEASURES, KOORKAH-1

Key : A = aromatic hydrocarbon; numbers refer to
carbon numbers of n-alkene/n-alkane
doublets

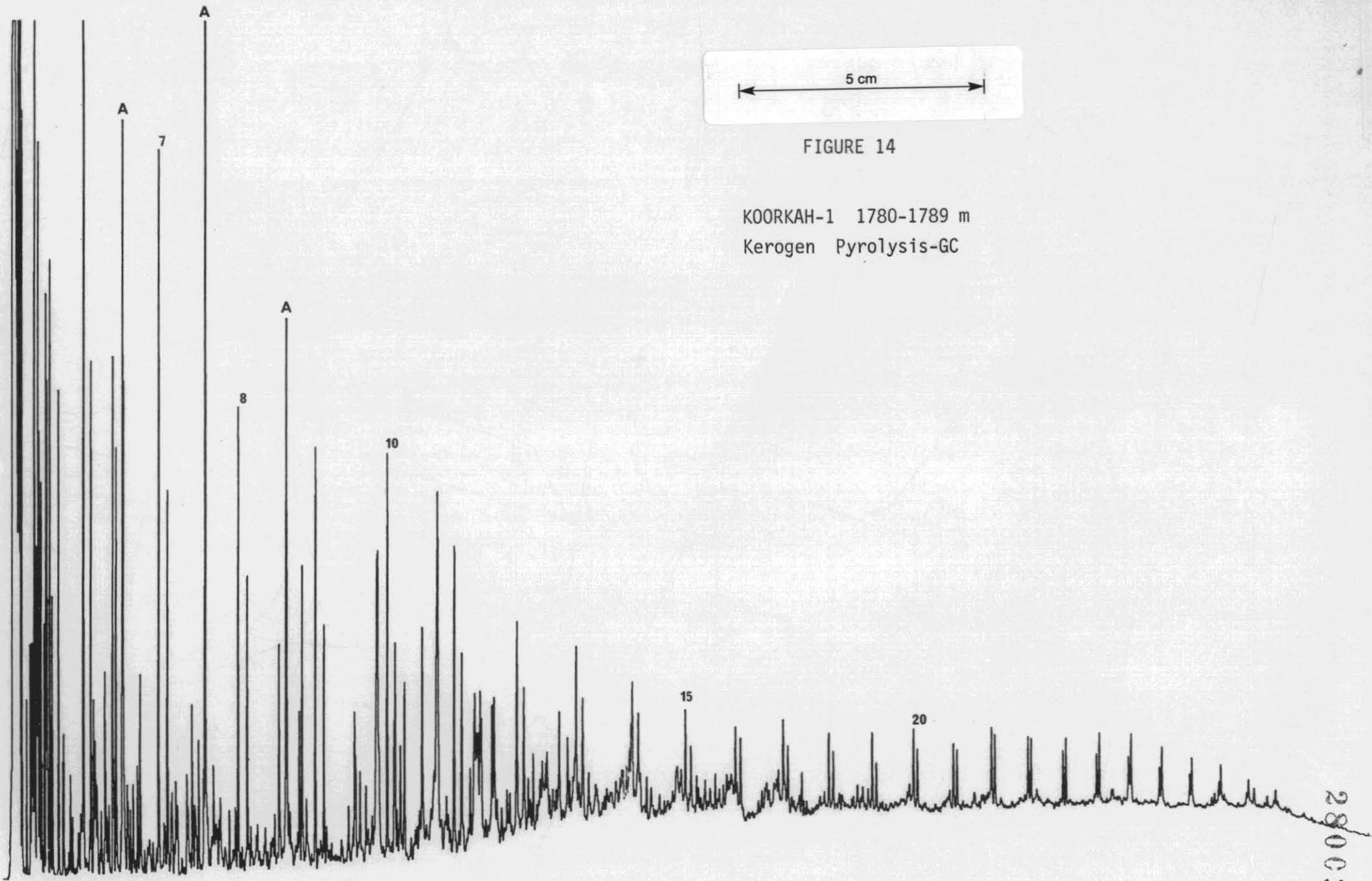


FIGURE 14

