# DEPARTMENT OF NATIONAL RESOURCES

# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

1978/72

In Confidence



A regression analysis on North Rankin No. 5 -

core porosity against log porosity



by

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## CONTENTS

## SUMMARY

The extensive coring and testing program on North Rankin No 5 afforded the opportunity of correlating core and log derived porosity values. This study assisted in the assessing of the reliability of the BMR LOG4 computer program.

True core depth to log depth matching was achieved by Woodside Petroleum Development (WPD) by their GRAMPER program. The matching has a resolution of about 20 to 30 cm. The core sampling distance was 15 cm (6 inches) but because of the limited accuracy of depth resolution and because the porosity in places fluctuated rapidly between sample points, the fifty cm averaged porosity values were used in the correlation study. A total of 314 data log porosity values were picked to correlate with the same number of core plug porosity values.

WPD introduced a three-fold subdivision (ND, NE, and NF) of the North Rankin cored pay section on the basis of environmental interpretation results (respectively lagoonal, braided, and flood plain-meandering deposits). The data were analysed in these three groups and fair to good porosity correlation was obtained in two (NE and NF).

The sandstone-shale thinly interbedded nature of ND group sands as opposed to the thick NE and NF group sands may be affecting the log responses and thus be a cause of poor correlation in group ND sands.

Overall, the LOG4 computer program is believed to evaluate porosity accurately, particularly where relatively thick uniform sand bodies exist.

## INTRODUCTION

The development of a computer log interpretation program (Kurylowicz, 1978b)required calibration of log-derived porosity values against core porosity values at some stage so that users could be confident in the program's reliability. The evaluation program of North Rankin No 5 afforded an ideal case for calibration. A comprehensive data gathering effort was made in the drilling of the well and included continuous coring through the pay zone, a full logging program, and extensive testing by wire-line, drill-stem, and production tests.

## CORING

The well was continuously cored from 2711 to 3264.6 m in Upper Triassic Mungaroo sediments. Recovery was 504.17 m out of the total of 547.67 m cut (92%). A total of thirty-nine cores were cut. They were measured, described, photographed, and sampled at the wellsite, then air-freighted to Shell's laboratories at Rijswijk, Holland, for detailed analysis. The cores cut are listed in Table 1.

## WIRE-LINE LOGGING

An exceptionally comprehensive logging program was run on North Rankin No 5, with the view of obtaining complete log data for calibration against cores. The following tools were run in various combinations, over eight open-hole suites plus cased-hole logging (Woodside Petroleum Development Pty Ltd, 1977a):

Dual laterolog simultaneous DLT

Induction spherically focussed ISF

Microlog ML

Microlaterolog MLL

Micro-spherically focussed MSFL

Proximity PML

Spontaneous potential SP

Borehole compensated sonic BHC

Sonic 9 ft/7 ft spacing (excentralised)

Compensated formation density FDC

Compensated neutron CNL

Sidewall neutron porosity SNP

Thermal neutron decay time TDT

Gamma ray GR

Spectral gamma ray

High resolution dipmeter HDT

Borehole geometry tool BGT

Caliper Cal

High resolution thermometer HRT

Redox

Cement bond log CBL

Casing collar locator CCL

Production combination tool PCT

Detailed logged intervals are listed in Table 2.

## TRUE CORE-DEPTH MATCHING

The formation density curve (FDC) of logging suite 7 was declared to be the depth reference log (Woodside Petroleum Development Pty Ltd, 1977b). Core-log depth correlation was achieved by Koninklijke/Shell Exploratie in Produktie Laboratorium (KSEPL) matching a core density log with the FDC log. A description of the method (called GRAMPER) is given below (after Woodside Petroleum Development Pty Ltd, 1977b).

"As an aid to establishing the most probable depth of origin of a certain core interval, the KSEPL laboratory in Rijswijk/Holland has developed gamma-ray absorption recording equipment which provides a detailed density profile of the core for direct correlation with the FDC log.

A section of core, up to 1 m long, is placed on a tray, which slides through a gamma-ray source-detector arrangement. At specified locations the attenuation of the gamma-rays across the core are measured. The resulting point measurements of the average bulk density of the core are then smoothed digitally to arrive at a signal of a smoothness and filtering compatible with the actual FDC signal.

The combined simulated bulk densities of specified lengths of core sections can then be computer matched or manually correlated to the actual FDC log to arrive at a depth correction of core depth to log depth."

