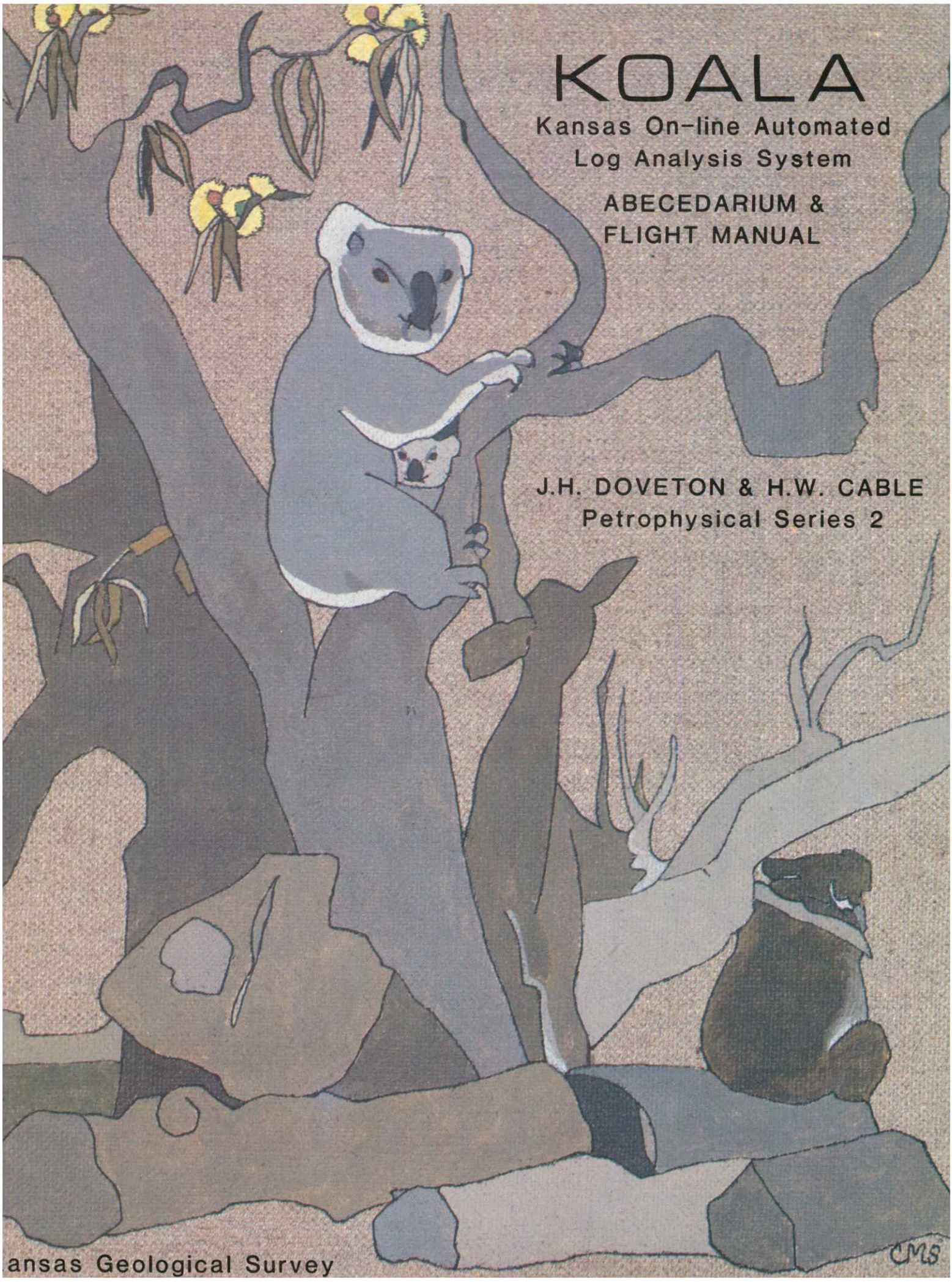
KOALA
Kansas On-line Automated
Log Analysis System
ABECEDARIUM &
FLIGHT MANUAL
J.H. DOVETON & H.W. CABLE
Petrophysical Series 2
ansas Geological Survey
CMS

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KOALA

Kansas On-line Automated
Log Analysis System

ABECEDARIUM &
FLIGHT MANUAL

John H. Doveton
and
Harold W. Cable

1980

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ACKNOWLEDGMENTS

The development of KOALA has benefitted from the thoughtful suggestions, provisions of study material, aid in algorithm design, and field trial reports by the following individuals: Ted Bornemann, Curt Conley, John Davis, Jim Ebanks, Dean Lebestky, Roberto Peveraro, and Lynn Watney. The manual cover illustrations were painted by Celia Smith, Lawrence artist. Some of the tool names mentioned in the manual text (such as SNP and CNL), as well as geographical techniques (such as M-N plot and Z-plot), are registered trademarks of Schlumberger, Ltd. KOALA is marketed under exclusive license by Terradata, Inc., Suite 400, 609 Mission Street, San Francisco, CA 94105, under the tradename, TERRALOG®.

INTRODUCTION

The proliferation of computers in the petroleum industry over the last two decades has led to an increasing emphasis on machine processing and analysis of borehole logs. This development has been welcomed (sometimes grudgingly) by petrophysicists as a partial solution to the problems of their work. Logging programs on typical modern wells routinely generate monumental quantities of data which threaten to overwhelm the log analyst.

In common with bankers, airline reservation agents, magazine subscription departments and others, the log analyst has recognized that the computer is an excellent means to process large quantities of information. In addition, standard log analysis procedures generally have proved to be trivial exercises in programming, since they are transparent mathematical metaphors of simple chart-book solutions. Almost all routine log analysis operations can be performed on inexpensive programmable calculators, as demonstrated in a recent series of articles in The Log Analyst.

Nevertheless, seasoned log analysts have found sound reasons to be dissatisfied with the performance of computer analyses as consistently reliable estimators of petrophysical parameters. Although many log analysis models have proven general applicability, the varied interplay of subsurface geology, borehole conditions and tool malfunctions frequently introduce problems which are difficult to resolve by unaided computational methods. The "unknowns" of the problem often exceed the explicit information content of the logs.

However, the log analyst is generally able to use his "experience" to attain solutions which, if not correct, are at least the most consistent interpretations of the available data. At a primary level, experience involves knowledge of the constraints of the natural world. For example, porosities can never be negative and cannot exceed a value that is consistent with a supportive rock framework; similarly, proportional water saturations are constrained between values of zero and one (allowing for measurement error). At a secondary level, experience observes that computed water resistivities should conform approximately to regional patterns, unless there are anomalous local conditions; and mineralogical assemblages should form rational lithologies.

The enormous ramifications of the "experience factor" are impossible to codify in a useable computer program. However, it is possible to assign responsibilities to man and computer which reflect their respective strengths in a coordinated strategy of analysis. The computer can rapidly solve complex equations without error and process large quantities of information. The log analyst can make fundamental decisions concerning the sequence of operations, engage in pattern recognition tasks and evaluate the quality of intermediate results. A certain element of "intelligence" can be incorporated into the computer operations by generating "diagnostics" which alert the user to inconsistencies in analysis.

The cooperation between computer and log analyst is extremely cumbersome in batch mode, when interaction has all the immediacy of postal chess. Fortunately, the current generation of minicomputers and time-sharing facilities has made real-time interaction a routine event.

Increasingly, there are signs that log analysis is coming of age. At a superficial level, this is reflected in the modern use of the term "petrophysics" as a discipline to replace the pragmatism of old-style log analysis. In part, this has been caused by the growing variety of logging tools and their broader range of applications. The rapidly escalating costs of modern wells and shortages of petroleum have placed heavier demands on petrophysicists for comprehensive, accurate analysis of log suites. Results from core analyses are increasingly being used as aids in log analysis, rather than being viewed as a rival source of information.

These developments have been influential in the design of the KOALA log analysis package at the Kansas Geological Survey. KOALA is an interactive system of log analysis routines which operates in real-time, using a conversational link between user and machine. Although the system has immediate applications in the petroleum industry, KOALA has been developed as a more comprehensive tool for the evaluation of any subsurface problem for which borehole geophysical measurements provide useful information. Potential applications exist in subsurface stratigraphy, geothermal appraisal, hydrology, seismic studies and exploration for minerals. The

divisions between these areas are artificial; this is readily apparent if borehole geophysics is regarded as a specialized branch of remote sensing.

The physical measurements made by logging tools in boreholes are frequently the same as those made by sensors on oceanographic vessels, orbiting satellites and interplanetary probes. Interpretation of remotely sensed data has relied heavily on machine processing, often using complex algorithms drawn from fields of pattern recognition and general mathematical theory. Procedures have been coded in KOALA which allow the user to engage in numerical analyses which are not normally part of a conventional log analysis package. These KOALA options do not substitute for analytical skills, but have been introduced as an aid in comprehensive evaluation.

A crucial feature of KOALA is its flexibility, both in the input and output of data and in its programmed operations. Although KOALA has been designed to operate with geophysical logs, there is no intrinsic reason why other sources of information cannot be incorporated, such as geochemical measurements or core analyses. The coding of the system has been written in FORTRAN, partly to gain access to a wide variety of machines, but also to allow the user to modify routines or add routines of his own devising. This feature will enable KOALA to evolve beyond the system described in this manual.

As a final note, we suggest an operational philosophy in the application of KOALA to real problems. The interactive element of the system is the key to successful analysis. There are no "approved" methods, but rather operational possibilities. The "success" of any KOALA analysis is a function of the skill of the user. A sequence of KOALA operations should be viewed as a dialog between the user, the system and the data, during which the user attempts to synthesize all available information, including that drawn from his experience.

We refer to this complex pattern of behavior as "wrangling." A wrangler has been variously defined as a disputant, a cowboy or herdsman, a First in mathematics at Cambridge and a codebreaker in counter-espionage. The successful KOALA user should combine attributes from all these individuals. Happy wrangling!

BASIC OPERATIONAL FEATURES

The separate elements of a comprehensive hardware configuration to run KOALA are:

- Computer — either a minicomputer with 32K core of 16 bit words, or a main-frame computer with time-sharing capability
- Mass storage device — disk, floppy disk or cassette tape system
- Graphics terminal — with teletype input, teletype output and graphics output
- High-speed printer/plotter
- Tape drive — 7 or 9 track , 800 bpi
- Digitizing table
- Drum or flat-bed plotter

The system components used in the development of KOALA at the Kansas Geological Survey are shown in Figure 1. Several of the units are optional and the crucial elements for minimal KOALA operation are a computer, storage device and graphics terminal.

KOALA software is written in ANSI "standard" FORTRAN IV with a minimum of machine-dependent features associated with the Data General Eclipse S/230 minicomputer, Tektronix 4014 graphics terminal and Xynetics 1100 flat-bed plotter in use at the Kansas Geological Survey. The choice of language was dictated partly by a desire to ensure that KOALA could be installed on a wide variety of computer systems. Secondarily, the FORTRAN coding should encourage users to modify and augment KOALA options for novel applications. In this way, the KOALA system has the potential to evolve and diversify into a variety of forms.

The alternatives for data entry of digital logs are either via field tapes, digitizing device or manual input. The incremental depth of the digitized interval is set by the user. Since the "standard conventions" for digital log tape formats are both legion and mutable, KOALA has its own starkly simple format code. Each digitized log is preceded by an optional 72-character title card, containing information regarding the well and log

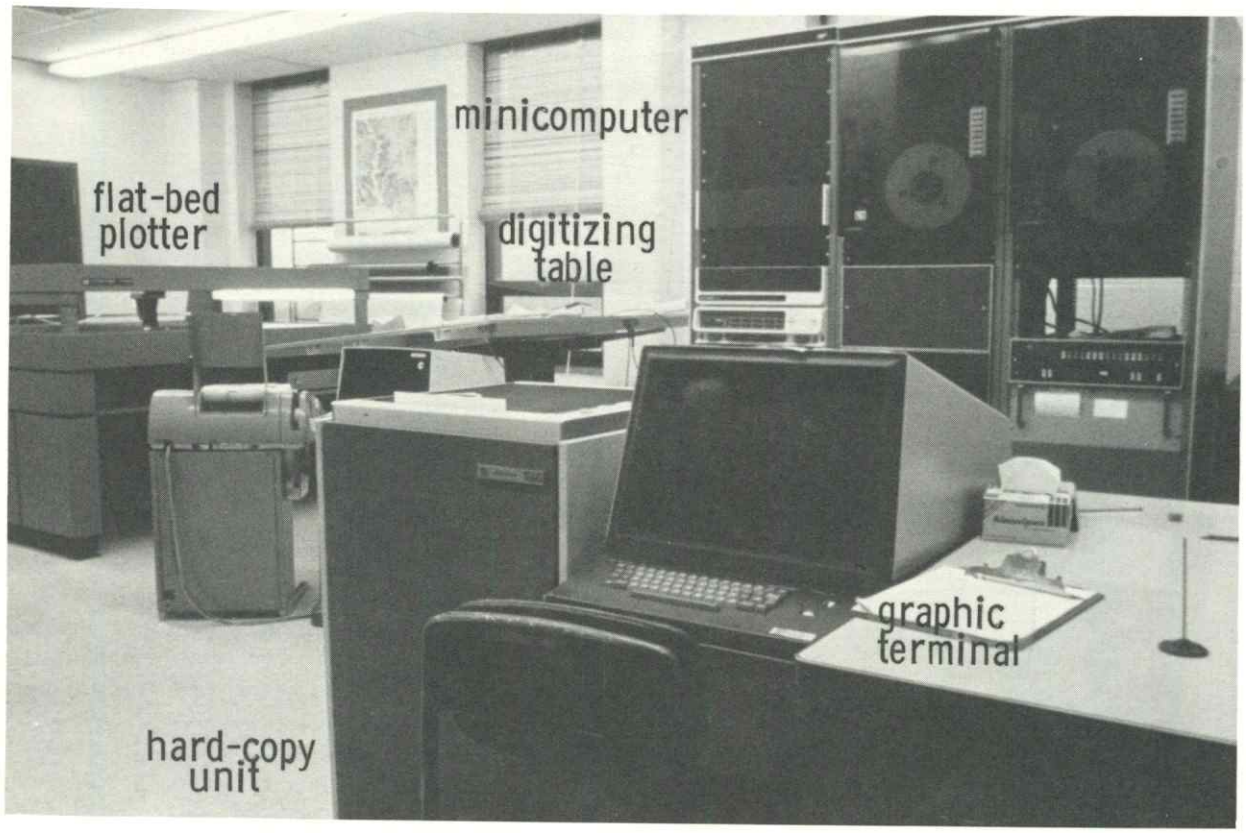

FIGURE 1: Hardware configuration used by Kansas Geological Survey for KOALA implementation.

type. This identifier is followed by the log string of paired depth and response values in (F12.5, 2X, F12.5) format, terminated by two -1 values. The convention is obviously useful for input from a digitizing device and presents no major problems for field entry via a buffer program. All forms of data entry into KOALA are initiated internally by a conversational sequence of commands from the control module.