KOORKAH-1 1780-1789 m
Kerogen Pyrolysis-GC

280034

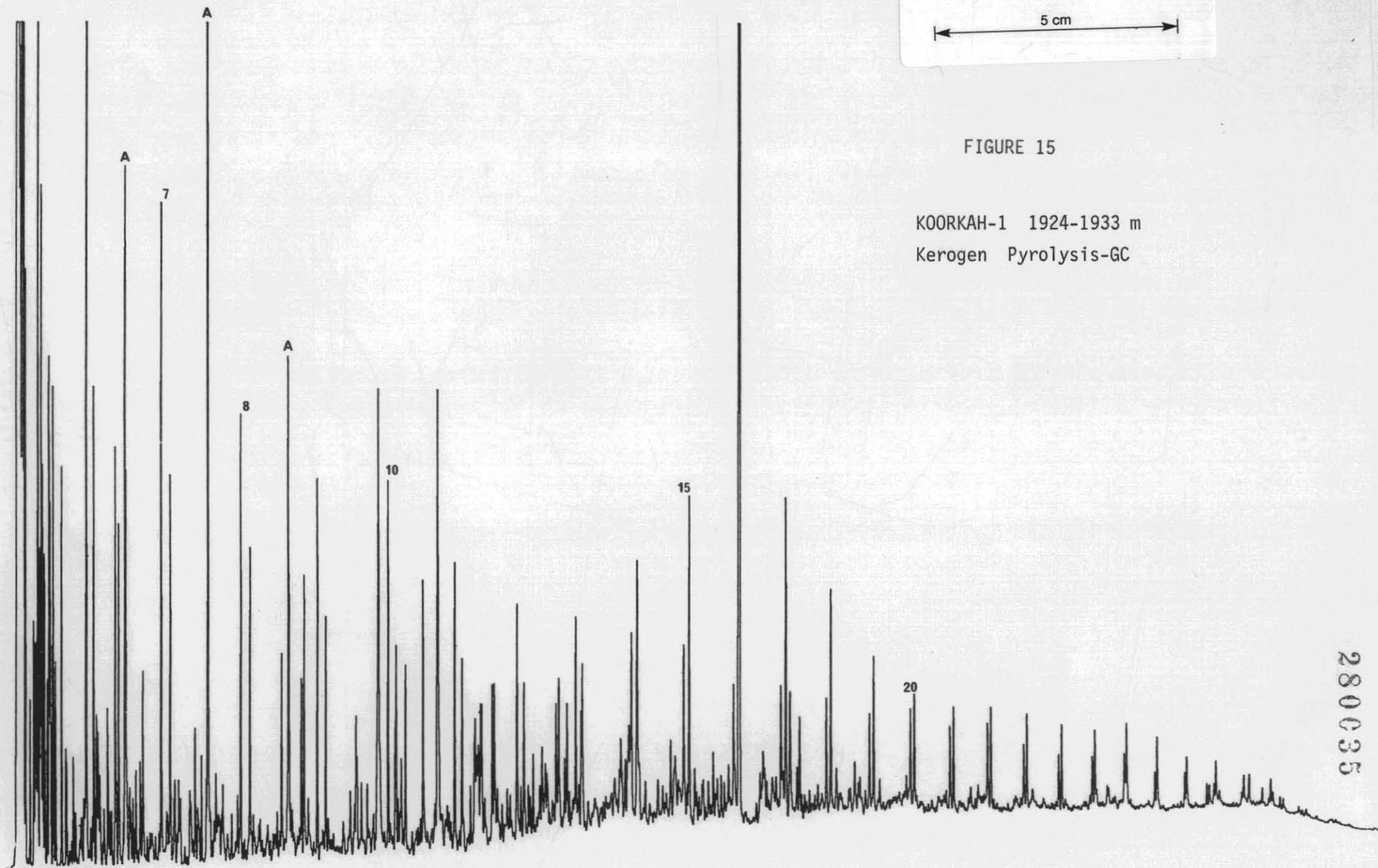


FIGURE 15

KOORKAH-1 1924-1933 m
Kerogen Pyrolysis-GC

280035