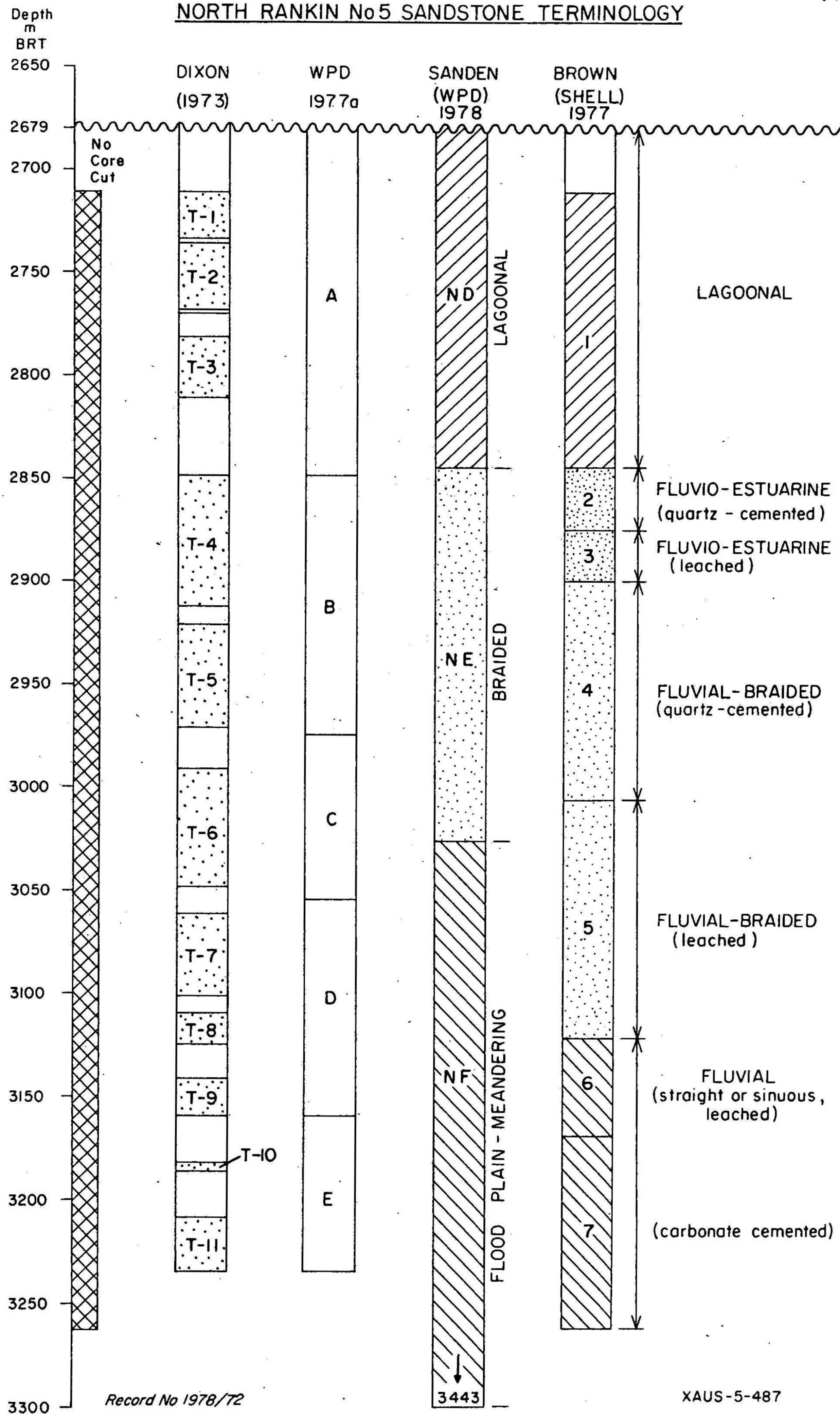
The depth matching has a resolution of only about 20 to 30 cm.

## SANDSTONE TERMINOLOGY AND INTERVALS USED

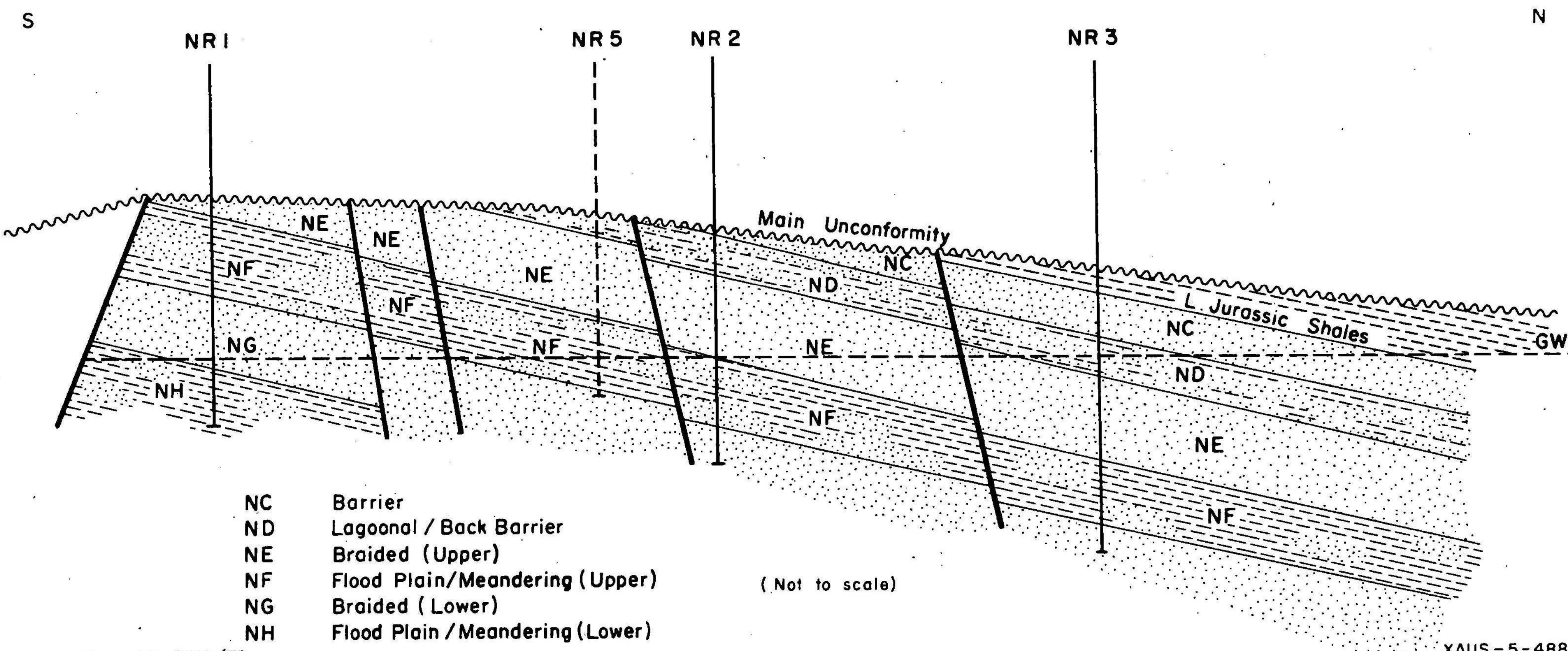
Dixon & others (1973) numbered the Upper Triassic sands in the North Rankin field in descending order, T1 to T20. Woodside Petroleum Development Pty Ltd (1977a) introduced a coarser subdivision of groups A to E (Fig. 1). Brown & others (1977), from the Shell production geology clastics team, introduced a terminology of group 1 to 7 based on environmental interpretation and leaching of cement. The Woodside Petroleum Development production geology team (von Sanden & Turner, 1978) introduced yet another terminology. Three groups ND, NE, and NF were delineated (Fig. 1 & 2) which correspond respectively to lagoonal, braided, and flood plain-meandering environments. The von Sanden & Turner (1978) subdivision was used as the basis of grouping plug core porosity and log porosity data for the purpose of a regression analysis.