Each well is assigned a separate file consisting of a "constants area" and a series of "channels." Global parameters (well location, mud filtrate resistivity etc.), usually written on the header of a conventional blue-line log, are entered in the constants area. There are 60 constant locations available, of which only a portion are preassigned as identified in Table 1.

TABLE 1: KOALA constants designations.
Details are given in Appendix 1. (Note that this and many other tables are reproduced directly from KOALA output displayed on the Tektronix screen.)

```
WELL NAME:
 LOCATION:
     DATE:
          01=MINIMUM DEPTH                02=MAXIMUM DEPTH
          03=INCREMENT                    04=ELEVATION
          05=LATITUDE                     06=LONGITUDE
          07=RM                           08=TRM
          09=RMF                          10=TRMF
          11=RMC                          12=TRMC
          13=BHT                          14=MEAN-T
          15=T-GRADIENT                   16=TIME-C-GR
          17=TIME-C-N                     18=LOG SPEED GR
          19=LOG SPEED N                  20=TD
          21=                             22=
          23=                             24=
          25=                             26=
          27=                             28=
          29=                             30=
          31=                             32=
          33=                             34=
          35=                             36=
          37=                             38=
          39=                             40=
          41=                             42=
          43=                             44=
          45=                             46=
          47=                             48=TOP VIOLA
          49=TOP SIMPSON                  50=TOP ARBUCKLE
          51=                             52=
          53=                             54=
          55=                             56=
          57=                             58=
          59=                             60=
```

The remaining "anonymous" constants are open to user stipulations, and are used typically for the entry of stratigraphic tops.

The digitized logs for the well are stored in appropriate channels within a set of 55, whose identifiers are shown in Table 2. The first 20 channels are set aside for input log data, while the remaining 35 are reserved for log transforms, generated by KOALA log analysis programs. As in the constants area, several channels are left blank for user designation. There is no intrinsic distinction between log and transform channels, so that the advanced KOALA user is free to preempt channels and reassign identities and contents almost at will. This fundamental flexibility of the KOALA system will become more apparent in the review of the operational characteristics of the control module.

TABLE 2: KOALA channel designations.
Details are given in Appendix 1.

```
01=DEPTH                02=SP                   03=GR
04=DENSITY              05=SONIC                06=GNT/SNP %
07=CNL %                08=NEUTRON COUNT        09=LL8
10=ILM                  11=ILD                  12=DEEP LATEROLOG
13=MICRORESISTIVITY     14=AZIMUTH              15=DIP
16=TEMPERATURE          17=INTEGRATED SONIC     18=CALIPER
19=                     20=                     21=PETRA SS
22=PETRA LS             23=PETRA DOL            24=PETRA SH
25=PETRA AN             26=PETRA HL             27=PETRA CL
28=PETRA POR            29=PETRA 2POR           30=PHIRA
31=SX0                  32=SW                   33=K
34=DI                   35=RT                   36=RX0
37=RWA                  38=M                    39=N
40=P                    41=ARCHIE M             42=SYNTH SEISM
43=MODEL SONIC          44=MODEL INT SONIC      45=
46=                     47=                     48=
49=                     50=ALPHA                51=BETA
52=GAMMA                53=DELTA                54=EPSILON
55=OMEGA
```

Figure 2 expresses a "mental map" of the KOALA program system linked with the well file contents of the constants area and log transform channels. The central GOPHER module is the KOALA control unit, which provides system management and access to the five other satellite modules. The basic functions of each module are summarized below, and reviewed in the following sections:

GOPHER — Data input, retrieval, modification and display

PETRA — Estimation of the composition and proportions of minerals and porosity types

KOBRA — Reservoir analysis

KERMIT — Dipmeter analysis

SNARK — Synthetic seismic modeling

MERLIN — Multivariate statistical and time series algorithms.

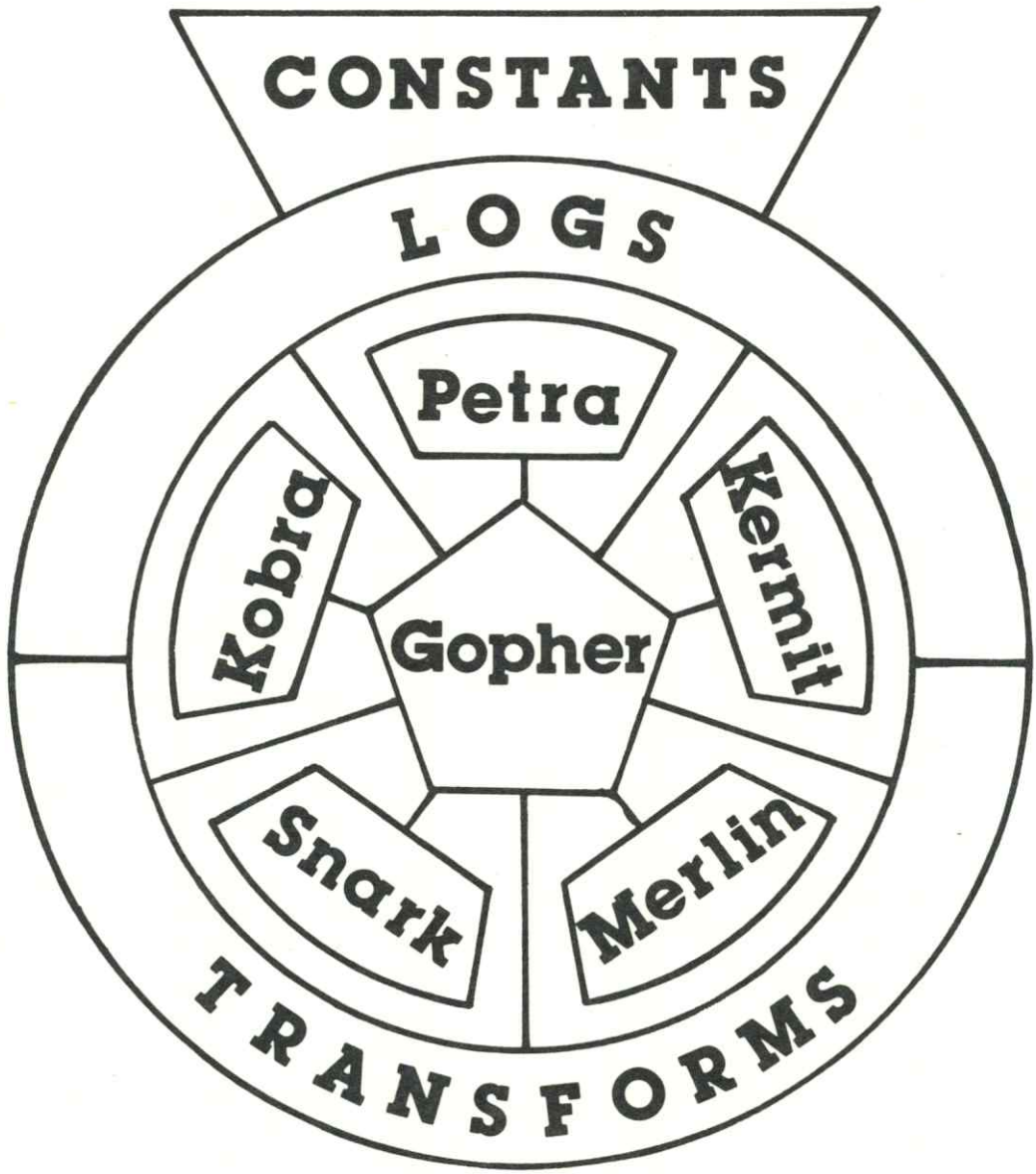

FIGURE 2: KOALA System "Mental Map."

THE GOPHER MODULE

When a KOALA run is initiated, the user is immediately located in the GOPHER module and presented with the option menu (Fig. 3). Options are grouped under four main areas of activity:

(1) Data entry and modification

(2) Data display

(3) Graphics link with peripheral plotter

(4) Access to KOALA satellite modules.

```
GOPHER CONTROL MODULE

DATA ENTRY AND MODIFICATION
        FILES ---------- DEFINE EXTERNAL INPUT, OUTPUT, AND
                         DATA FILES
        DATABASE ------- INITIALIZE KOALA WELL LOG FILE
                         ADD, DELETE, AND MODIFY CHANNELS
                         CHANGE LABEL AND CONSTANTS
        ECHO ----------- LIST CONSTANTS AND CHANNEL CONTENTS
        STORE ---------- COPY CHANNEL ONTO EXTERNAL FILE
        ABACUS --------- RESCALE OR TRANSFER CHANNEL
                         MULTIPLEX TWO CHANNELS
                         SUM CONTENTS OF CHANNEL
        LEXICON -------- CHANGE ASSUMED NAMES FOR CHANNELS
                         OR CONSTANTS
        SHIFT ---------- DEPTH SHIFT CHANNEL
        COMMENT -------- ADD, DELETE, OR RETRIEVE DEPTH-INDEXED
                         COMMENT INFORMATION

DATA DISPLAY
        STATISTICS ----- LIST STATUS OF ALL CHANNELS AND
                         CONSTANTS, WITH MINIMUM, MAXIMUM
                         AND AVERAGE VALUES.  PLOT HISTOGRAMS
                         FOR DESIRED CHANNELS
        LOGPLOT -------- PLOT CONTENTS OF SPECIFIED CHANNELS
                         IN CONVENTIONAL WELL LOG FORMAT ON
                         TERMINAL SCREEN
        AUTOPLOT ------- FIXED-FRAME FREQUENCY CROSSPLOTS OF
                         COMBINATIONS OF GAMMA RAY, DENSITY,
                         SONIC, AND NEUTRON LOGS
        CROSSPLOT ------ CROSSPLOT ANY TWO CHANNELS WITH USER
                         SPECIFIED FRAME EITHER AS FREQUENCY
                         OR Z-PLOT
        MNP ------------ COMPUTE, LIST, AND STORE ALL POSSIBLE
                         M, N, AND P VALUES

EXTERNAL PLOTTER OPTIONS
        XYPLOT ---------- TRANSFER OF LOGPLOT TO PLOTTER
        XYPETRA --------- TRANSFER OF PETRA OUTPUT TO PLOTTER

ACCESS TO KOALA SATELLITE MODULES
        PETRA ----------- MINERALOGY, LITHOLOGY, AND POROSITY
                          RESOLUTION
        KOBRA ----------- RESERVOIR ANALYSIS FUNCTIONS
        KERMIT ---------- DIPMETER ANALYSIS
        SNARK ----------- SYNTHETIC SEISMIC MODELLING
        MERLIN ---------- MULTIVARIATE STATISTICS AND TIME SERIES
                          ANALYSIS
        BYE ------------- EXIT KOALA SYSTEM

INPUT NAME OF DESIRED OPTION
```

FIGURE 3: GOPHER menu as it appears on the screen of the interactive console.

DATA ENTRY AND MODIFICATION

FILES

The FILES command is used to access any external files required by the KOALA system. Possible files include:

(1) File containing well log names and constant names, which can be changed only by LEXICON

(2) User defined input/output files, consisting of DATABASE, an input file containing digitized well log information, STORE, an output file receiving well log information, XYPLOT and XYPETRA, output files containing plotter commands.

(3) KOALA system data file, containing all log data available for one well.

Possible responses and their effects include:

(1) NO, which will rewind and release a previously existing file.

(2) SAME, which leaves a previously existing file at its current location.

(3) YES, which rewinds and releases a previously existing file. Then, the name of the new file to be used is input to open the file.

DATABASE

This option is taken either to create a new well file or to update an existing file. The contents of both constants and channels may be inserted, modified, or deleted.

ECHO

This option is used to retrieve and display the numerical values stored in any stipulated channel for a chosen depth interval.

STORE

When data from one or several log or transform channels are required for use by an external program or device, STORE copies the channels in a user-specified format. An optional header can be included on the copied file.

ABACUS

ABACUS is one of the most powerful options of the KOALA package, allowing almost any log analysis procedure to be implemented under direct user control. ABACUS consists of three types of arithmetic operations which may be executed singly or in sequential combinations.

The contents of a single channel may be modified by the SCALE function which offers five alternative equations, given here in FORTRAN notation:

NEW = A + B * OLD + C * (OLD **2)
NEW = A + B * LOG 10 (OLD) + C * LN (OLD)
NEW = A + B * (10 ** OLD) + C * (e ** OLD)
NEW = A + 10 ** (B + C * OLD)
NEW = A + B * (OLD ** C)

The input (OLD) and the output (NEW) channel numbers are set by the user, together with the choice of the equation and values of constants A, B and C. There are many potential uses for SCALE, including rescaling of a neutron log from counts to porosity units, correction of a miscalibrated log, reciprocal conversion of a resistivity log to conductivity or transit times to velocities. The most basic application is the transfer of the contents of one channel to another by use of the first equation.