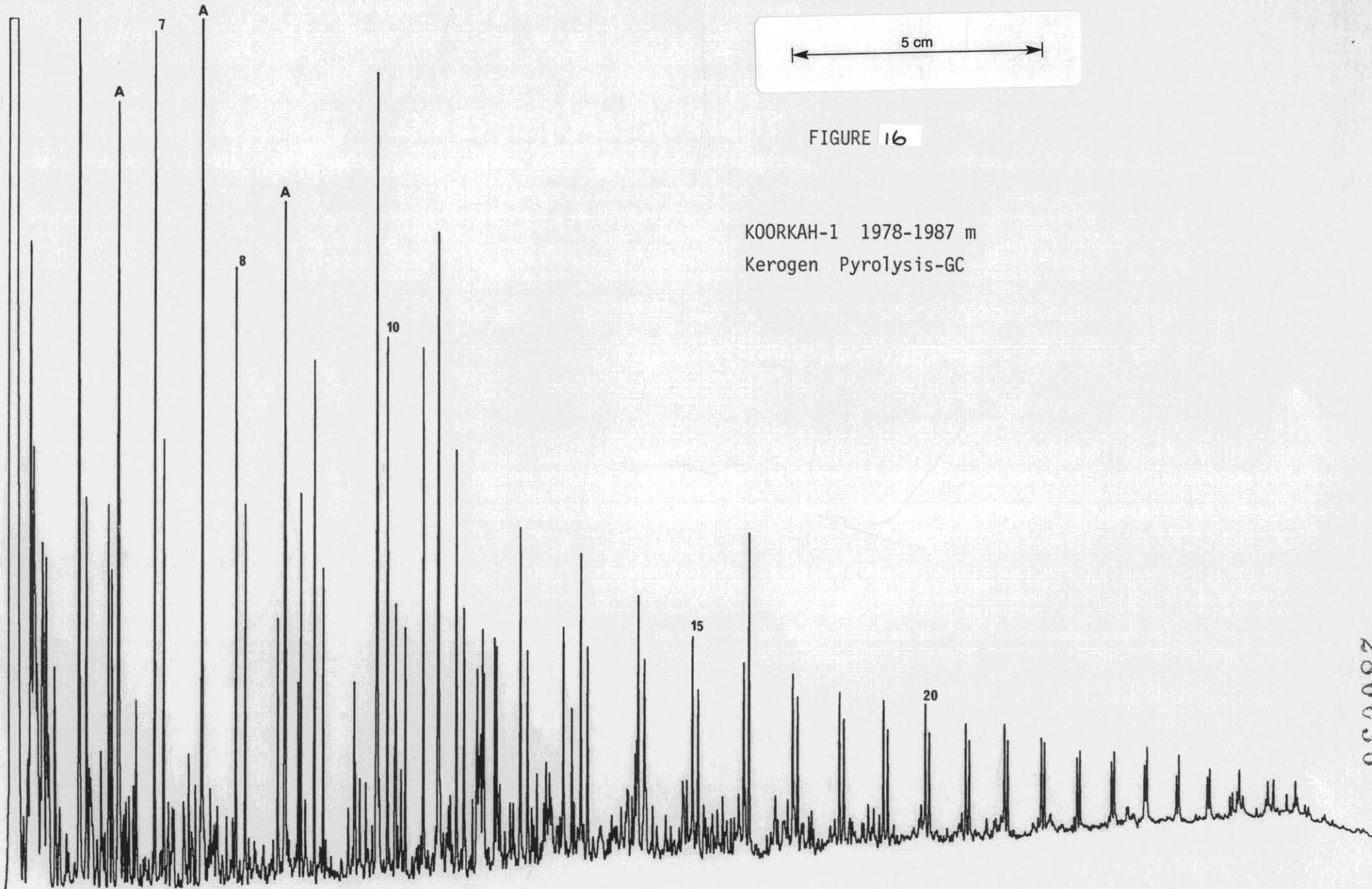


FIGURE 16

KOORKAH-1 1978-1987 m
Kerogen Pyrolysis-GC

280036

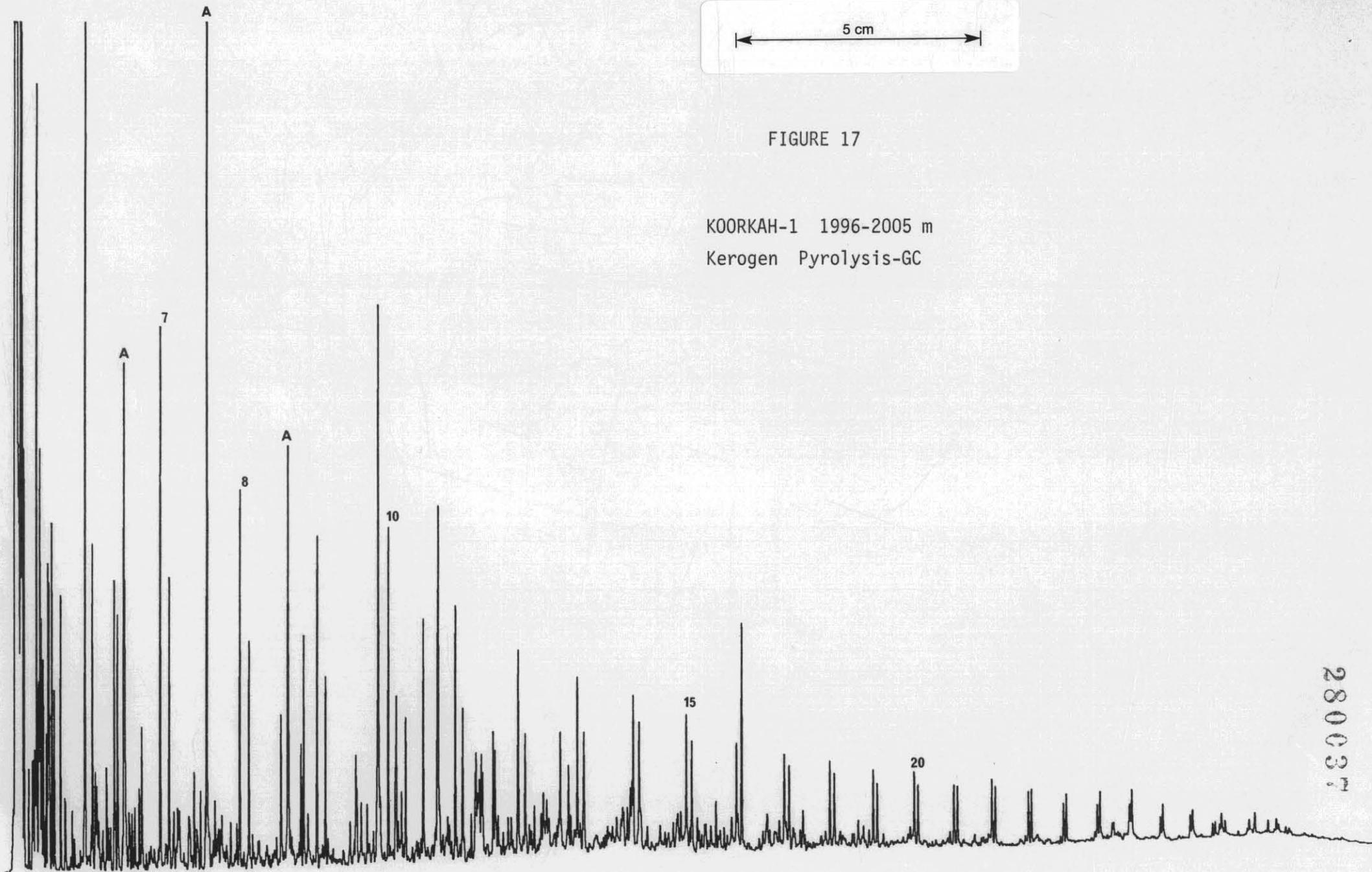


FIGURE 17

KOORKAH-1 1996-2005 m
Kerogen Pyrolysis-GC