Fig. 1

NORTH RANKIN No 5 SANDSTONE TERMINOLOGY



NORTH RANKIN FIELD
Schematic Cross-Section
(after von Sanden & Turner, 1978)




*Record No 1978/72*

Fig. 2

## LOG INTERPRETATION PROGRAM

A log interpretation program (LOG4) which evaluates porosity and water saturation has been developed by BMR (Kurylowicz, 1978b). It uses log values from sonic, neutron, density, and micro-resistivity devices in evaluating final log porosity values. This program supercedes LOG1 (Kurylowicz, 1978a).

## APPLICATION

Log values were read at all significant deflection levels rather than at fixed intervals. The corresponding core plug porosity values averaged over 0.5 m intervals were obtained from Woodside Petroleum Development Pty Ltd (1977b). These were used in preference to the 15 cm (6 inch) interval values because of the resolution of depth matching (20-30 cm) and because plug porosity values in places fluctuated rapidly. Three sets of data were then prepared (ND, NE, and NF Groups) to run through the regression analysis computer program. The regression program (appendix 1) is based on that used by Woodside Petroleum Development (1978). Woodside Petroleum Development used their regression analysis program to test permeability as a function of porosity, water saturation, and gamma ray; cation exchange capacity as a function of porosity and permeability; and mini permeameter permeability as a function of gamma ray. They did not correlate core porosity against log porosity in their report.

## RESULTS AND CONCLUSIONS

Detailed regression analysis results on groups ND, NE, and NF are shown respectively in Tables 3, 4, and 5. The linear equation of best fit is of the form $Y = A + BX$, where

$Y$ = log porosity

$A$ = intercept on the x-axis

$B$ = slope of line

$X$ = core porosity

The regression coefficient ($r^2$) is represented as R2 in the computer program.

ND Group

The equation that resulted after analysis of 65 data points was $Y = 0.074 + 0.55X$. The correlation coefficient R2 (0.17) is not significant.

NE Group

The equation that resulted after analysis of 171 data points was $Y = 0.017 + 0.82X$. The correlation coefficient was equal to 0.53 and is considered to be fair to good.

NF Group

The equation that resulted after analysis of 78 data points was $Y = -0.027 + 1.12X$. The correlation coefficient was equal to 0.71, which is considered to be very good in plug porosity correlation analysis.

The average core porosity for the 314 samples was 0.188 compared to the log value of 0.173.

Unit ND is characterised by a 'rugose' (serrated) gamma-ray log profile that is interpreted to be indicative of a generally thinly interbedded shale and sandstone sequence. This contrasts to groups NE and NF sandstones which are cylinder-shaped in gamma-ray log profile; thus they are thicker, and probably more continuous and extensive than the ND type. The highly interbedded ND group may be affecting log responses.

Heslop (1975) in studying whole core porosity values against log-derived values concluded that log analysis may provide the most meaningful measurement of in-situ proosity in shaly-sand reservoirs. His study showed that humidity-controlled analysis indicated some reduction in the measured porosity as compared to dry core analysis methods for the same core samples.

The reduction in measured porosity increases as the clay volume of the sample increases.

It is not known whether the KSEPL analyses were humidity-controlled or not. However the closeness in overall average porosity values between the core and log derived values suggests good reliability of the LOG4 computer program.

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TABLE 1 NORTH RANKIN NO. 5 CORES

Depths shown are core depths, not corrected to logs

| Core No. | Interval Cut | Interval Recd. | Recovery | % | Remarks |
|---|---|---|---|---|---|
| 1 | 2711.0-2727.0 | 2711.0-2726.18 | 15.8 | 95 | |
| 2 | 2727.0-2744.8 | 2727.0-2744.5 | 17.5 | 98 | |
| 3 | 2744.8-2760.4 | 2744.8-2759.93 | 15.13 | 97 | |
| 4 | 2760.4-2777.7 | 2760.4-2777.7 | 17.27 | 100 | |
| 5 | 2777.7-2795.7 | 2777.7-2795.7 | 18.0 | 100 | |
| 6 | 2795.7-2814.0 | 2795.7-2813.45 | 17.9 | 98 | |
| 7 | 2814.0-2829.6 | 2814.0-2829.6 | 15.59 | 100 | |
| 8 | 2829.6-2848.0 | 2829.6-2847.25 | 17.65 | 96 | |
| 9 | 2848.0-2854.5 | 2848.0-2853.83 | 5.83 | 90 | Cut short due to poor progress. |
| 10 | 2854.5-2863.0 | 2854.5-2862.38 | 7.88 | 93 | Cut short due to mechanical failure. |
| 11 | 2863.0-2871.0 | 2863.0-2870.6 | 7.6 | 95 | |
| 12 | 2871.0-2879.1 | 2871.0-2879.1 | 8.1 | 100 | |
| 13 | 2879.1-2895.85 | 2879.1-2895.85 | 16.75 | 100 | |
| 14 | 2895.85-2908.68 | 2895.85-2908.17 | 12.32 | 96 | Drilled on junk 1.32m gap. |
| 15 | 2910.0-2928.35 | 2910.0-2926.44 | 16.44 | 90 | |
| 16 | 2928.35-2944.8 | 2928.35-2944.8 | 16.45 | 100 | |
| 17 | 2944.8-2963.0 | 2944.8-2963.0 | 18.2 | 100 | |
| 18 | 2963.0-2975.0 | 2963.0-2974.25 | 11.25 | 94 | |
| 19 | 2975.0-2987.5 | 2975.0-2987.14 | 12.14 | 94 | |
| 20 | 2987.5-3005.67 | 2987.5-3003.47 | 15.97 | 88 | |
| 21 | 3005.67-3023.9 | 3005.67-3023.72 | 18.05 | 99.9 | |
| 22 | 3023.9-3040.5 | 3023.9-3037.42 | 13.52 | 81 | Drilled on junk 1.0m gap. |
| 23 | 3041.5-3048.5 | 3041.5-3046.02 | 4.52 | 65 | |
| 24 | 3048.5-3061.0 | 3058.05-3061.0 | 2.95 | 24 | Mechanical failure |
| 25 | 3065.0-3070.0 | 3065.0-3069.14 | 4.14 | 83 | 4m gap. Drilled junk. |
| 26 | 3070.0-3088.0 | 3070.0-3087.96 | 17.96 | 99.8 | |
| 27 | 3088.0-3106.0 | 3088.0-3103.96 | 15.96 | 89 | |
| 28 | 3106.0-3114.5 | 3106.0-3108.78 | 2.78 | 33 | Mechanical failure |
| 29 | 3114.0-3130.67 | 3114.0-3129.35 | 15.35 | 92 | 0.5m depth adjustment |
| 30 | 3130.67-3148.7 | 3130.67-3148.7 | 18.03 | 100 | |
| 31 | 3148.7-3158.14 | 3148.7-3152.6 | 3.9 | 41 | Mechanical failure |
| 32 | 3158.14-3167.04 | 3158.14-3165.82 | 7.68 | 86 | |
| 33 | 3167.04-3185.0 | 3167.04-3184.64 | 17.6 | 98 | |
| 34 | 3185.0-3199.89 | 3185.0-3199.16 | 14.16 | 95 | |
| 35 | 3199.89-3217.0 | 3199.89-3217.0 | 18.11* | 100 | * + 1m |
| 36 | 3217.0-3231.0 | 3217.0-3230.93 | 13.93 | 99.5 | |
| 37 | 32131.0-3249.3 | 3231.0-3248.65 | 17.65 | 96.5 | |
| 38 | 3249.3-3253.0 | 3249.3-3251.82 | 2.52 | 68 | |
| 39 | 3253.0-3264.6 | 3253.0-3264.6 | 11.59 | 100 | |
| | Total cut 547.67 | | 504.17 | 92 | |