The contents of two channels may be combined in three alternative ways by using the MULTIPLEX functions:

NEW = (A * OLD1) + (B * OLD2)
NEW = (A * OLD1) * (B * OLD2)
NEW = (A * OLD1)/(B * OLD2)

where OLD1 and OLD2 are the input channels and the NEW is the output channel. Again, the equation and values for constants are selected by the user. Simple applications include the correction of gamma ray and density readings for varying hole diameter, as registered by the caliper; computation of moveable hydrocarbons from the formation and flushed zone fluid saturation; and calculation of acoustic impedance as the product of velocity and density.

SCALE and MULTIPLEX functions may be performed for the entire sequence or a specified subinterval. The third function, SUM, accumulates the values of a single channel as the arithmetic summation for any selected depth range.

The ability to designate input and output channels and to make multiple runs of SCALE, MULTIPLEX, and SUM, allows the system to be used as a programming device. For example, total oil-in-place of a reservoir zone may be estimated in barrels per acre by the following procedure. Subtract water saturation from unity (SCALE), multiply by porosity (MULTIPLEX), multiply by a conversion constant for barrels per acre-foot (SCALE) and sum the result for the reservoir interval (SUM). Alternatively, exotic shaly sand models can be programmed as multiple steps of an ABACUS operation. In short, ABACUS frees the imaginative user to implement his own log analytical models within the KOALA system, without the necessity of adding a new FORTRAN coding.

LEXICON

When unnamed constant locations are used to store well information, or when channel identities are changed, some record should be made of the new status of these storage areas. This function is performed by LEXICON which is used to recall the current designations, to modify the label of a constant or to modify the label of a channel. These label changes are "temporary." Permanent modifications require the creation of a separate file through the use of the FILES option.

SHIFT

Small incremental depth shifts are commonly observed in the registration of logs run in a well. SHIFT provides the capability to move the contents of a channel either up or down by a discrete number of incremental depth units.

COMMENT

Supplementary alphanumeric information such as stratigraphic tops, drill-stem test locations, or core data may be stored in a COMMENT track at appropriate levels of the depth sequence. Each item will accommodate ten characters. These comments may be added, retrieved or deleted. In runs of PETRA (mineralogical/porosity analysis), the contents of the COMMENT track appear automatically.

DATA DISPLAY

STATISTICS

The STATISTICS option provides a numerical summary of the contents of the constants area and the full complement of channels for a specified depth interval. The output stipulates the number of real and default values in each channel, and the maximum, minimum and average values. This option provides an immediate "bird's-eye view" of the contents of a well file. The maximum and minimum values are aids in setting boundaries for graphic LOGPLOT and CROSSPLOT presentations. Average values of log channels are useful for log calibration, and averages of transform channels can be accumulated with their equivalents from files of neighboring wells for mapping by an external automated contouring package.

An auxiliary option of STATISTICS provides simple histograms with user-specified class intervals of selected channels. This feature allows the identification of a mode or "most typical value" to supplement the range and average of the numerical summary.

LOGPLOT

A conventional log presentation is provided by LOGPLOT in the form of a graphic playback of digitally sampled channel contents as a function of depth. A maximum of three tracks can be displayed, in addition to the standard depth track. In each track, up to three logs may be plotted using either solid line, broken line or dotted conventions. Each log may be plotted on an arithmetic or logarithmic, or exponential scale. The left and right boundary values for each log are set by the user. When channel contents stray outside these boundaries, the traces in these intervals may either be reflected or clipped. Areas between two designated logs may be shaded provided that both traces are clipped. This shading feature is useful in the overlay of two logs plotted on compatible scales. The LOGPLOT option makes no distinction between logs and transforms since the contents of any channel may be displayed.

AUTOPLOT

The selection of AUTOPLOT creates a sequence of frequency crossplots between all possible combinations of gamma ray, density, neutron and sonic channels, as availabile in the well file. The scales of these crossplots conform approximately to the dimensions of crossplots found in many service company chartbooks. The depth interval is specified by the user. Each crossplot frequency element is a two-character unit in which the first character is alphabetic and the second is numeric. Under this convention, for example, A3 = 13, C7 = 37, 6 = 6. The numbers flanking the horizontal and vertical axes are the sum of the frequencies contained in each respective row or column, and are equivalent to histogram summaries of each log. The AUTOPLOT presentation also states the number of values within the specified interval that occur within the dimensions of the plot, as well as the number of those whose values exceed the bounds of the plot. These general features are indexed on a typical AUTOPLOT output shown in Figure 4. The fixed dimensions of the AUTOPLOT

crossplots allow the use of drafted transparent overlays with sandstone, limestone and dolomite lines as aids in lithology identification.

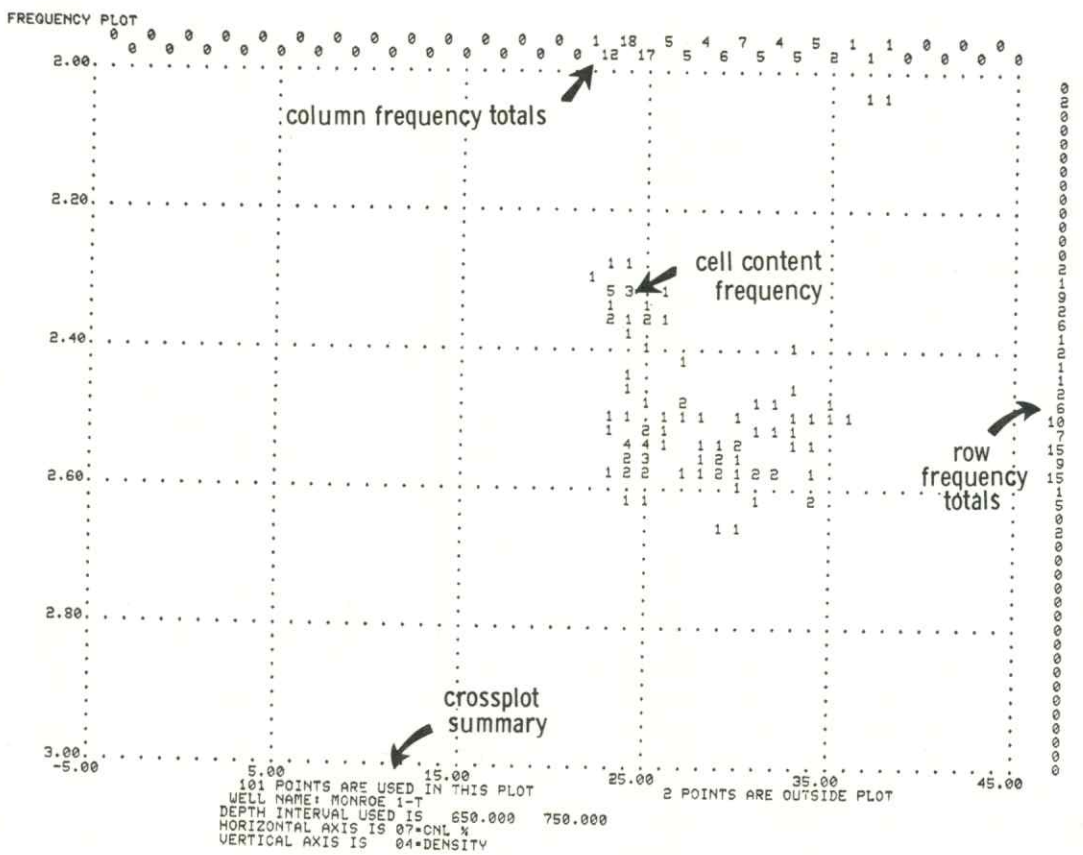

FIGURE 4: An example of output from the AUTOPLOT option.

CROSSPLOT

CROSSPLOT provides for user control in the stipulation of the dimensions of the crossplot frame, allowing expansion, contraction or translation of the plotting area. The depth range of the plotted area is set by the user. The convention for presentation of plotted frequencies is the same as AUTOPLOT. Unlike AUTOPLOT, the contents of any two channels may be crossplotted so that any combination of log or transform channels may be used. Non-linear axis scales are possible, following the application of an appropriate ABACUS function to the desired channel.

In addition to frequency plots, CROSSPLOT has an alternative "Z-plot" option in which the values in a third channel are substituted for frequencies. A minimum and maximum value for the third variable are set by the user, and the intermediate range is partitioned into ten discrete classes. Values falling outside the specified range are assigned to two additional classes. The numerical

quantity printed in each crossplot element corresponds to the digit average of the third variable readings located at the crossplot coordinates. Any channel may be used as a third variable.

MNP

The composite variables M, N, and more recently P, have been widely used as aids in the recognition of mineral components of lithologies. Each variable combines two porosity tool readings into a single quantity which is keyed to the matrix components and an effective suppression of the pore volume contribution. The equations are:

$$M = \frac{\Delta t_f - \Delta t}{\rho_b - \rho_f} \times 0.01$$

$$N = \frac{\phi N_f - \phi N}{\rho_b - \rho_f}$$

and

$$P = \frac{\phi N_f - \phi N}{\Delta t_f - \Delta t}$$

Specification of MNP for a designated interval initiates the computation and storage (channels 38, 39, and 40) of all possible M, N and P values, as dictated by the availability of values in the neutron, density and sonic channels. The option calculates these quantities with reference to a fresh- or salt-water mud, as dictated by the user.

The stored values of M, N and P may be retrieved by the user and displayed by CROSSPLOT. These plots can be envisaged as conical projections, with the fluid point located at the focus. M, N and P values can be computed for common rock-forming minerals from data contained in the manual Appendix 2, and may be used as reference points for evaluations of lithological composition. Examples of the use of M and N values in mineralogical identification are reported in Burke and others (1969).

GRAPHICS LINK WITH PERIPHERAL PLOTTER

GOPHER contains two options, XYPLOT and XYPETRA, which initiate the transfer of KOALA files to a large plotter for hard copy drafting. The coding is written to drive a Xynetics 1100 flat-bed plotter, but may be readily adapted for other models. Either plotting option may be used to make black-and-white or color displays.

XYPLOT is directly equivalent to LOGPLOT in command specifications and output presentation. XYPETRA drafts the results of analyses by the PETRA module as a graphic log of mineralogical compositions and porosity.

ACCESS TO KOALA SATELLITE MODULES

Entry to the specialized analytical modules of KOALA may be triggered by typing in the module name. The modules are PETRA (mineralogical/porosity estimation), KOBRA (reservoir analysis), KERMIT (dipmeter analysis), SNARK (synthetic seismic modeling), and MERLIN (multivariate statistical and time series algorithms). After completion of activities within any satellite module, the system is transferred to the GOPHER option menu interface. The internal GOPHER options of retrieval and display provide useful auxiliary methods in the review and evaluation of satellite module analyses.

KOALA processing of well files may be completed, or temporarily adjourned, by typing BYE.

o-o-o

THE PETRA MODULE

The PETRA module consists of a system of coordinated subroutines whose purpose is to estimate the quantitative proportions of mineral components and pore fractions in the lithologies of a logged sequence. Work with PETRA should be preceded by the processing and pattern recognition routines of GOPHER to ensure common depth registration of the logs, normalization of scales, depth delineation of facies units, and the preliminary identification of mineral species in each unit.

PETRA INPUTS AND OUTPUTS

The input for PETRA is drawn from the spontaneous potential, gamma ray, density, sonic and neutron (GNT, SNP or CNL) logs. An appropriate selection is made by the user from the suite available in the analyzed section. Any combination from nine different components may be resolved: quartz (SS), calcite (LS), dolomite (DOL), shale (SH), anhydrite (AN), halite (HL), coal (CL), "primary" (or total) porosity (POR) and "secondary" porosity (2POR).

Default values for response coefficients for each of the components with respect to each of the logs are stored within PETRA (Table 3). They may be retrieved on demand and modified to different values by the user. This modification option also allows other mineral species to be incorporated, by redesignating unused PETRA components as surrogates. For example, in a sandstone-shale sequence where pyrite is a significant constituent, CL (or AN, HL, etc.) could be equated with pyrite and appropriate changes made to the response coefficients of CL. A note of this substitution may be made in a supplementary statement to the key (Fig. 5). Log response coefficients for the common rock-forming minerals are listed in Appendix 2.

The PETRA graphic output utilizes the conventional lithographic symbols for the nine components and these are printed as a key in the header to a PETRA run. A log of compositional variation as a function of depth may be plotted using either a "polygonal" or a "block" convention (Fig. 6). There are four alternative operational modes for a PETRA run:

(1) The compositional variation of a previously stored run or runs may be displayed. Diagnostics are not printed, but may be recalled independently from the scratch file channels ALPHA, BETA, and GAMMA (provided that they have not been overwritten by other KOALA option usage).

(2) The compositional variation of a designated interval may be computed and displayed together with diagnostics. The user has the option to store the solution (in channels 21-29) or discard it if it proves unsatisfactory.

(3) The compositional variation may be computed and stored without graphic display.

(4) The compositional variation of a previously stored run may be sharpened by an inverse filter.

TABLE 3: Default values used by PETRA for log response coefficients.

	SP	GAMMA	DENSITY	SONIC	SNP NEUTRON	CNL NEUTRON
SS	0	30	2.65	55.5	-4.0	-5.0
LS	0	20	2.71	47.5	0.0	0.0
DOL	0	20	2.87	43.5	3.0	7.5
SH	0	100	2.50	100.0	40.0	40.0
AN	0	10	2.98	50.0	-0.5	-0.2
HL	0	10	2.03	67.0	4.0	-1.0
CL	0	10	1.60	130.0	50.0	50.0
POR	0	10	1.00	189.0	100.0	100.0
2 POR	0	10	1.00	0.0	100.0	100.0

In practice, the application of the PETRA module to a log suite which records a diversity of mineralogical associations is an interactive process of trial solutions and revisions. As described in the next section, several numerical diagnostics are computed to aid the user in his assessment of the feasibility of any solution. The diagnostics indicate inconsistencies which are implied between the component set of the solution and the input log data. Their intelligent interpretation often reveals the nature of the problem and allows the user to take remedial steps in a revised PETRA run. Possible inconsistencies may result from poor depth registration or log miscalibration, as well as the implied presence of unaccounted components. Trouble shooting of problematical zones is also aided by the GOPHER display and modification options.