280037

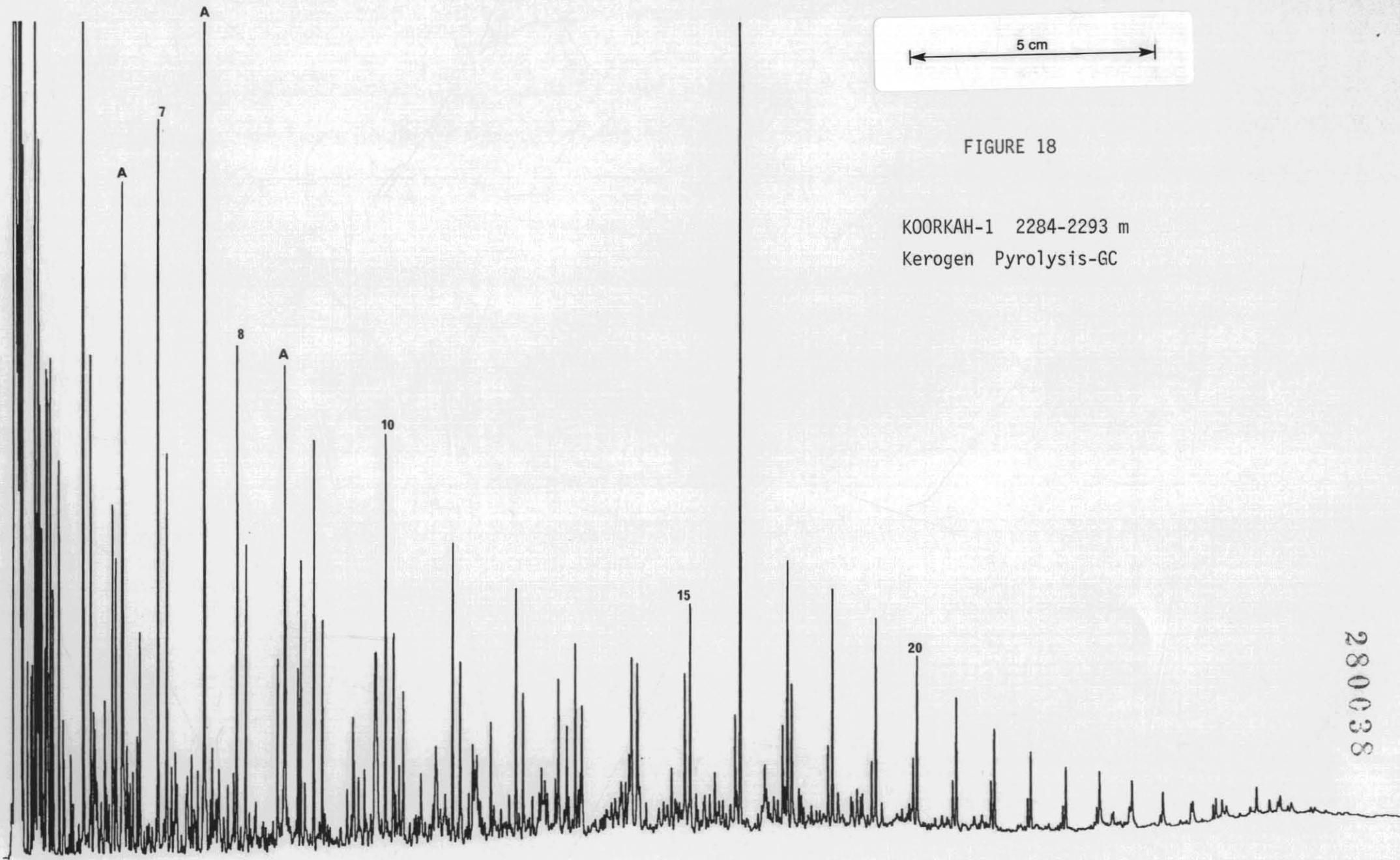


FIGURE 18

KOORKAH-1 2284-2293 m
Kerogen Pyrolysis-GC

280038

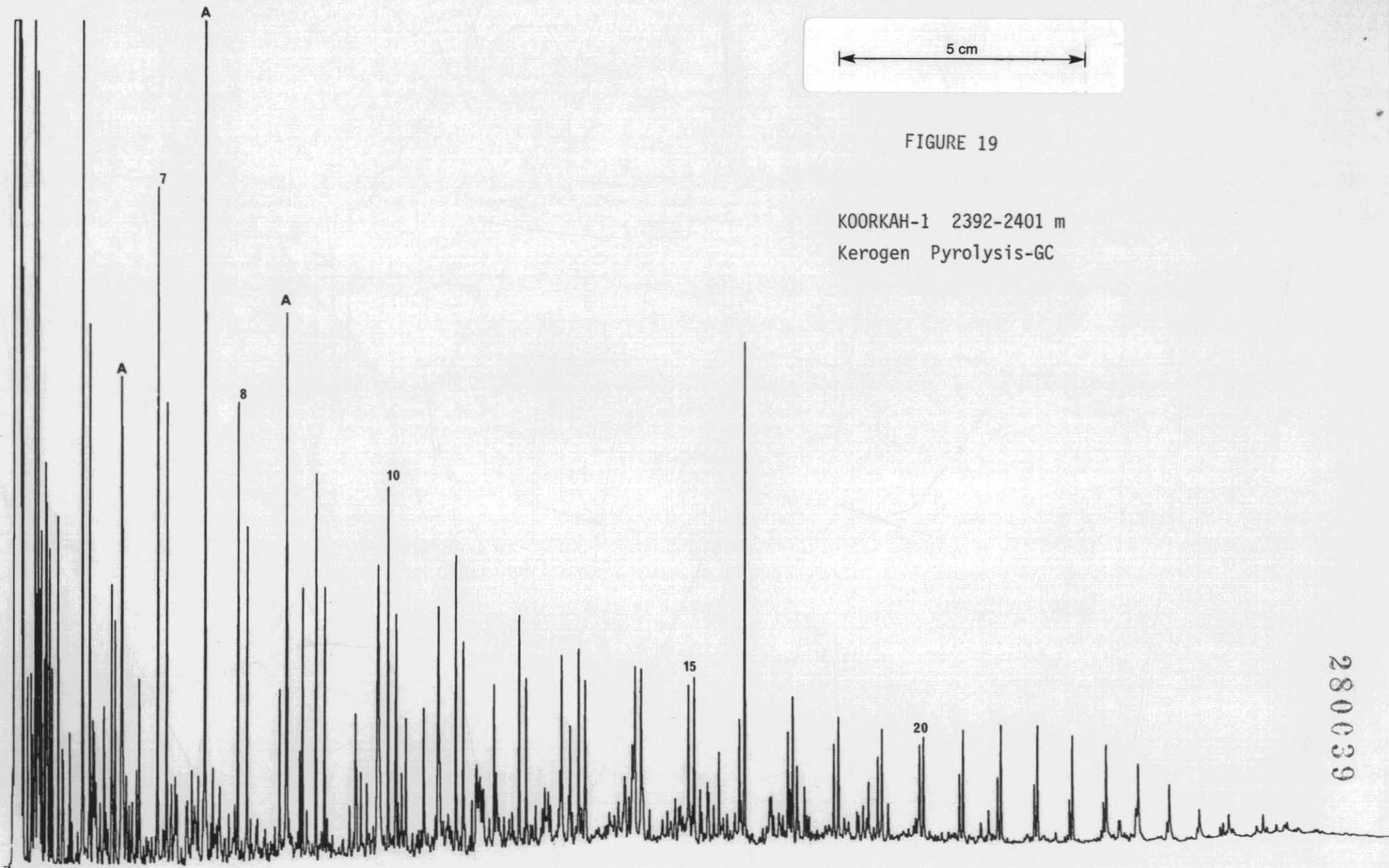


FIGURE 19