TABLE 2. DETAILED LOGGED INTERVALS

| SUITE | LOG | INTERVAL (metres) |
|---|---|---|
| 1 | DLT/SP | 1210 - 448 |
| | BHC/GR | 1215 - 449 (GR to seabed) |
| | CNL/FDC/GR/Cal | 1214 - 449 |
| 2 | DLT/MSFL/SP/Cal/GR | 2712 - 1205 |
| | BHC/GR | 2710 - 1205 |
| | CNL/FDC/GR/Cal | 2712 - 1205 |
| | HDT | 2712 - 1205 |
| 3 | DLT/MSFL/SP/Cal/GR | 2724 - 2400 |
| | BHC/GR | 2722 - 1205 |
| | CNL/FDC/HR/Cal | 2724 - 2400 |
| | SNP | 2724 - 2400 |
| | | 1410 - 1205 |
| | ML/MLL/Cal | 2725 - 2400 |
| | | 1410 - 1205 |
| | ISF/Sonic/SP/GR | 2722 - 2400 |
| | | 1425 - 1205 |
| | HDT | 2723 - 2040 |
| | BGT | 2563 - 1205 |
| | HRT | 0015 - 2724 |
| 4 | DLT/MSFL/SP/Cal/GR | 2907 - 2600 |
| | BHC/GR/Cal | 2902 - 2600 |
| | CNL/FDC/GR/Cal | 2907 - 2600 |
| | SNP/GR/Cal | 2907 - 2600 |
| | ML/MLL/Cal | 2903 - 2600 |
| | HDT | 2902 - 2400 |
| | HRT | 2000 - 2906 |
| 5 | DLT/MSFL/SP/Cal/GR | 3109 - 3675 |
| | Sonic 9ft/7ft spacing | 3104 - 2400 |
| | BHC/GR/Cal | 3106 - 2400 |
| | CNL/FDC/GR/Cal | 3108 - 2675 |
| | Spectral GR | 3075 - 120 |
| | SNP/GR/Cal | 3109 - 2675 |
| | ML/MLL/Cal | 3108 - 2675 |
| | HDT | 3108 - 2590 |
| | HRT | 1196 - 3105 |
| 6 | DLT/MSFL/SP/Cal/GR | 3248 - 2675 |
| 7 | DLT/MSFL/SP/Cal/GR | 3494 - 2675 |
| | DLT/SP/Cal/GR | 3489 - 2400 (Repeat) |
| | BHC/GR | 3494 - 2675 |
| | Sonic 7ft spacing | 3492 - 2675 |
| | CNL/FDC/GR/Cal | 3499 - 2650 |
| | ISF/Sonic/SP/GR | 3490 - 2400 |
| | ML/MLL/Cal | 3491 - 2675 |
| | Proximity | 3496 - 2675 |
| | SNP/GR/Cal | 3492 - 2675 |
| | TDT | 3493 - 1900 |
| | | 1450 - 1150 |
| | HDT | 3495 - 2675 |
| | BGT | 3500 - 1205 |
| | HRT | 1150 - 3494 |
| | Redox | 3494 - 2675 |
| 8 | Cal | 3301 - 2500 |
| Cased hole | CBL/CCL/GR | 3247 - 2360 |
| | HRT | 2000 - 3251 |
| | FDC/GR | 2868 - 2650 |
| | PCT/CCL | Test intervals |

Plus several CCL logs for perforating.

TABLE 3. REGRESSION ANALYSIS RESULTS ON GROUP ND

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NR-5(2679-2844M) ND GROUP. 0001