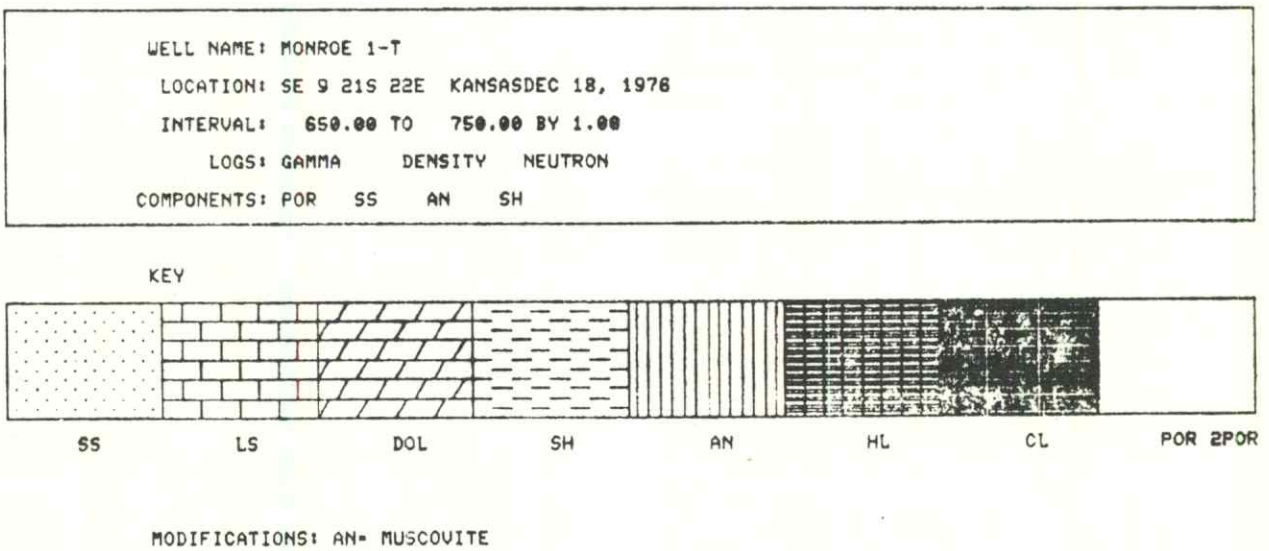

FIGURE 5: Graphic conventions used on the PETRA output header. Note that the symbol conventionally used for anhydrite has been assigned to muscovite in this example.

In summary, the interactive character of the system allows an extraordinarily diverse range of alternatives to be explored rapidly, and their consistency with the basic log data to be monitored. Intervals and their subdivisions may be analyzed separately in a flexible strategy, with piecemeal storage of satisfactory solutions. In this manner, the compositional variation of log sequences may be successively modified and collated over a series of sessions. The status of a current PETRA interpretation may be reviewed at any time, and separate intervals or entire sequences can be drafted on a plotting device by the XYPETRA option of the GOPHER module.

COMPUTATIONAL MODEL OF PETRA

The algorithms employed in PETRA are all simple matrix algebra procedures, which have the advantages of fast execution speeds, immediate geometric implications and the potential for feedback of useful diagnostics to the user. These properties are collectively valuable in the realization of a practical interactive medium for analysis.

Although highly complex lithologies may be resolved with PETRA, the mathematics are equally appropriate for the simple analyses which are more commonly performed by the log analyst. Examples of these routine applications include the estimation of porosity from a single "porosity" log (density, sonic or neutron) in a pure sandstone, limestone or dolomite and the estimation of shale content from an SP or gamma ray log.

In either simple or complex mineralogical/porosity associations, the log responses for any zone may be related to the sum of the proportions of the components each multiplied by the appropriate response coefficients in a series of simultaneous equations. The equations take the form:

$$\sum_{i}^{n} c_i v_i = L$$

where n is the number of components:

v_i is the proportion of the ith component

c_i is the log response of the ith component

L is the log response of the zone.

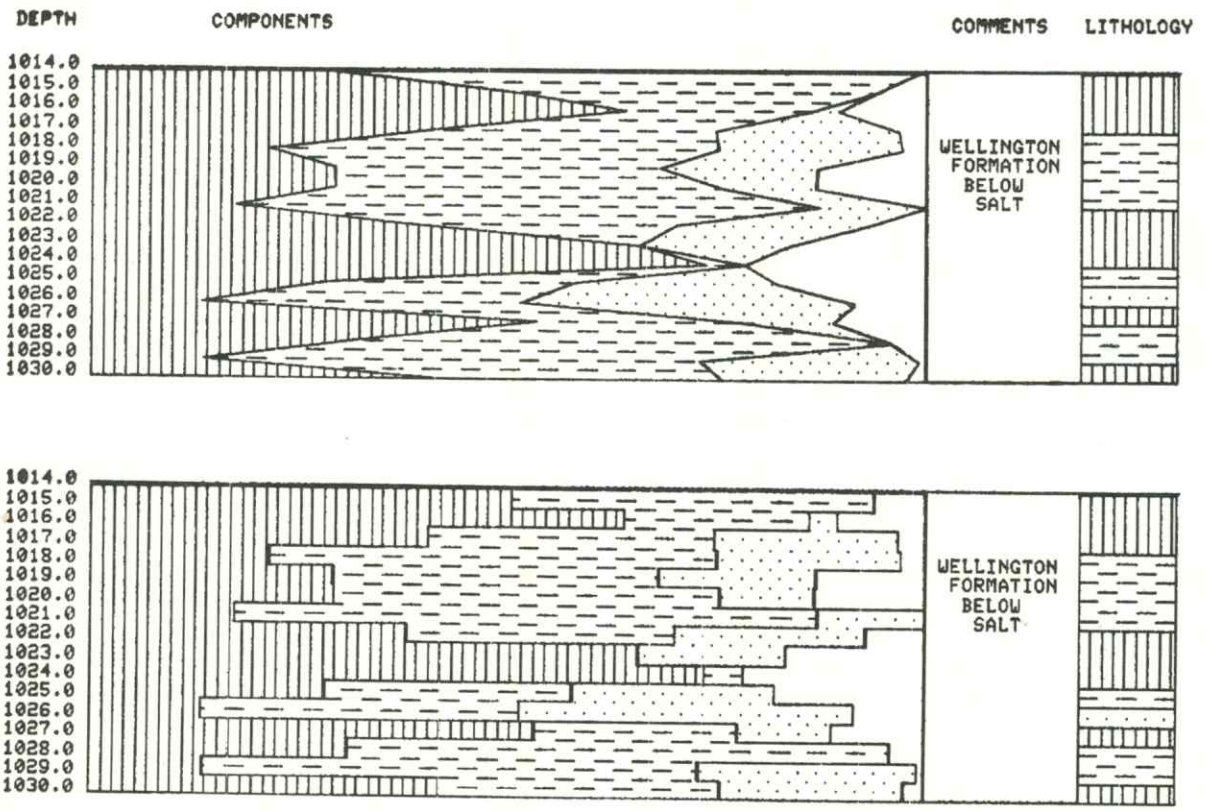

FIGURE 6: Polygonal (upper) and block (lower) conventions for PETRA graphic output.

Because the proportions of the components sum to one, there must also be a "unity equation":

$$\sum_{i}^{n} v_i = 1$$

Rewriting these equations in matrix algebraic terms:

$$CV = L$$

This approach was introduced by Savre (1963) and further developed by Burke and others (1967), and by Dawson-Grove and Palmer (1968). The matrix formulation is a linear model, and generally provides a satisfactory first approximation for compositional solutions, as confirmed by core analyses and laboratory studies. However, various sources of non-linearity are introduced by the borehole environment, tool design characteristics and the physics of the measurement variable. Obvious non-linear functions, such as those relating the pore volume to the neutron response, can be easily accommodated by local-fit linear models within PETRA. Corrective measures may also be taken by the use of appropriate equations executed by ABACUS.

The matrix algebra concisely relates the budget between the information available and the degree of complexity of the component association. Each log provides a single equation, and the collective set is supplemented by the additional "unity equation." Since the component proportions constitute a closed system, n logs are necessary to resolve (n + 1) components uniquely. In this situation, the system is "determined." If the number of logs is inadequate, the system is "underdetermined" and the solutions are downgraded to estimates stipulated by external constraints, or by prior geological knowledge. If the number of logs exceeds the minimum requirement, the system becomes "overdetermined" and a solution must be chosen which is most consistent with all the available data. The algorithms used to resolve these three possible states of determinancy have strong structural similarities and are reviewed in the following sections. An expansion on the theoretical aspects is given in Doveton and Cable (1979).

THE UNDERDETERMINED SYSTEM

(a) Maximum Variance Solution

When a log suite is restricted, the composition of a complex lithology is inevitably subject to uncertainty. Predictions must be phrased in terms of "least error" rather than "most correct." McCammon (1970, 1972) pioneered the research in this area, drawing on concepts of information theory which dictate that the least biased estimate corresponds to that which maximizes the entropy quantity. The computational aspects of this approach may be simplified by the use of proportional variance, which closely parallels entropy. Proportional variance is given by the equation:

$$p = (n/n-1)\ \Sigma v_i(1-v_i)$$
$$= (n/n-1)(1-\Sigma v_i^2)$$

The goal of maximizing the proportional variance is therefore equivalent to minimizing the quantity Σv_i^2. This solution corresponds to:

$$V = C^T (CC^T)^{-1} L$$

A graphic example of a maximum variance solution in a halite-anhydrite-shale system is shown in Figure 7. The line which transects the triangle identifies all the possible solutions which satisfy a density log reading of 2.7 gm/cc. The point on the line with the highest proportional variance is selected as the best estimate of the zone compositon in the absence of more specific information.

In all PETRA runs, the proportional variance of each zone solution is output as a first diagnostic (indexed as "PROP VAR"). When the solution composition is a homogeneous mixture of equal proportions, the proportional variance reaches a maximum of one. When the solution is a single component, with zero proportions for the remaining components, the proportional variance is a minimum of zero. Typical rock units are generally dominated by relatively few components and their proportions are distributed in a highly unequal manner. "Realistic" solutions of an underdetermined system generally yield moderately low proportional variances. In zones which generate compositions with high proportional variances, the maximum variance solutions faithfully indicate that there is a high degree of uncertainty regarding an appropriate choice from a set of rather disparate alternatives. The log readings for these zones are not "component-specific" and are relatively ambiguous.

The maximum variance algorithm contains no constraint which holds computed proportions between values of zero and one. As a result, negative proportions may be computed, although the unity equation will be honored. In geometrical terms, these unrealistic solutions are located outside the system composition space. The situation is monitored by a second diagnostic called the "sum deviation" (labelled on PETRA runs as "SUM DEV"). If the sum deviation is zero, the computed proportions are all positive and the solution is located within the composition space. If the sum deviation is greater than zero, one or more components has been attributed a negative proportion; and the sum deviation represents the distance to the nearest feasible solution. The

units of sum deviation are expressed in a common standard of apparent limestone porosity units.

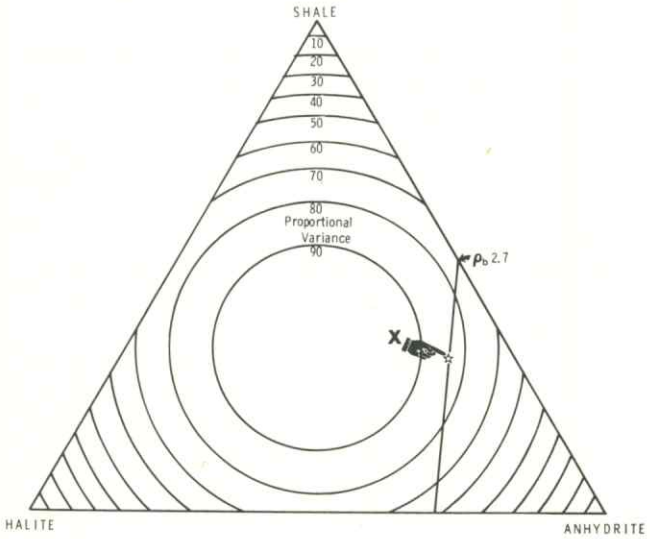

FIGURE 7: Graphic example of a maximum variance solution in a halite-anhydrite shale system.

For any zone with a non-zero sum deviation, a "dummy" solution is computed by reproportioning the positive components. However, this does not represent a maximum variance solution. Since negative proportions imply the absence of these components, revised PETRA solutions may be immediately run, using a reduced component set.

(b) Guided Minimum Variance Solution

Usually, some source of supplementary geological information is available to aid in the resolution of restricted log suites. Such information may be drawn from cuttings descriptions in the well, or from knowledge of the compositions of equivalent horizons in neighboring wells or outcrops. Collectively, these data may be used to define "guide-points" of component proportions which typify average compositions in the intervals of interest. When coordinating the guide-points with the log information, solutions should be selected from the feasible sets which have minimum differences from the guide-point.

The matrix algebra formulation of this concept may be programmed as a variant of the maximum variance algorithm. The solution is given by:

$$V = C^T (CC^T)^{-1} (L + CD) - D$$
$$D = N - Z$$

where N is a vector of proportions, 1/n, and Z is a vector of the guide-point proportions. The geometrical implications of this solution, as applied to a single zone, are shown in the composition triangle in Figure 8.

The diagnostics of proportional variance and sum deviation are output by PETRA runs using this option. In addition, the proportions of computed compositions are themselves useful for diagnostic purposes. Where these compositions differ radically from the guide-point proportions, there is a clear indication of one of two types of problem. Either the log quality is poor (depth registration shifts or miscalibrations) or the guide-points are illusory and not representative of the sections analyzed.