KOORKAH-1 2392-2401 m
Kerogen Pyrolysis-GC

280039

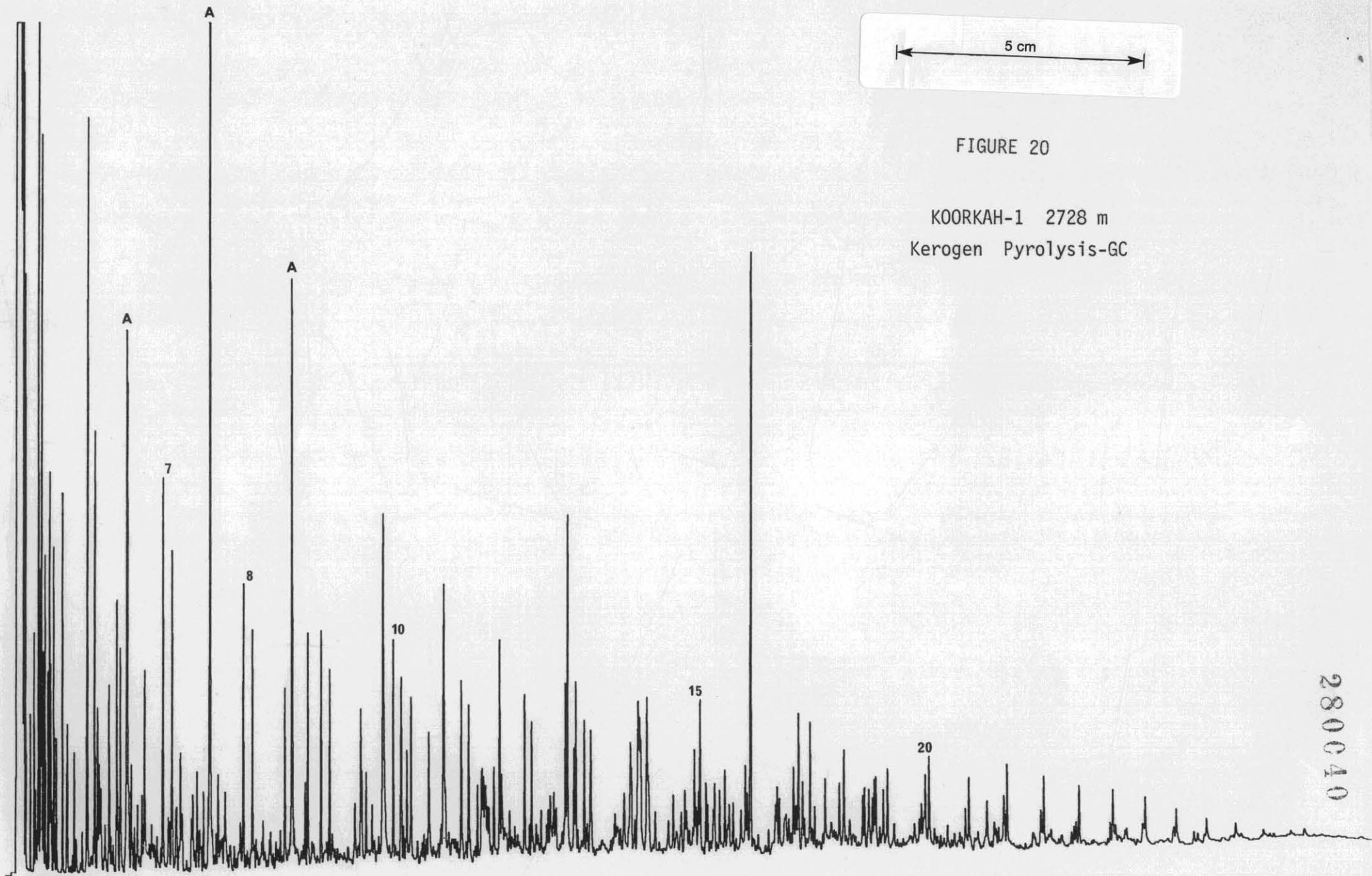


FIGURE 20

KOORKAH-1 2728 m
Kerogen Pyrolysis-GC

280040

APPENDIX 1

ANALYTICAL METHODS

1. HEADSPACE GAS (C₁-C₅₊)

A silicone rubber septum was glued to the lid of each can. The lid was punctured through the septum and a 5 ml sample of headspace gas withdrawn with a gas-tight syringe. Cans were not shaken prior to sampling. The sample was analysed by gas chromatography using the following instrumental parameters:

| | |
|---------------------|---|
| Gas chromatograph: | Perkin Elmer Sigma 2 fitted with flame ionisation detector |
| Column: | 6' x 1/8" i.d. copper packed with activated alumina (80-100 mesh) |
| Column temperature: | 40-275°C at 15° per minute |
| Carrier gas: | N ₂ |
| Quantitation: | Peak areas integrated with Perkin Elmer Sigma 10 Data System. Peak areas calibrated against a standard mixture comprising 100 ppm of each of methane, ethane, propane, n-butane, n-pentane and n-hexane in N ₂ . |

Cuttings gas (C₁-C₄) yields are expressed as ppm by volume of headspace.

$$\text{Percent wet gas} = \frac{C_2-C_4}{C_1-C_4} \times 100\%$$

Also determined from headspace analysis were total C₅₊ hydrocarbon yield (ppm by volume) and i-pentane/n-pentane ratio.

2. SAMPLE PREPARATION

Cuttings were washed in water to remove mud and lost circulation material and then air-dried at 60°. Clean dry cuttings and sidewall cores (scraped free of mud cake) were ground in a Siebtechnik mill for 20-30 secs. In the case of the samples selected for residual oil analysis, aliquots of intact cuttings or sidewall core were set aside for solvent extraction.

3. TOTAL ORGANIC CARBON (TOC)

Total organic carbon was determined by digestion of a known weight (≈0.2 g) of powdered rock in 50% HCl to remove carbonates, followed by combustion in oxygen in the induction furnace of a Leco IR-12 Carbon Determinator and measurement of the resultant CO₂ by infra-red detection.

4. ROCK-EVAL ANALYSIS

A 100 mg portion of powdered rock was analysed by the Rock-Eval pyrolysis technique (Girdel IFP-Fina Mark 2 instrument; operating mode, Cycle 1).

5. RESIDUAL OIL ANALYSIS

Intact cuttings and sidewall core chips (13-33 g) were extracted with dichloromethane in Soxhlet apparatus for 4-5 hours. Removal of solvent by careful rotary evaporation gave the crude extract (nominally C₁₅₊ EOM).

In most cases, a total hydrocarbon fraction (saturates and aromatics) was isolated from the EOM by liquid chromatography on activated alumina (sample : adsorbent ratio = 1:100). Hydrocarbons were eluted with petroleum ether/dichloromethane (50:50).

6. GAS CHROMATOGRAPHY (GC)

Total hydrocarbons (or EOM) were examined by gas chromatography using the following instrumental parameters:

| | |
|-----------------------|---|
| Gas chromatograph: | Perkin Elmer Sigma 2 fitted with on-column injector |
| Column: | 25 m x 0.3 mm fused silica, SGE QC3/BP1 |
| Detector temperature: | 300°C |
| Carrier gas: | He at 85 kPa |
| Column temperature: | 100-290°C at 5° per minute and held at 290°C until all peaks eluted |
| Quantification: | Relative concentrations of individual normal and iso-prenoid alkanes obtained by measurement of peak areas with a Perkin Elmer LCI-100 integrator |

7. KEROGEN ISOLATION AND PYROLYSIS-GC

Solvent-extracted rock powder was forwarded to Laola Pty Limited, Perth, for kerogen isolation by a standard palynological acid digestion technique.

Kerogen concentrates were then submitted to the Petroleum Geochemistry Group, Western Australian Institute of Technology for analysis by pyrolysis-GC using a Chemical Data Systems Pyroprobe 120 in the subambient mode.

APPENDIX 2

VITRINITE REFLECTANCE PROFILE, KOORKAH-1
(after Watson, 1986)

VITRINITE REFLECTANCE Vs. DEPTH PLOT, KOORKAH-1