REGRESSION ANALYSIS RESULTS

| SAMPLE NUMBER | DEPTH (METRES BELOW RT) | X (PRECISELY KNOWN) | Y (IMPRECISELY KNOWN) |
|---|---|---|---|
| 1 | 2714.5 | .291 | .139 |
| 2 | 2715.0 | .291 | .245 |
| 3 | 2715.5 | .229 | .199 |
| 4 | 2716.0 | .273 | .209 |
| 5 | 2716.5 | .283 | .233 |
| 6 | 2717.0 | .292 | .235 |
| 7 | 2718.0 | .284 | .230 |
| 8 | 2718.5 | .284 | .244 |
| 9 | 2736.0 | .262 | .205 |
| 10 | 2736.5 | .237 | .200 |
| 11 | 2735.5 | .207 | .274 |
| 12 | 2738.5 | .295 | .301 |
| 13 | 2739.0 | .300 | .277 |
| 14 | 2739.5 | .226 | .249 |
| 15 | 2740.5 | .263 | .220 |
| 16 | 2741.0 | .261 | .249 |
| 17 | 2746.0 | .270 | .191 |
| 18 | 2747.5 | .268 | .247 |
| 19 | 2748.0 | .278 | .256 |
| 20 | 2748.5 | .288 | .153 |
| 21 | 2749.5 | .239 | .250 |
| 22 | 2751.5 | .259 | .254 |
| 23 | 2752.0 | .268 | .243 |
| 24 | 2753.0 | .275 | .277 |
| 25 | 2754.0 | .276 | .290 |
| 26 | 2756.0 | .268 | .106 |
| 27 | 2761.0 | .231 | .270 |
| 28 | 2766.5 | 172 | .168 |
| 29 | 2767.0 | .206 | .148 |
| 30 | 2768.0 | .202 | .255 |
| 31 | 2768.5 | .237 | .275 |
| 32 | 2784.0 | .255 | .266 |
| 33 | 2785.0 | .287 | .177 |
| 34 | 2787.5 | .220 | .138 |
| 35 | 2788.5 | .256 | .228 |
| 36 | 2790.0 | .266 | .093 |
| 37 | 2790.5 | .211 | .207 |
| 38 | 2793.0 | .224 | .097 |
| 39 | 2794.5 | .243 | .256 |
| 40 | 2796.5 | .169 | .142 |
| 41 | 2797.5 | .144 | .194 |
| 42 | 2798.0 | .244 | .209 |

| | | | |
|---|---|---|---|
| 43 | 2799.0 | .196 | .208 |
| 44 | 2800.0 | .194 | .066 |
| 45 | 2801.0 | .231 | .250 |
| 46 | 2803.5 | .197 | .194 |
| 47 | 2804.5 | .281 | .277 |
| 48 | 2805.0 | .274 | .255 |
| 49 | 2805.5 | .280 | .229 |
| 50 | 2807.0 | .252 | .234 |
| 51 | 2808.0 | .240 | .238 |
| 52 | 2809.5 | .187 | .208 |
| 53 | 2810.0 | .167 | .214 |
| 54 | 2810.5 | .166 | .191 |
| 55 | 2812.0 | .207 | .226 |
| 56 | 2816.0 | .274 | .205 |
| 57 | 2821.5 | .219 | .103 |
| 58 | 2824.0 | .227 | .101 |
| 59 | 2825.0 | .241 | .236 |
| 60 | 2827.5 | .269 | .229 |
| 61 | 2832.5 | .105 | .069 |
| 62 | 2833.5 | .311 | .236 |
| 63 | 2834.0 | .270 | .151 |
| 64 | 2836.0 | .237 | .196 |
| 65 | 2837.5 | .186 | .125 |
| | | AVGE=.242 | AVGE=.208 |

Y = .742152E-01+ .553573 X
R2= .169350

## TABLE 4. REGRESSION ANALYSIS RESULTS ON GROUP NE

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NR-5 (2844-3126M):NE GROUP 0001

### REGRESSION ANALYSIS RESULTS

| SAMPLE NUMBER | DEPTH (METRES BELOW RT) | X (PRECISELY KNOWN) | Y (IMPRECISELY KNOWN) |
|---|---|---|---|
| 1 | 2849.5 | .125 | .142 |
| 2 | 2850.0 | .153 | .048 |
| 3 | 2851.0 | .155 | .112 |
| 4 | 2851.5 | .124 | .118 |
| 5 | 2852.5 | .128 | .101 |
| 6 | 2853.0 | .134 | .110 |
| 7 | 2854.0 | .135 | .094 |
| 8 | 2855.0 | .117 | .115 |
| 9 | 2855.5 | .134 | .118 |
| 10 | 2856.0 | .144 | .118 |
| 11 | 2857.0 | .117 | .134 |
| 12 | 2859.5 | .129 | .073 |
| 13 | 2860.5 | .137 | .116 |
| 14 | 2861.0 | .144 | .160 |
| 15 | 2861.5 | .153 | .164 |
| 16 | 2862.5 | .142 | .152 |
| 17 | 2863.0 | .168 | .156 |
| 18 | 2864.0 | .145 | .148 |
| 19 | 2864.5 | .152 | .151 |
| 20 | 2865.5 | .159 | .157 |
| 21 | 2866.5 | .165 | .160 |
| 22 | 2868.5 | .147 | .099 |
| 23 | 2869.0 | .081 | .110 |
| 24 | 2870.0 | .155 | .132 |
| 25 | 2870.5 | .160 | .126 |
| 26 | 2872.0 | .138 | .128 |
| 27 | 2872.5 | .160 | .119 |
| 28 | 2873.0 | .148 | .125 |
| 29 | 2881.5 | .185 | .172 |
| 30 | 2882.5 | .172 | .186 |
| 31 | 2883.0 | .165 | .143 |
| 32 | 2884.5 | .171 | .168 |
| 33 | 2885.0 | .236 | .186 |
| 34 | 2886.0 | .210 | .176 |
| 35 | 2886.5 | .206 | .214 |
| 36 | 2889.5 | .202 | .186 |
| 37 | 2890.5 | .194 | .188 |
| 38 | 2891.0 | .186 | .162 |
| 39 | 2891.5 | .199 | .172 |
| 40 | 2892.5 | .196 | .150 |
| 41 | 2893.5 | .215 | .209 |
| 42 | 2894.5 | .190 | .187 |