THE UNIQUELY DETERMINED SYSTEM

When the number of logs is less than the number of components by one, the equations satisfy the unknowns and the appropriate matrix algorithm is a conventional simultaneous equation solution procedure. Since,

$$CV = L$$
then
$$V = C^{-1} L$$

Figure 9 illustrates a unique composition solution for a hypothetical zone in the halite-anhydrite-shale system using both sonic and density readings.

This is the most common matrix method that is used for the calculation of porosity and mineral component proportions. Clearly, its application in practice requires a felicitous coincidence that matches the number of components with the logs available. In general, it is impossible to resolve all the components that actually occur, using the limited log suites which are typically run through

the section. However, the selection of the major components for solution will usually reduce errors in estimation to low levels, which reflect the minor contaminating minerals.

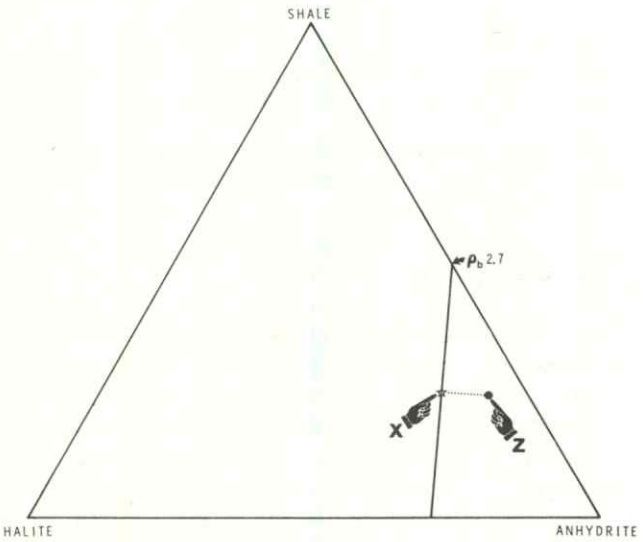

FIGURE 8: Graphic example of a guided minimum variance solution in a halite-anhydrite shale system.

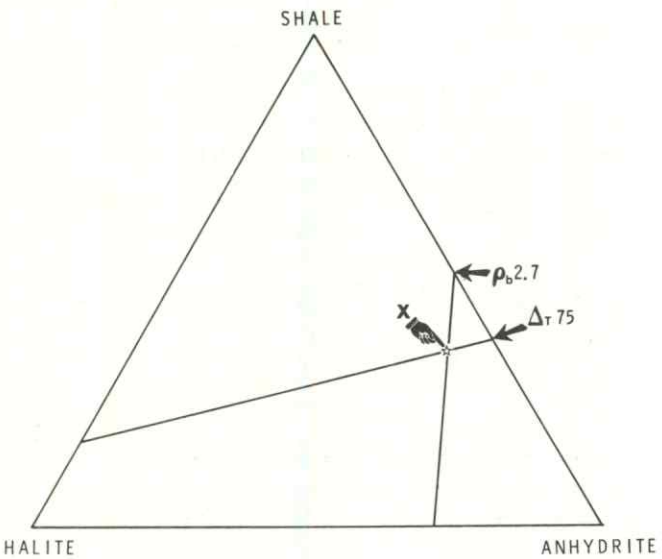

FIGURE 9: Graphic example of a determined unique solution in a halite-anhydrite shale system.

As in the underdetermined system algorithms, the component proportions are not constrained to be positive in value. Non-zero sum deviations again indicate solutions which lie outside the composition base. However, the determined solution is a unique point rather than a best estimate of a range of feasible alternatives, as is the case with an underdetermined system. Consequently, positive sum deviations directly indicate inconsistencies in the solution.

Even when the component system has been accurately defined and the logs have good quality, minor negative proportions may be expected routinely. This reflects the common heterogeneity of rock units, in which most compositions tend to be located close to the faces, edges and vertices of the system composition space. As a result, even minor calibration errors inevitably result in small negative proportions. However, these minor deviations should be contrasted with large negative values which are symptomatic of significant problems. Anomalous proportions may result from poor data quality (bad depth registration of logs, log miscalibration), or from the influence of an unaccounted component. In the latter case, these "negative components" give important clues regarding the physical properties of an unresolved component. Its identification may be aided by further recourse to GOPHER crossplots of the anomalous zones. At the same time, the user should never be immediately satisfied with a solution that generates positive proportions throughout. The solution is not necessarily correct, but is merely consistent with the available data.

THE OVERDETERMINED SYSTEM

If a full suite of logs is run, and lithologies occur which contain only a few major components, the system becomes overdetermined. In this situation, the number of equations provided by the logs exceeds the number of components.

An appropriate estimate of zone composition can be drawn from a least-squares model in which the error is minimized between the log responses and their corresponding values predicted by the solution. Since the logging measurements are recorded in radically different units, a common reference scale is required to avoid undue weighting with respect to any of the logs. A

natural choice for standardization is a porosity scale referenced to a reservoir rock mineral such as calcite.

The matrix solution of the least-squares model is:

$$V = (C^T C)^{-1} C^T L$$

A graphic example of a least-squares solution in the system halite-anhydrite-shale is shown for a hypothetical zone with three log readings in Figure 10.

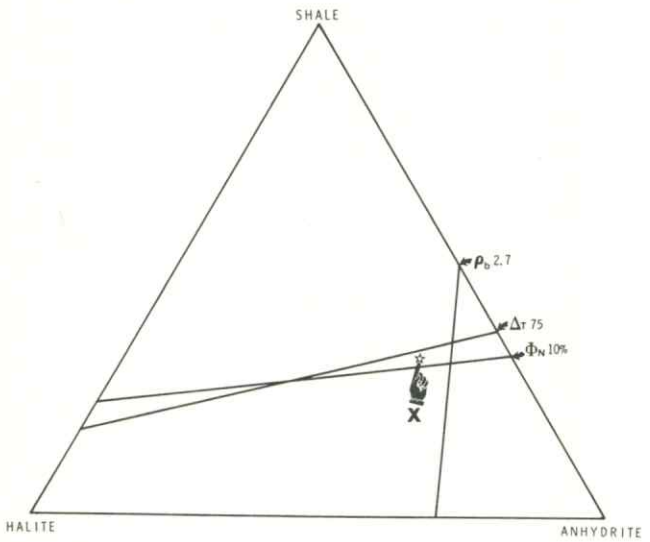

FIGURE 10: Graphic example of an over-determined least-squares solution in a halite-anhydrite shale system.

A vector of errors may be computed for any zone solution and summarized by the mean absolute deviation. This statistic is output by a PETRA overdetermined run as a third diagnostic, "ERROR." The mean absolute deviation is an indication of the degree of spread of the component log readings about the composite solution.

The ideal of a zero error is impractical, due to logging measurement errors, non-linearity effects, variable borehole conditions, and the inevitable contribution of minor components. In practice, a small error value indicates a feasible solution for the major components which is mildly compromised by the factors mentioned. Large error values indicate either significant borehole/tool problems or systematic perturbation by unaccountable major components. Since the system is overdetermined, there is adequate flexibility for the introduction of additional mineral candidates and the reapplication of a PETRA algorithm.

SHARPENED RESOLUTION OF PETRA OUTPUT

The analog trace recording of any logging tool represents some type of moving average of the real variation of the measured variable in the borehole section. In other words, the natural raw variability is convolved by a filter to yield a smoothly fluctuating trace. The form of the filter may be linear, as with sonic logs, or non-linear, as with resistivity logs.

As a simple example, the record of a compensated sonic log is a sequence of transit times which is the linear convolution of the section acoustic variation by a filter whose linear dimension is set by the spacing (or "span") of the tool receivers. Several authors, including Foster and others (1962) and Lindseth (1966), have demonstrated that the recorded traces from long-spaced sonic logs may be "deconvolved" through use of an appropriate "inverse filter" to yield more finely resolved variation. These processed traces show convincing matches with short-spaced field records. The methodology clearly has many parallels in modern seismic processing and has strong theoretical roots in general communication theory.

The vertical variation of component proportions generated, as output by PETRA algorithms, are the result of a composite log convolution of the real proportions. As a first order approximation, the compound convolution function can be modelled simply as a moving average, whose window is the generalized vertical resolution of the tool combination. The selection of an appropriate inverse filter for deconvolution is highly pragmatic and is most honestly viewed as a

semiquantitative "sharpening filter." The design of effective filters is a skilled blend of art and science, because an inverse filter will amplify noise in the data. Consequently, an optimum filter is a practical compromise which maintains a balance between errors introduced by sharpened noise and errors resulting from incomplete sharpening of real data variation.

The PETRA inverse filter has the modest objective to perform as a generalized enhancement procedure. The convolved composition is equated with a weighted moving average of each zone and its immediately adjacent neighbors. This convolution function takes the form:

$$[1/4, 1/2, 1/4]$$

a widely used smoothing function, known as a Hanning filter. A least-squares solution of an appropriate inverse filter with the same window dimension yields:

$$[-2/3, 7/3, -2/3]$$

This filter is incorporated as a sharpening option of the PETRA module, and may be applied as a supplementary modification to component proportions generated by the PETRA matrix algorithms. The graphic results are presented in a "block" mode to accentuate bed discrimination further. Although the user is allowed to store the quantitative proportions generated by the inverse filter, this option is not encouraged, because of the enhancement of the noise associated with the raw data. More realistically, the sharpened compositions should be used for final graphic presentations of lithological variation in those situations when an enhanced display is desired.

STRATEGIC IMPLEMENTATION OF PETRA

In dealing with a lengthy stratigraphic succession, the GOPHER programs should be used to subdivide facies units which appear to have common associations of components. Work with PETRA algorithms may then be directed to estimating the component compositions within these intervals, drawing on the cumulative geological information and interpretation.

When the user stipulates the logs to be used and the components to be solved, PETRA identifies the degree of determinancy involved and proceeds with the appropriate algorithm. In the underdetermined case, the user is given the additional option of supplying a guide-point. The PETRA diagnostics are particularly useful in isolating problem zones and inconsistencies.

Results from preliminary analyses may suggest finer divisions of facies units, corrective measures that should be applied to the raw logs, or modifications of the component associations. In the process of piecemeal resolution, revision and modification, solutions may be stored and collated in the appropriate channels over a period of several sessions. The partial or complete records may be reviewed at any time, and other KOALA programs may be called on to aid in their analysis. The final results of component composition can be transferred to an external file by XYPETRA, to be drafted on a plotting device either as a black-and-white or color copy.

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THE KOBRA MODULE

The KOBRA module programs perform the functions of classical reservoir analysis including estimation of invasion parameters, formation water resistivity, Archie equation constants, formation and flushed zone water saturations, and permeability indices. Each program is a separate option, with different inputs which are drawn from KOALA channels and constants.

Logging suites and information (or lack of it) concerning petro-physical parameters are highly variable from well to well. Accordingly, the organization of KOBRA has been designed for maximum flexibility. The log analyst is free to execute his own strategy in a logical sequence of option usage which is tailored for the problem in hand. The interactive character of KOALA allows for learning by multiple runs, in which revisions are stored in the appropriate KOALA channels.

The KOBRA module is entered by selecting the command "KOBRA" from the main GOPHER menu. The user is then presented the KOBRA menu of options, shown in Figure 11. Input data used in KOBRA operations are drawn from the following channels:

01 Depth
02 Spontaneous potential
09 Laterolog - 8
10 Medium induction log
11 Deep induction log
12 Deep laterolog
13 Microresistivity
24 PETRA SH = Shale
28 PETRA POR = Porosity
29 PETRA 2POR = "Secondary porosity"

```
KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    PPPLOT ---- PICKETT PLOT
    SPPW ------ WATER RESISTIVITY FROM SP
    PWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
```

FIGURE 11: KOBRA menu, as displayed on the interactive terminal screen.

As these last three channels indicate, the evaluation of porosity and shale content is the task of the PETRA module. Porosities used by KOBRA are the sum of channels 28 and 29. Channels which are used both to store output from KOBRA options and as input for other options are:

30 PHIRA = Water-filled porosity
31 SXO = Flushed-zone water saturation
32 SW = Formation water saturation
33 K = Permeability index
34 DI = Diameter of invasion
35 RT = Small slam estimate of R_t
36 RXO = Small slam estimate of R_{xo}
37 RWA = Reconnaissance water resistivity
41 ARCHIE M = Cementation factor

For many options, no explicit distinction is made between flushed zone and virgin formation evaluations. The choice is dictated by the user's stipulation of the resistivity log to be used by the option. If MICRO-RESISTIVITY (13) or RXO (36) are selected, a flushed zone evaluation will be

made; if another resistivity log is chosen, analysis will be directed to the virgin formation. For a flushed zone analysis, KOBRA will refer to the values stored in the CONSTANTS area of the file:

09 RMF (R_{mf})
10 TRMF (temperature of R_{mf} measurement)
13 BHT (bottom-hole temperature)
14 MEAN-T (mean annual surface temperature)
20 TD (total depth)

Using these constants, KOBRA will compute the zone temperature for the depth interval selected and correct R_{mf} to this temperature. If the constants are missing, KOBRA will request them from the user.

When directed to evaluate the virgin formation, some of the options will request a formation water resistivity and its measurement temperature to be entered by the user.

With the exception of SHSAT and WASP, most KOBRA options assume a set of shale-free model equations for computation of reservoir parameters. However, the estimations of shale content made in execution of the PETRA module are generally indexed with KOBRA option output. By this means, potential perturbations introduced by shale contents are monitored.

In the computation of the required parameters each KOBRA option draws on numerical values stored in various KOALA channels. For zones where the necessary data are not available (default values occur in the KOALA channels), the option output contains "-1" for the appropriate parameter value(s).

KOBRA OPTIONS

The general input needs, functions and output of the KOBRA options are reviewed in the following paragraphs.