| | | | |
|---|---|---|---|
| 43 | 2896.0 | .194 | .202 |
| 44 | 2896.5 | .176 | .172 |
| 45 | 2897.0 | .218 | .193 |
| 46 | 2897.5 | .229 | .187 |
| 47 | 2898.0 | .219 | .183 |
| 48 | 2902.5 | .167 | .160 |
| 49 | 2903.0 | .180 | .170 |
| 50 | 2903.5 | .175 | .170 |
| 51 | 2904.5 | .183 | .157 |
| 52 | 2905.0 | .172 | .159 |
| 53 | 2905.5 | .154 | .124 |
| 54 | 2907.0 | .141 | .171 |
| 55 | 2907.5 | .169 | .135 |
| 56 | 2908.0 | .126 | .142 |
| 57 | 2908.0 | .126 | .142 |
| 58 | 2908.5 | .146 | .136 |
| 59 | 2910.0 | .131 | .141 |
| 60 | 2910.5 | .150 | .141 |
| 61 | 2911.0 | .160 | .113 |
| 62 | 2912.0 | .158 | .106 |
| 63 | 2922.5 | .135 | .116 |
| 64 | 2923.0 | .139 | .071 |
| 65 | 2923.5 | .126 | .079 |
| 66 | 2924.5 | .128 | .074 |
| 67 | 2925.0 | .143 | .106 |
| 68 | 2926.0 | .119 | .067 |
| 69 | 2926.5 | .125 | .073 |
| 70 | 2927.0 | .123 | .093 |
| 71 | 2928.0 | .136 | .118 |
| 72 | 2928.5 | .130 | .119 |
| 73 | 2929.0 | .160 | .126 |
| 74 | 2930.5 | .140 | .124 |
| 75 | 2931.0 | .130 | .113 |
| 76 | 2931.5 | .138 | .131 |
| 77 | 2932.5 | .149 | .133 |
| 78 | 2933.5 | .112 | .111 |
| 79 | 2934.0 | .125 | .097 |
| 80 | 2938.0 | .086 | .056 |
| 81 | 2938.5 | .131 | .130 |
| 82 | 2939.5 | .109 | .141 |
| 83 | 2940.0 | .139 | .143 |
| 84 | 2940.5 | .141 | .145 |
| 85 | 2941.0 | .161 | .167 |
| 86 | 2941.5 | .153 | .164 |
| 87 | 2943.5 | .162 | .151 |
| 88 | 2944.0 | .160 | .144 |
| 89 | 2945.0 | .134 | .167 |
| 90 | 2945.5 | .145 | .134 |
| 91 | 2946.0 | .148 | .155 |
| 92 | 2947.0 | .147 | .174 |
| 93 | 2947.5 | .183 | .146 |
| 94 | 2948.0 | .134 | .168 |
| 95 | 2849.0 | .152 | .129 |
| 96 | 2950.0 | .159 | .155 |
| 97 | 2950.5 | .174 | .150 |

| | | | |
|---|---|---|---|
| 98 | 2951.0 | .184 | .171 |
| 99 | 2952.0 | .170 | .170 |
| 100 | 2952.5 | .170 | .172 |
| 101 | 2953.5 | .171 | .155 |
| 102 | 2954.0 | .128 | .165 |
| 103 | 2955.0 | .183 | .173 |
| 104 | 2956.0 | .154 | .164 |
| 105 | 2956.5 | .156 | .160 |
| 106 | 2957.0 | .166 | .181 |
| 107 | 2958.0 | .170 | .158 |
| 108 | 2959.0 | .171 | .184 |
| 109 | 2960.0 | .171 | .170 |
| 110 | 2962.0 | .163 | .197 |
| 111 | 2963.0 | .182 | .182 |
| 112 | 2964.0 | .172 | .155 |
| 113 | 2964.5 | .178 | .180 |
| 114 | 2965.0 | .171 | .161 |
| 115 | 2966.0 | .157 | .169 |
| 116 | 2967.0 | .167 | .157 |
| 117 | 2967.5 | .174 | .167 |
| 118 | 2868.0 | .179 | .156 |
| 119 | 2968.5 | .163 | .144 |
| 120 | 2969.0 | .159 | .163 |
| 121 | 2969 5 | .154 | .152 |
| 122 | 2970.0 | .202 | .163 |
| 123 | 2971.0 | .176 | .160 |
| 124 | 2971.5 | .174 | .166 |
| 125 | 2976.0 | .049 | .064 |
| 126 | 2977.0 | .129 | .118 |
| 127 | 2977.5 | .170 | .154 |
| 128 | 2978.0 | .206 | .189 |
| 129 | 2979.0 | .184 | .177 |
| 130 | 2980.0 | .205 | .190 |
| 131 | 2993.5 | .167 | .147 |
| 132 | 2994.0 | .149 | .147 |
| 133 | 2994.5 | .153 | .174 |
| 134 | 2995.5 | .187 | .116 |
| 135 | 2996.0 | .156 | .155 |
| 136 | 2997.0 | .192 | .165 |
| 137 | 2997.5 | .196 | .181 |
| 138 | 2990.0 | .172 | .172 |
| 139 | 2999.5 | .153 | .082 |
| 140 | 3000.0 | .199 | .170 |
| 141 | 3001.0 | .179 | .170 |
| 142 | 3002.0 | .116 | .086 |
| 143 | 3002.5 | .183 | .122 |
| 144 | 3003.0 | .178 | .172 |
| 145 | 3004.0 | .162 | .080 |
| 146 | 3005.0 | .180 | .199 |
| 147 | 3005.5 | .175 | .168 |
| 148 | 3006.0 | .190 | .192 |
| 149 | 3007.0 | .187 | .164 |
| 150 | 3009.0 | .204 | .192 |
| 151 | 3010.0 | .236 | .245 |
| 152 | 3011.5 | .214 | .179 |

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| | | | |
|---|---|---|---|
| 153 | 3012.0 | .237 | .200 |
| 154 | 3014.0 | .240 | .191 |
| 155 | 3014.5 | .243 | .210 |
| 156 | 3015.0 | .216 | .202 |
| 157 | 3015.5 | .231 | .192 |
| 158 | 3016.0 | .234 | .166 |
| 159 | 3017.0 | .208 | .134 |
| 160 | 3021.0 | .160 | .170 |
| 161 | 3022.0 | .196 | .215 |
| 162 | 3022.5 | .200 | .177 |
| 163 | 3023.0 | .172 | .184 |
| 164 | 3023.5 | .183 | .206 |
| 165 | 3025.0 | .167 | .194 |
| 166 | 3025.5 | .212 | .207 |
| 167 | 3026.0 | .167 | .217 |
| 168 | 3027.0 | .211 | .199 |
| 169 | 3029.0 | .145 | .192 |
| 170 | 3029.5 | .216 | .191 |
| 171 | 3032.0 | .197 | .188 |
| | | AVGE=.165 | AVGE=.152 |

Y = .165201E-01+ .820444 X
R2= .533277

TABLE 5. REGRESSION ANALYSIS RESULTS ON GROUP NF

CONFIDENTIAL

NR-5 (3063-3235M) NF GROUP 0001

REGRESSION ANALYSIS RESULTS

| SAMPLE NUMBER | DEPTH (METRES BELOW RT) | X (PRECISELY KNOWN) | Y (IMPRECISELY KNOWN) |
|---|---|---|---|
| 1 | 3063.0 | .227 | .256 |
| 2 | 3063.5 | .207 | .203 |
| 3 | 3064.5 | .211 | .224 |
| 4 | 3065.0 | .222 | .230 |
| 5 | 3065.5 | .230 | .223 |
| 6 | 3069.0 | .240 | .233 |
| 7 | 3069.5 | .218 | .224 |
| 8 | 3071.0 | .210 | .237 |
| 9 | 3072.0 | .227 | .234 |
| 10 | 3072.5 | .232 | .240 |
| 11 | 3073.0 | .234 | .203 |
| 12 | 3074.0 | .235 | .240 |
| 13 | 3074.5 | .220 | .217 |
| 14 | 3075.0 | .258 | .231 |
| 15 | 3076.0 | .245 | .227 |
| 16 | 3076.5 | .184 | .176 |
| 17 | 3077.5 | .215 | .211 |
| 18 | 3078.0 | .214 | .217 |
| 19 | 3079.0 | .215 | .211 |
| 20 | 3079.5 | .214 | .223 |
| 21 | 3080.0 | 231 | .222 |
| 22 | 3081.5 | .184 | .172 |
| 23 | 3082.0 | .193 | .198 |
| 24 | 3083.5 | 215 | .217 |
| 25 | 3084.0 | .219 | .187 |
| 26 | 3086.0 | .181 | .205 |
| 27 | 3087.0 | .209 | .192 |
| 28 | 3087.5 | .214 | .214 |
| 29 | 3088.5 | .172 | .207 |
| 30 | 3089.5 | .208 | .218 |
| 31 | 3090.5 | .218 | .232 |
| 32 | 3091.5 | .149 | .158 |
| 33 | 3092.5 | .209 | .229 |
| 34 | 3094.5 | .196 | .188 |
| 35 | 3096.5 | .204 | .219 |
| 36 | 3098.5 | .213 | .218 |
| 37 | 3101.5 | .224 | .219 |
| 38 | 3116.0 | .198 | .191 |
| 39 | 3116.5 | .174 | .190 |
| 40 | 3117.0 | .173 | .214 |
| 41 | 3118.0 | .229 | .205 |
| 42 | 3119.0 | .229 | .219 |

| | | | |
|---|---|---|---|
| 43 | 3120.0 | .198 | .233 |
| 44 | 3121.5 | .190 | .213 |
| 45 | 3122.5 | .216 | .206 |
| 46 | 2123.5 | .195 | .190 |
| 47 | 3142.0 | .172 | .110 |
| 48 | 3144.5 | .203 | .180 |
| 49 | 3145.0 | .182 | .128 |
| 50 | 3147.0 | .086 | .089 |
| 51 | 3149.5 | .167 | .162 |
| 52 | 3150.5 | .170 | .166 |
| 53 | 3183.5 | .046 | .015 |
| 54 | 3184.0 | .225 | .286 |
| 55 | 3211.0 | .138 | .126 |
| 56 | 3212.0 | .148 | .128 |
| 57 | 3212.5 | .189 | .213 |
| 58 | 3214.0 | .163 | .192 |
| 59 | 3215.0 | .151 | .164 |
| 60 | 3216.0 | .194 | .196 |
| 61 | 3217.0 | .137 | .000 |
| 62 | 3219.0 | .147 | .170 |
| 63 | 3220.0 | .153 | .128 |
| 64 | 3221.0 | .166 | .174 |
| 65 | 3222.0 | .170 | .148 |
| 66 | 3224.0 | .151 | .146 |
| 67 | 3224.5 | .186 | .189 |
| 68 | 3226.0 | .166 | .141 |
| 69 | 3227.0 | .155 | .147 |
| 70 | 3228.0 | .159 | .148 |
| 71 | 3228.5 | .162 | .158 |
| 72 | 3229.0 | .195 | .175 |
| 73 | 3230.0 | .177 | .164 |
| 74 | 3231.0 | .195 | .169 |
| 75 | 3232.0 | .140 | .131 |
| 76 | 3233.0 | .188 | .165 |
| 77 | 3234.0 | .178 | .171 |
| 78 | 3235.0 | .208 | .186 |
| | | AVGE=.192 | AVGE=.188 |

Y = -.271473E-01+ 1.12244 X
R2= .713971

APPENDIX 1. LISTING OF REGRESSION ANALYSIS COMPUTER PROGRAM

```
LES KURYLOWICZ    LKREG
     △TERMINAL      50
OUTPUT LOGICAL UNIT =       6
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```
FTN4,B
      PROGRAM REGAN
C     A PROGRAM TO CALCULATE THE COEFFICIENTS OF A SIMPLE
C     LINEAR REGRESSION  AND THE COEFFICIENT OF CORRELATION
C     PREPARED BY L.E.KURYLOWICZ FEB 1978
C     AFTER CHANCE W.A.,1969-STATISTICAL METHODS FOR DECISION MAKING
C     DPHM - DEPTH IN METRES BELOW ROTARY TABLE
C     X - PRECISELY KNOWN VARIABLE
C     Y - IMPRECISELY KNOWN VARIABLE
C     NSP - NUMBER OF SAMPLES
C     IREG - REGRESSION MANIPULATION CODE:
C        1=DATA AS READ (Y=A+BX)
C        2=TAKE LOGARITHM OF EACH (LOG(Y)=A+BLOG(X))
C        3=TAKE EXPONENTIAL OF EACH (EXP(Y)=AEXP)BX))
C        4=TAKE LOG OF X ONLY (Y=A+BLOG(X))
C        5=TAKE EXPONENTIAL OF X ONLY (Y=AEXP(BX))
      INTEGER TITLE
      DIMENSION ILUN(5),IDCB(144),NAMEF(3),IBUFF(40),
     1 DPHM(500),X(500),Y(500),TITLE(26)
      DATA IBUFF/40*2H  /,TITLE /26*2H  /
      CALL RMPAR(ILUN)
      LX=ILUN
      WRITE(LX,101)
  101 FORMAT("ENTER REGRESSION ANALYSIS DATA FILE NAME")
      READ (LX,102) NAMEF
  102 FORMAT(3A2)
      CALL OPEN(IDCB,IERR,NAMEF)
      IF(IERR.GE.0) GO TO 105
  103 WRITE(LX,104)IERR
  104 FORMAT("IERR =",I4)
C     INCORRECT DATA FILE CALL ESCAPE
      GO TO 1100
  105 CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      CALL CODE
      READ(IBUFF,106)(TITLE(J),J=1,20)
  106 FORMAT(20A2)
C     READ WELL NAME AND DEPTH
      CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      CALL CODE
      READ(IBUFF,107)(TITLE(J),J=21,26)
  107 FORMAT(6A2)
C     READ RUN NUMBER AND DATE (000116-02-78)
      CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      CALL CODE
      READ(IBUFF,*)NSP,IREG
C     READ NUMBER OF SAMPLE POINTS AND REGRESSION CODE
      DO 2000 I=1,NSP
      CALL BLANK(IBUFF)
```