DEPTH

The DEPTH option is used to define the range of the interval to be analyzed. The KOBRA default range is the entire well section stored on the KOALA well file. The range set by the user will be maintained for the period that the system is under KOBRA control. The interval may be changed by recalling DEPTH. If the user leaves KOBRA to access another module or exit the system, the depth range reverts to its default value.

TORNADO

The TORNADO option is a programmed solution of readings from a Schlumberger Dual Induction - Laterolog 8 suite, used to estimate diameter of invasion (DI), formation resistivity (RT), and flushed zone resistivity (RXO). This "small slam" solution conforms to a "step profile" model of the borehole environment (Figure 12).

The program algorithm is drawn from Bateman and Konen (1978), who computed formulae as approximations to the two $LL8\text{-}IL_m\text{-}IL_d$ tornado charts in the 1978 Schlumberger chart book. The two charts are drawn for the conditions $R_{xo}/R_m = 20$ and $R_{xo}/R_m = 100$. The decision criterion used in the choice of the appropriate chart/algorithm is equated by KOBRA with a porosity value of 15%. In the solution of any zone, TORNADO matches the KOALA stored porosity value against this criterion. If porosity values are not available, the user is asked to specify whether the porosity range of the analyzed unit is generally greater or less than 15%.

TORNADO output consists of graphic profiles of invasion diameter, R_t and R_{xo}. The user is given the option to store these values in designated channels. The numerical results may be viewed by use of ECHO.

RPPLOT

The option RPPLOT generates a log-log plot of resistivity versus porosity. The resistivity channel to be used is selected by the user. This type of presentation is often called a "Pickett Plot" in honor of the log analyst who has popularized its use in several papers (Pickett, 1966, 1973). As described in these publications, the plot is an excellent tool for graphic pattern recognition and is useful in the estimation of water resistivity, Archie equation constant values and zone water saturations.

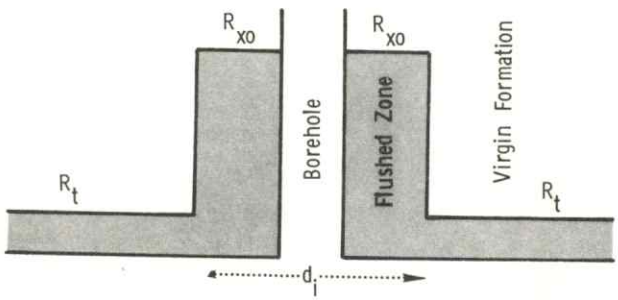

FIGURE 12: "Small slam" step profile model as assumed by the KOBRA TORNADO option.

The user may elect to plot a "water line" on the plot, if he has values for water resistivity and Archie equation constants a and m. For flushed-zone plots, the mud filtrate resistivity will be used.

The RPPLOT program supplies the maximum and minimum resistivity and porosity values found within the analytical zone, which aid the user in the selection of appropriate bounds to be used for the plot.

SPRW

The SPRW option is a programmed version of the classical derivation of formation water resistivity from the spontaneous potential log. The conventional chart procedure was transformed into a numerical algorithm by Bateman and Konen (1977) and is used as the basis for the SPRW coding.

Temperature/depth/mud filtrate parameters are drawn from the file CONSTANTS area or, if missing, are requested from the user. A static self potential value is supplied by the user and may be derived from an inspection of a LOGPLOT, STATISTICS or ECHO of the SP channel. The program then computes a value for formation water resistivity at the zone temperature, together with an estimate of salinity.

RWA

RWA computes "reconnaissance" or "apparent" water resistivity values for zones within the specified depth interval. The user stipulates the resistivity log to be used, while zone porosities are drawn from the PETRA porosity channels. The user also supplies values for the Archie equation constants, a and m.

The reconnaissance water resistivity is computed for each zone by the conventional formula:

$$R_{wa} = R \cdot \phi^m / a$$

If the user is satisfied with the computed values, he may elect to store them in the designated RWA channel (37).

PHIRA

PHIRA computes water-filled porosity as a proportion of bulk composition. The user selects the input channel for resistivity from the choice available (drawn from channels 9, 10, 11, 12, 13, 35, and 36). This determines the use of either mud filtrate or formation water resistivity. The computation of water-filled porosity in each zone follows the equation:

$$PHIRA = \sqrt[m]{(a \cdot R_w)/R}$$

If the computed results are satisfactory, PHIRA values may be stored in the PHIRA channel (30).

POREG

POREG evaluates the geometrical characteristics of the pore network, as expressed by the "cementation factor" (m of the Archie equation) and the tortuosity implied by the resistivity/porosity relationship. These values will be controlled directly by fabric geometry in clean, water-wet zones, but will be perturbed by other factors in shaly intervals or hydrocarbon zones.

The Archie equation used by POREG is in its specific form of $F = 1/\phi^m$, rather than the more generalized relationship of $F = a/\phi^m$. Then,

$$m = (\log R_w - \log R)/\log \phi$$

Tortuosity expresses the ratio of the length of the conductance path through the pore medium (L_a) to the thickness of the pore medium (L),

$$T = (L_a/L)^2$$

It has been shown theoretically (Pirson, 1963) and experimentally (Winsauer and others, 1952) that:

$$T = F\phi$$

so that,

$$T = a\phi^{1-m}$$

The user selects the resistivity log to be used as input, which is matched with either a mud filtrate or formation water resistivity. The appropriate fluid resistivity is determined by available values in the constants area and user responses. POREG then computes estimates of cementation factor (m), tortuosity (T), and conductance path length ratio (L). The user may elect to store the cementation factor values.

CLSAT

CLSAT is used to compute water saturation in shale-free reservoir zones by the classic equation set:

$$F = R_o/R_w = a/\phi^m$$
$$I = R_t/R_o$$
$$S_w^n = 1/I$$

Required input data are porosity, drawn from the PETRA channels, and a resistivity log nominated by the user, which determines whether computations will be made of SW (virgin formation) or SXO (flushed zone).

The user is requested to supply values for the Archie equation constants, a and m, and the saturation exponent, n. For virgin formation evaluations, a water resistivity and temperature of measurement must also be supplied. Flushed zone evaluations retrieve the mud filtrate resistivity from the CONSTANTS area or, failing this, question the user.

Water saturations are computed for each zone and output in both numerical and graphic form. For zones with less than 1 percent porosity, the option substitutes a default value of total water saturation.

In reviewing the output results, the user may elect to rerun the option with revised estimates of the equation constants. The output values of shale content and water saturation should be used as diagnostics in assessing the validity of the model computation. Water saturations which markedly exceed unity indicate significant problems in log quality (miscalibration, depth shifting), poor choice of equation constants or water resistivity values, or the influence of shale, which is monitored by the shale constant track.

If satisfied with the water saturations generated by a CLSAT run, the user may store these in the appropriate KOALA channels. For flushed zone evaluations, they will be stored in channel 31 (SXO); for evaluations of virgin formation, channel 32 (SW) will be used. When stored, all values exceeding unity will be truncated to this limiting value.

SHSAT

SHSAT performs a function similar to CLSAT, but incorporates corrective elements for shale content conductivity in modified computations of water saturation. The option draws on the same input data as CLSAT, with the additional requirement of shale proportions from channel 24 (SH) and a value for shale resistivity to be entered by the user.

There is a vast literature on the reservoir analysis of shaly sands, and an extraordinary variety of model equations have been proposed. The majority of these equations are developments of the basic clean-reservoir formulation, in byzantine algebras which incorporate shale proportion and resistivity. SHSAT incorporates three of the most widely used shaly sand reservoir analysis models for independent solutions of water saturation. These are:

(1) Laminar shale model (Poupon and others, 1954)

(2) Dispersed shale model (deWitte, 1950)

(3) Total shale model (Simandoux, 1963)

In the analysis of any zone, water saturations for all three models are computed and printed. In addition, the total shale model water saturation is output in graphic and numerical form. The selection of the resistivity log to be used determines whether a flushed zone or virgin formation evaluation will be made.

In reviewing the results, the user may elect to rerun the option with revised values for Archie equation constants, saturation exponent, water resistivity or shale resistivity. As with CLSAT, the output quantities should be used as diagnostics to aid in this decision. The three model water saturations are automatically stored in channels ALPHA, BETA, and GAMMA (50, 51, and 52). When satisfied with the results from one of the models, the user may request the storage of water saturations computed by this model. These will be stored in channel 32 (for virgin formation evaluations) or channel 31 (for flushed zone evaluations). Alternative shaly sand model equations may be programmed within KOALA by use of the ABACUS option.

WASP

In recent years, there has been a growing awareness that realistic shaly sand evaluations are linked with a knowledge of clay mineral species, surface areas, and cation exchange capacities. The "classic" shaly sand equations used in SHSAT often provide unreliable water saturation estimations. Intrinsic weaknesses include the use of a shale resistivity from shale interbeds (where clay mineral species and morphology may differ drastically from those in porous reservoir zones), and shale indicators which estimate volumes rather than active surface areas.

The WASP option equations are based on the widely known Waxman-Smits model, described by Waxman and Smits (1968) which marked an extension of earlier work by Hill and Milburn (1956). The basic predictive equation is:

$$S_w^{n*} = F^* R_w / Rt \, (1 + R_w B Q_v / S_w)$$

where $F^* = a^* / \phi^{m*}$

and F^* = shaly sand formation factor,

a^*, m^* = shaly sand Archie constants,

n^* = shaly sand saturation exponent,

B = specific counterion activity,

Q_v = exchange cations concentration.

The quantities marked by asterisks in this expression are conceptual transfers of their clean sandstone equivalents to a shaly sandstone medium. Their values are controlled by the clay mineral characteristics specific to the reservoir units to be analyzed. Since these parameters cannot be estimated directly from modern logging suites, supplementary core measurements must be made of porosity, water saturation, cation exchange capacity, and formation water resistivity.

The user may evaluate these quantities independently, or include this task as a KOALA operation, using analytical options external to WASP. If KOALA is selected for this purpose, the user should enter core analysis results in user-designated channels at the appropriate depth locations. The KOALA options of CROSSPLOT, ABACUS, REGRESS, and RMA provide the necessary tools for numerical analysis in the derivation of values for a^*, m^* and n^*.

The equivalent conductance of counterions, denoted by B, is related to formation water resistivity and temperature, and is computed within WASP by equations developed by Waxman and Thomas (1974).

Since values of the concentration of exchange cations, Q_v, can only be calculated directly from cation exchange capacity measurements, a theoretical/empirical link with some log response must be established in order for the Waxman-Smits equation to be usable in practical log analysis. "Shale indicators," such as the gamma ray log, have generally proved to be disappointing as predictors of Q_v (see e.g., Kern and others, 1976). However, in studies from the North Sea, Lavers

and others (1974) introduced the empirical relationship:

$$Q_v = d\phi^{-e}$$

in which the porosity term appears to serve as an estimator of the crucial variable, specific surface area. In the WASP module, a modification is utilized,

$$Q_v = d(1-\phi)\phi^{-e}$$

which we consider to be more compatible with the fundamental equation:

$$Q_v = CEC(1-\phi)\rho ma/100\phi$$

and Kozeny-Carman concepts of porosity/specific surface area relationships.

In common with the parameters discussed earlier, the constants d and e are specific to reservoir units and must be established either by analysis external to KOALA or as an integral task for the KOALA options of ABACUS, REGRESS and RMA.

The use of all these parameters in conjunction with formation water resistivity and some values of resistivity and porosity allows the computation of the elements of the basic predictive equation on a zone-by-zone basis. In the special case where n* = 2, the equation will reduce to a quadratic expression for water saturation. Otherwise, the relationship will be one involving real number exponents and is solved by WASP through use of Newton's method (Conte, 1965).

In executing a WASP run, the user is asked to supply values for Rw, a*, m*, n*, e, and d which are appropriate for the reservoir unit to be analyzed. As output, WASP provides estimates of concentration of exchange cations and water saturation in addition to values of depth, shale volume, porosity and resistivity.

As with CLSAT and SHSAT, the user's choice of input resistivity channel determines whether a flushed zone or virgin formation evaluation is being made. Following the tabulation of results, the user may either decline or elect to store the water saturation values. Storage will be effected in either channel 31 (residual water saturation) or channel 32 (formation water saturation).

PERM

PERM is used to generate predictions of a permeability index, based on either porosity alone, or a combination of porosity and irreducible water saturation.

(1) Permeability Index Estimation From Porosity

Empirical relations of the type:

$$K = A\phi^{B}$$

have been widely used to gauge relationships between permeability and porosity. In general, a positive monotonic trend should be observed between these two variables. However, permeability is not directly determined by pore volume, but is controlled by internal surface area, pore network tortuosity, pore throat geometry and other variables.

Reasonable predictions of a permeability index, based on porosity, are generally feasible in reservoir units which have relatively homogeneous matrix characteristics. The utility of such a procedure for any given unit may be assessed by regression analysis of permeability and porosity values drawn from core data. The fundamental equation may be rewritten as:

$$\log K = \log A + B \log\phi$$

which expresses a linear relationship between the logarithms of the two variables. A regression analysis will estimate values for A and B which can be used in the construction of a prediction equation. The variance terms of the regression determine the range of error associated with any prediction and the overall fit of the trend line to the data. A poor fit should discourage the use of the trend equation for prediction.

If the PERM user elects to use porosity alone in the prediction of permeability indices, the program requests appropriate values for the prediction equation constants, A and B. The user may choose to use the PERM default values for these quantities, which match the two reservoir rock types of sandstone (SS) or carbonate (LS).

The PERM A and B default values for sandstones are based on a maximum likelihood regression of permeability as a function of porosity. The data were drawn from 42 American reservoir sandstones reported in Bond (1978). A correlation coefficient of 0.75 between the logarithms of permeability and porosity indicates that the computed permeability indices are reasonable estimates of permeability in "average" sandstones.