IN CONFIDENCE

CANCELLED

```
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      CALL CODE
      READ(IBUFF,*) DPHM(I),X(I),Y(I)
 2000 CONTINUE
      CALL BLANK(IBUFF)
      CALL READF(IDCB,IERR,IBUFF,40,LEN)
      IF(IERR.LT.0) GO TO 103
      CALL CODE
      READ(IBUFF,*) IEND
 1100 CALL CLOSE(IDCB,IERR)
      IF(IEND.NE.-1) STOP01
C     THE FOLLOWING CONVERTS INPUT DATA TO LOGARITHM AND/OR
C     EXPONENTIAL FORM IF REQUIRED
      DO 2010 I=1,NSP
      IF(IREG.EQ.2.OR.IREG.EQ.4) X(I)=ALOGT(X(I))
      IF(IREG.EQ.2) Y(I)=ALOGT(Y(I))
      IF(IREG.EQ.3.OR.IREG.EQ.5) X=EXP(X(I))
      IF(IREG.EQ.5) Y(I)=EXP(Y(I))
 2010 CONTINUE
C     CALL LEAST-SQUARES SUBROUTINE
  900 CALL LSQ1(X,Y,NSP,A,B,R2)
C     IF(IREG.EQ.2.OR.IREG.EQ.4) A=10.0**A
C     IF(IREG.EQ.3.OR.IREG.EQ.5) A=ALOG(A)
C     PRINT OUT INPUT DATA AND RESULTS
      WRITE(6,201)(TITLE(J),J=1,26)
  201 FORMAT(1H1,2/,50X,"CONFIDENTIAL",/,50X,12("-"),/,
     A 40X,20A2,22X,2A2,5X,4A2,2/)
      WRITE(6,202)
  202 FORMAT(45X,"REGRESSION ANALYSIS RESULTS",2/,
     1 30X,"SAMPLE",10X,"DEPTH",10X,"X",18X,"Y",/,
     2 30X,"NUMBER",9X,"(METRES",3X,"(PRECISELY KNOWN)",
     3 3X,"(IMPRECISELY KNOWN)",/,45X,"BELOW RT)",/)
      DO 2001 I=1,NSP
      WRITE(6,203) I,DPHM(I),X(I),Y(I)
  203 FORMAT (31X,I3,10X,F6.1,7X,F8.3,9X,F8.3)
 2001 CONTINUE
      AVX=0.0
      AVY=0.0
      DO 2002 I=1,NSP
      AVX=AVX+X(I)
      AVY=AVY+Y(I)
 2002 CONTINUE
      AVX=AVX/FLOAT(NSP)
      AVY=AVY/FLOAT(NSP)
      WRITE(6,211)AVX,AVY
  211 FORMAT(56X,"AVGE=",F4.3,8X,"AVGE=",F4.3)
      IF(IREG.EQ.1) WRITE(6,204) A,B
      IF(IREG.EQ.2) WRITE(6,205) A,B
      IF(IREG.EQ.3) WRITE(6,206) A,B
      IF(IREG.EQ.4) WRITE(6,207) A,B
      IF(IREG.EQ.5) WRITE(6,208) A,B
  204 FORMAT(3/,15X,"Y =",G14.6,"+",G14.6,"X")
  205 FORMAT(3/,15X,"LOG(Y) =",G14.6,"+",G14.6,"LOG(X)")
  206 FORMAT(3/,15X,"EXP(Y) =",G14.6,"EXP(",G14.6,"X)")
  207 FORMAT(3/,15X,"Y =",G14.6,"+",G14.6,"LOG(X)")
```

```
  208 FORMAT(3/,15X,"Y =",G14.6,"EXP(",G14.6,"X)")
      WRITE(6,209) R2
  209 FORMAT(15X,"R2=",G14.6)
      WRITE(LX,210)
  210 FORMAT("PROGRAM REGAN COMPLETED")
      STOP02
      END
      SUBROUTINE BLANK(IBUFF)
C     THIS SUBROUTINE CLEARS ARRAY "IBUFF" BETWEEN READ STATEMENTS
      DIMENSION IBUFF(40)
      DO 100 I=1,40
      IBUFF(I)=2H
  100 CONTINUE
      RETURN
      END
      SUBROUTINE LSQ1(X,Y,NSP,A,B,R2)
      DIMENSION X(500),Y(500)
      SX=0.0
      SY=0.0
      SX2=0.0
      SY2=0.0
      SXY=0.0
      DO 10 I=1,NSP
      T1=X(I)
      T2=Y(I)
      SX=SX+T1
      SY=SY+T2
      SX2=SX2+T1*T1
      SY2=SY2+T2*T2
      SXY=SXY+T1*T2
   10 CONTINUE
C     B - SLOPE OF LINE
C     A - INTERCEPT GIVING ESTIMATED VALUE OF Y AT X=0.0
C     R2 - CORRELATION COEFFICIENT
      EN=NSP
      B=(SXY-SX*SY/EN)/(SX2-SX*SX/EN)
      A=(SY/EN-B*SX/EN)
      R=(SXY-(SX*SY/EN))/(SQRT(SX2-SX*SX/EN)*(SQRT(SY2-SY*SY/EN)))
      R2=R*R
      RETURN
      END
      END$
```