The corresponding default values for carbonates are based on data from 69 carbonate reservoirs listed in Chilingar and others (1972). The dismal correlation coefficient of 0.12 reflects the extraordinary diversity of fabric geometries which are found in carbonate reservoir units. This carbonate prediction equation should only be used for indications of general permeability trends. The permeability index values are likely to be most reasonable in calcarenite zones, optimistic in calcilutites and pessimistic in calcirudites Significant fracture porosity will generally cause severe discrepancies between predicted and actual values.

In any serious work on permeability index estimation, the user is urged to develop the appropriate prediction equations by analyses of core data from units of interest. This will not only provide a quantitative relationship, but will give immediate indications of the practical feasibility of its application.

(2) Permeability Index Estimation From Porosity and Irreducible Water Saturation

An alternative method for permeability index prediction uses both porosity and irreducible water saturation (computed by CLSAT, SHSAT, or WASP). The prediction equation takes the form:

$$K=A\phi^{B}/S_{wi}{}^{C}$$

The equation is predicated on the assumption that water saturations in the zone of interest are irreducible. This criterion may be satisfied in reservoir intervals above the oil/water contact, but does not hold in transition or water-wet zones.

The user is requested to supply appropriate values for the constants A, B, and C. Failing this, he may elect to use the PERM default values for either sandstone (SS) or carbonate (LS).

The default values for the sandstone model correspond to the widely used Timur equation. Timur (1968) derived a permeability index equation from laboratory measurements of permeability, porosity, and irreducible water saturations of sandstones from Colorado, California, and the Gulf Coast. His sample correlation coefficient of 0.97 suggests that the equation has powerful predictive properties. Its success, in practice, is geared to the accuracy of log analysis estimations of porosity and water saturation.

The corresponding equation for carbonates was computed as a maximum likelihood plane, fitted to the logarithms of permeability, porosity, and irreducible water saturation reported from the 69 carbonate reservoirs in Chilingar and others (1972). The associated correlation coefficient of 0.35 indicates that this default equation should only be used for general indications of permeability. Again, the user is encouraged to extract equation constants from core measurements which are directly pertinent to the interval he wishes to analyze.

Permeability indices computed by either of these methods are output both in numerical and graphical format. The user may choose to store the permeability index values in KOALA channel 33 (K).

CHERNOFF

The key variables used in the assessment of reservoir potential are porosity, hydrocarbon saturation, permeability, and shale proportion. These four quantities may be graphed as continuous profiles through the operation of LOGPLOT and the appropriate KOALA channels. Alternatively, they may be output as composite geometrical shapes which express their simultaneous variation in each incremental zone.

It is a challenge to devise graphic representations of multivariate data sets which effectively convey their total information content to the observer. An example that is widely familiar to oil explorationists is the Stiff diagram. This is a six-pointed polygonal figure which outlines the composition of a subsurface brine in terms of its composition of six major ions.

Herman Chernoff, statistics professor at Stanford University, proposed the use of cartoon faces in the representation of multivariate data (Chernoff, 1973). He argued that human beings are especially attuned to the subtle variations of facial expressions, since this is a lifelong study for all of us. Consequently, a large number of variables can be coded within a cartoon face, while trends and discriminations within sets of faces can be readily recognized. Although the idea is reasonable, its intrinsic outrageousness has inhibited its widespread adoption.

The KOBRA Chernoff face is constructed using the following rules:

(1) The area of each eye is proportional to porosity. At a maximum theoretical porosity of 42%, the eyes will touch.

(2) The dark sector of each eye is proportional to hydrocarbon saturation; the blank sector is matched with water saturation.

(3) The area of the nose is proportional to the shale content, using the same scaling function as the eyes.

(4) The curvature of the mouth is a direct function of permeability. A neutral set corresponds to a permeability of 5 md. Smiles represent permeabilities higher than this figure, grimaces are permeabilities which are lower.

An example of Chernoff faces computed for Pennsylvanian carbonate zones from a Kansas well are shown in Figure 13. Examination of the figure suggests an eerie correspondence between the general expressions of the faces and the results of drill-stem tests which were run for the intervals.

Required input for the generation of Chernoff faces are values from channels 28 and 29 (POR and 2POR), 24 (SH), 32 (SW), and 33 (K). Default channel values cause the absence of the associated facial feature. A face is computed for each incremental zone and displayed in row sequence for the interval specified by DEPTH.

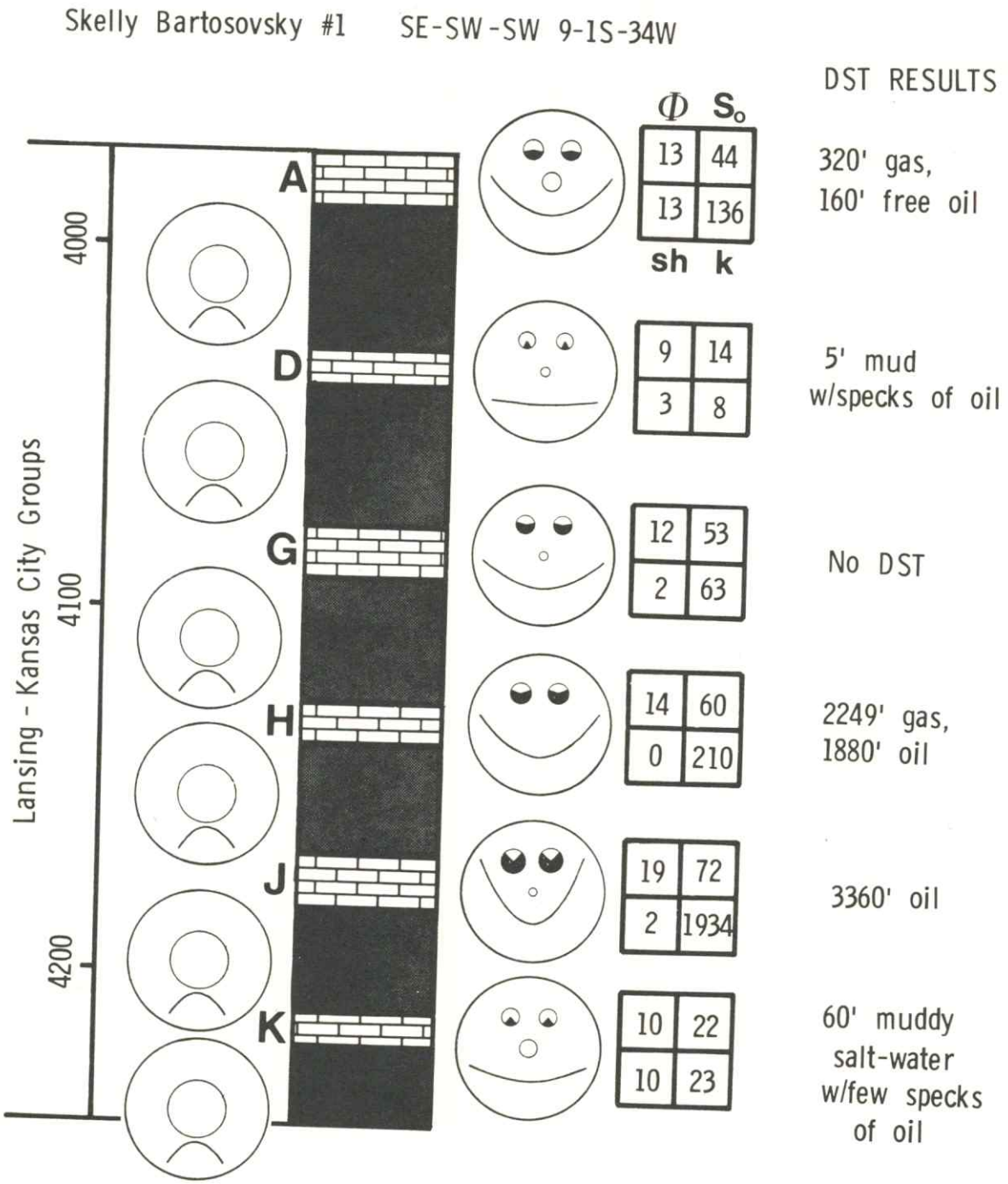

FIGURE 13: Chernoff face computed for limestone/shale zones in a Pennsylvanian section.

o-o-o

THE KERMIT MODULE

KERMIT is designed to analyze and display orientation measurements computed from a high-resolution dipmeter. Input data are stored as azimuths (channel 14) and dips (channel 15) in locations corresponding to the depths at which they are estimated (channel 1). Intervening depth increments for which there are no azimuths or dips are assigned default values (-9999.).

The module is accessed from the GOPHER control menu by keyboard entry of the prompt "KERMIT." The user is then presented a KERMIT menu of alternative programs for graphic display and analysis (Fig. 14). The functions and operating characteristics of each program are discussed in the following sections. Examples of output may be reviewed in a later case-study application.

```
KERMIT DIPMETER ANALYSIS MODULE

    DEPTH ------ SELECT DESIRED DEPTH INTERVAL
    TADPOLE ---- VECTOR PLOT
    ROSE ------- AZIMUTH FREQUENCY PLOT
    POLAR ------ SCHMIDT OR WULFF POLAR PLOT
    2DCYL ------ PLANAR CYLINDRICAL PLOT
    3DCYL ------ PERSPECTIVE CYLINDRICAL PLOT
    EIGEN ------ EIGENVECTOR ORIENTATION ANALYSIS
    STOP ------- KERMIT EXIT

INPUT NAME OF DESIRED OPTION
```

FIGURE 14: KERMIT menu as it appears on the display screen.

KERMIT OPTIONS

DEPTH

DEPTH fulfills the same function as its namesake in the KOBRA module. Unless otherwise advised, the KERMIT options will operate on the entire section stored in the well file as a default interval. The DEPTH option allows the user to specify the depth bounds of an interval of interest. This interval will set the depth range which is analyzed by the other KERMIT options, provided the user does not leave the module. Upon leaving the module, the range will revert to the full default interval. The interval for analysis may be changed at any time by using the DEPTH option.

TADPOLE

The most common graphic presentation of azimuth/dip results is by a vector plot, often known as a "tadpole plot." This may be generated by use of the TADPOLE option. The user may specify either a linear or logarithmic scale of dip. If a linear scale is selected, the user stipulates minimum and maximum dip values for the margins of the plot, as well as reference tic mark spacing. Choice of a logarithmic scale will fix the margins at 1 and 90 degrees.

The output of TADPOLE is a conventional vector plot presentation with the vertical axis indexed by depth and horizontal axis referenced to dip. Individual observation vectors are plotted as circles, with tails oriented in the direction of azimuth.

ROSE

The "rose diagram," or azimuth frequency plot, is widely used in many studies as a circular histogram summary of a sample of orientation measurements. The radius of each sector of the rose diagram is proportional to the number of observations which occur within the angular range of the sector. The rose diagram presents the distribution of azimuths, but neglects their associated dips.

The convention used by the ROSE option subdivides the compass range into octants, whose axes match the cardinal points (N, S, E, W) and the intermediate directions (NE, NW, SE, SW). In the graphic output, the rose diagram is centered within a reference circle, whose radius represents the number of observations. The radii of the rose octants are scaled with respect to the reference circle, and represent the number of azimuths observed within the angular range of each octant.

POLAR

The POLAR option allows the user to plot dipmeter orientations on a polar plot. Either a Schmidt net (the Lambert equal area projection) or a Wulff net (the stereographic projection) presentation may be chosen. On either projection, the poles, or normals to the dipping planes, are plotted with respect to an upper hemisphere. With

this convention, the poles of horizontal planes plot at the center of the projection, while others are displaced as a function of dip angle along radial directions matched with their azimuths.

The selection criterion for projection type is dictated either by user preference or the useful properties of each projection. The Schmidt net is isomorphic so that equal areas on the sphere appear as equal areas on the projection. This property makes the Schmidt net the natural choice for statistical summaries, because point distributions can be contoured in isodensities per unit area. The Wulff net is conformal and shapes on the sphere are preserved on the projection, so that meridians and parallels remain exact circles. This feature allows rotational operations to be made on the projection, through the use of a stereonet, and is particularly useful in the solution of structural problems (Schlumberger, 1970). A graphic impression of the general characteristics of the two conventions may be drawn from the two world northern hemisphere projections shown in Figure 15.

After selecting a projection type, the user is asked to stipulate the radius of the latitudinal boundary circle and the spacing of the interior reference circles. This feature is particularly useful when dips are fairly low and their projection poles would be virtually indistinguishable on a full hemisphere projection. The observation poles are plotted as points on the projection, and the user is advised concerning the number of points which are located both inside and outside the projection boundary circle.

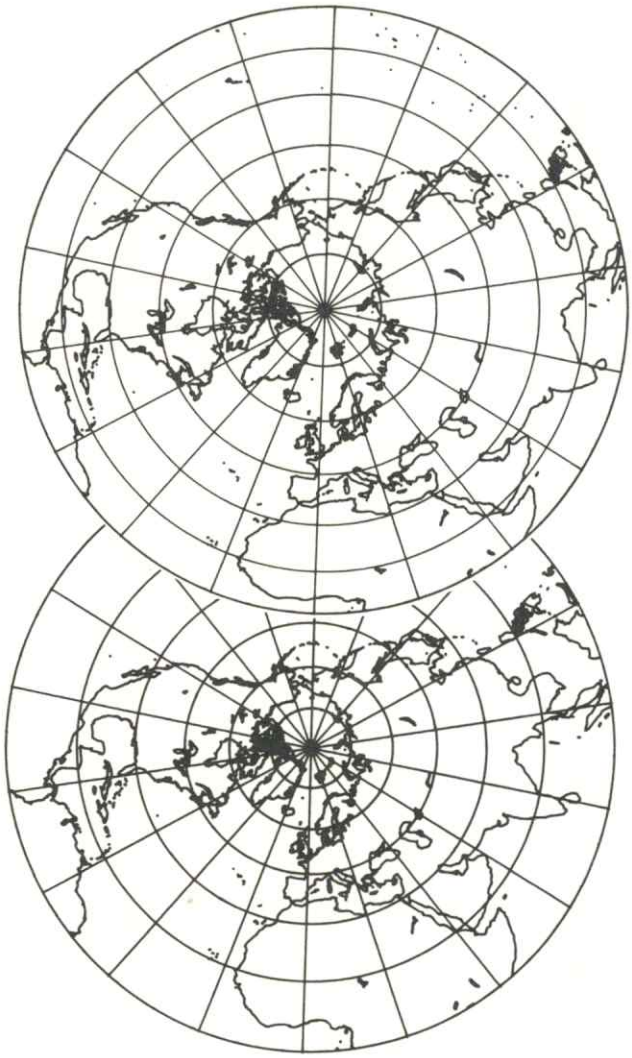

FIGURE 15: Geographic polar projections using the Schmidt (top) and Wulff (bottom) conventions).

2DCYL

Cylindrical plots are sometimes used as alternative graphic presentations of dipmeter data. If the planes associated with each observation are projected onto an enlarged hypothetical borehole wall which is "unrolled" in the plane of the paper, the intersections sketch out sinusoidal traces. On this presentation, the horizontal axis corresponds to azimuth, the vertical axis to depth.

Selection of the 2DCYL option causes a cylindrical plot to be drawn for the interval set by DEPTH. The user may also specify a "reference log" to be drawn in parallel with the plot, using values from any of the KOALA channels. Although the result is displayed on the terminal screen, a hard-copy may be made and photocopied on a transparent plastic sheet. If this is rolled on itself about a vertical axis, the sinusoidal curves form dipping circles and the result is a physical scale model of the dipmeter information.

3DCYL

The 3DCYL option performs essentially the same function as 2DCYL, but displays the cylindrical plot as a perspective three-dimensional view on the terminal screen. Again, the user may plot a reference log drawn from any KOALA channel adjacent to the cylinder. Under this option, the user must specify an azimuth for viewing angle, which is indexed on the plotted result. Multiple use of 3DYCL allows the same cylindrical plot to be viewed from different directions.

EIGEN

In contrast with the other KERMIT options, which are primarily graphic summaries, EIGEN performs an orientation analysis of observations within the interval specified by DEPTH.

If azimuth is denoted by A and dip by D, direction cosines L, m, and n may be computed for each observation vector with respect to the east-west, north-south, and vertical axes. The formulae are:

$$L = \sin A \sin D$$
$$m = \cos A \sin D$$
$$n = \cos D$$

The orientation tensor for the N cumulative observations in the analytical interval is then:

$$O = 1/N \begin{bmatrix} \Sigma L^2 & \Sigma Lm & \Sigma Ln \\ \Sigma Lm & \Sigma m^2 & \Sigma mn \\ \Sigma Ln & \Sigma mn & \Sigma n^2 \end{bmatrix}$$

The eigenvectors of the orientation tensor specify the major, intermediate, minor axes of the distributions of normals, and are identified by the size of their respective eigenvalues. Each eigenvector contains the direction cosines which specify its orientation. Each eigenvalue measures the proportion of the total variance which is accounted for by its associated eigenvector. The scattering angle of the normals about the principal axis may be computed by the formula:

$$\theta = \arccos \lambda$$

where λ is the eigenvalue of the principal eigenvector.

This methodology is now widely used in structural geological studies (Woodcock, 1977), both to specify the statistical preferred orientation of tectonic data, and to furnish numerical descriptors of the general shape of orientation fabrics. Examples of applications to sedimentology are given by Scheidegger (1965).

If EIGEN is selected by the user, the analysis is performed for the stipulated depth interval. Output includes numerical summaries of the orientation tensor, eigenvectors, and eigenvalues. In a final summary statement, the option specifies the azimuth and dip of the principal vector, together with its associated scattering angle, in conventional degree units.

o-o-o

THE SNARK MODULE

The function of SNARK is to generate synthetic seismograms, based on either the well section or model sections devised by the user. Models may be designed to represent hypothetical lateral equivalents of the well section, which can incorporate changes in structural elevation, stratigraphic unit thickness, or lithology. The modelling option is executed as an option within SNARK.

In order to maintain the short processing times demanded by an interactive medium, the SNARK synthetic seismogram algorithm is relatively simple, when contrasted with more comprehensive programs. Reflection coefficients are derived exclusively from either the sonic log (channel 05) or the integrated sonic log (channel 17) of a well section profile; or from a model sonic log (channel 43) for a model profile. The source pulse used in convolution is approximated by a first-order Ricker wavelet with a user-specified frequency.

The seismogram alogrithm follows the development presented by Peterson and others (1955), Durschner (1958), and Biggs and others (1960). In spite of the limitations imposed by the simplified assumptions, synthetics produced by this approach have generally shown good general agreement with field seismic records. Two principal factors which are neglected are the depth attenuation of seismic energy and the initiation of multiple reflections within a multilayered sequence. However, it has been suggested by Trorey (1962) that significant attenuation may reduce the magnitude of multiple generation. The reflection coefficients computed by the algorithm are restrictive (but close) approximations to their real values, since they are based on layer velocity contrasts, rather than on differences in impedence.

Although the synthetic seismogram is keyed to a sonic log, the user may provide a pseudo-sonic log in channel 05. This facility is obviously essential in wells which were not logged by a sonic tool. So, for example, a density log may be used for this purpose. The strong correlation between bulk density and acoustic velocity of lithologies is widely known, and Gardner and others (1974) derived an empirical linear relationship of the form:

$$V = 0.308\ \rho v + 3460$$

where V = velocity and ρ = bulk density.

Rudman and others (1976) have also demonstrated the practicality of generating pseudo-sonic logs from resistivity traces by use of the general equation:

$$TT = A + BR^{-1/C}$$

where TT = transit time, R = resistivity, and A, B, C = constants.

The constants A, B, and C are a function of the section stratigraphy and must be derived from local empirical studies.

Pseudo-velocity transformations are also possible from other logs, although the degree of their match with the true velocity profile will obviously dictate the degree of the utility of synthetic seismograms which are produced. The generation of a pseudo-sonic log, based on a log in another channel in the KOALA well file, is easily accomplished through use of ABACUS option, by applying the appropriate transformation equation and specific constants. It should be remembered that any pseudo-log should be computed in transit time units of microseconds per foot.

SNARK OPTIONS

The SNARK module is accessed from the GOPHER control module menu by input of the command "SNARK." The user will then be presented with the SNARK menu (Fig.16), which itemizes three options, SEISM, MODEL, or STOP.

```
SNARK SYNTHETIC SEISMIC MODULE

    SEISM ---- SYNTHETIC SEISMIC COMPUTED FROM
               WELL SONIC LOG(05), INTEGRATED
               SONIC(17), OR MODEL SONIC LOG(43)
    MODEL ---- CREATION OF A SONIC LOG(43) FOR A
               HYPOTHETICAL MODEL SECTION
    STOP ----- EXIT SNARK MODULE

INPUT NAME OF DESIRED OPTION
```

FIGURE 16: SNARK menu as it appears on the terminal screen.

SEISM

SEISM is the computational option of SNARK, which triggers the generation of a synthetic seismogram based on either the well sonic log (channel 05), and integrated well sonic log (channel 17), or a model sonic log (channel 43). The integrated sonic log is assumed to be scaled in millisecond increments of two-way travel time. If the well sonic log is stipulated, an integrated sonic log will be computed automatically and stored in channel 17. If the model sonic log is selected, an integrated sonic log will be stored in channel 44.

The user will then be asked to stipulate the Herz frequncy for the first-order Ricker wavelet used in convolution. The wavelet is computed as a digital filter with elements calculated for two millisecond increments of two-way travel time. Time-sampled velocities and reflection coefficients are generated internally within the program. The reflection coefficients are convolved with the Ricker wavelet and the synthetic seismogram amplitudes stored in channel 42.

Output from SEISM consists of the well name and Ricker wavelet characteristics, followed by a graphic trace of the wavelet. This information precedes the synthetic seismogram, drawn in a four-track, relief-shaded convention, and is paralleled by a trace of the interval velocity. The presentation is scaled in two-way travel time, recorded on a left-hand scale in millisecond units. The time origin is set to the depth of the first recorded sonic value. On a right-hand scale, the corresponding depths in feet are recorded at intervals of 10 milliseconds. An example of typical output is shown in Case Study 6 as part of an example of the application of SNARK.

MODEL

The MODEL option constructs a model sonic log to be used as input for synthetic seismogram generation. In the most obvious application, the well section is used as the source of a reference velocity profile to be modified to model profiles of hypothetical lateral equivalents. These profiles can be designed to accommodate changes in structure and/or stratigraphy, which are suggested by neighboring well control or other information. Multiple use of MODEL in conjunction with SEISM would allow the assembly of a laterally continuous synthetic seismic record. However, a limitation is imposed by the one-dimensional structure of the algorithm, which fails to take account of two-dimensional refraction characteristics of dipping beds in the modeled section.

The model sonic log may be assembled from either or both of two types of components; these are termed "quotes" and "constants." Quotes correspond to slices of the well sonic log which are positioned at stipulated depths on the model log. Constants are selected intervals on the model log to which the user assigns a specific transit time.

In most applications, a model sonic log may be constructed from an appropriate combination of quotes, which collectively accommodate lateral thinnings, thickenings, and changes in structural elevation. By contrast, a model log composed entirely of interval constants describes a "layer-cake" model, with non-zero reflection coefficients generated exclusively at the boundaries of intervals. A hybrid RDT (rumbledethumps) model, comprising both quotes and constants, is sometimes useful in modeling sections, particularly those involving new intervals not presented on the original section, and which cannot be simulated by other intervals with similar velocity characteristics.

When the MODEL option is accessed, the user is asked to stipulate the number of quotes (if any) that he will draw from the well sonic log. For each quote, he is requested to supply the top and bottom depths of the quote on the well sonic log, and the depth of the top of the quote in its position on the model log. The user is also asked the number of constants he will use (if any). For each constant, he identifies the top and bottom of the constant interval on the model log, and the transit time to be associated with this interval.

The current contents of the model log are stored in channel 43, and may be modified over a series of runs. Before executing a SEISM run on the model, the user should check for the presence of "gaps" on the model record which would be misinterpreted by SEISM as the end of the record. Prior to the construction of a new model log, the user should default both the model sonic and integrated sonic logs (channels 43 and 44) through the ABACUS option, in order to eliminate residual

model sections which are not overwritten by the new model.

The modeling procedure may be used to generate profiles which are closely tied with the well section or as a more generalized exercise in serendipity to construct profiles based on more abstract considerations. Useful examples of simple seismic modeling applications to regional geological problems are documented by Galloway and others (1977).

STOP

As with options of the same name in other modules, the use of "STOP" will transfer the user to the GOPHER control module menu.

o-o-o

THE MERLIN MODULE

The MERLIN module is an armory of general-purpose multivariate procedures for the processing of designated channels. While the other KOALA satellite modules are grounded in specific petrophysical models, the implementation of MERLIN is dictated entirely by analysis concepts devised by the user. The individual MERLIN options are drawn from methods routinely used in statistics, pattern recognition, and time series analysis. In one sense, they can be viewed as an advanced extension of the simple arithmetic operations provided by the ABACUS option in the GOPHER module.

It is beyond the scope of this manual to give detailed background theory for these methods. Indeed, it would be redundant, since a vast expository literature is readily accessible to any interested user. However, readers with minimal experience in this area are recommended to study Davis (1973), who provides an excellent review of most of these techniques as applied to earth science data.

While the name "MERLIN" is suggestive of the arcane reputation often attributed to these methods, it also contains a warning. In order to apply the MERLIN options as useful analytical tools, the user should have some experience in their theory and limitations. Naive tinkering may generate misleading results with some similarity (but less spectacular consequences) to those caused by the Sorcerer's Apprentice.

The MERLIN module is accessed from the GOPHER control menu by the input of the module name. The user is then provided with the MERLIN menu of available options (Fig. 17).

```
MERLIN NUMERICAL PROCESSING MODULE
    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    FILTER ---- CONVOLVE WITH USER-DESIGNED FILTER
    REGRESS --- SIMPLE POLYNOMIAL OR MULTIPLE LINEAR
                REGRESSION
    RMA -------- REDUCED MAJOR AXIS
    PCA ------- PRINCIPAL COMPONENT ANALYSIS
    DISCRIM --- DISCRIMINANT FUNCTION ANALYSIS
    FOURIER --- SINGLE CHANNEL FOURIER ANALYSIS
    COSPECT --- MULTI-CHANNEL COSPECTRAL ANALYSIS
    STOP ------ EXIT FROM MERLIN
```

FIGURE 17: MERLIN menu.

Unless otherwise specified by the user, the channels intended for output of the MERLIN options are the six "Greek channels," alpha to omega (50 to 55). Multiple option use will result in an overwriting of previous option output. Consequently, users wishing to preserve analytical results should either transfer data by use of ABACUS to a "safe" channel (and use LEXICON to supply an identifier) or use STORE to copy onto an external file. (It should be remembered that ALPHA, BETA, and GAMMA may contain proportional variance, sum deviation, and error diagnostics generated by a previous PETRA run.)

MERLIN OPTIONS

DEPTH

The DEPTH option performs the same function as its namesake in the KOBRA and KERMIT modules. Unless changed by the user of the DEPTH option, the other MERLIN options will assume the interval of interest to be the entire section available as the "default range." Changes in the depth range will be maintained, unless further modified through use of DEPTH, or departure from MERLIN, when range will revert to its default value.

FILTER

FILTER allows the user to convolve a specified channel with a filter of his own design and store the result in a designated channel. The length of the filter may range from one to nine elements as specified by the user. The "central element" of the filter must also be nominated. An "orthodox" filter will consist of an odd number of elements with an obvious central element. For even-numbered filters, there is no unique central element. Essentially, the identity of the central element dictates the location of the filtered value in the storage channel as related to the filter position. The numerical values for the filter elements are typed in as direct keyboard entry.

The possible applications of FILTER are legion, but obvious examples include enhanced resolution of sonic logs by inverse filter processing, and simple deconvolution of temperature logs by regression filters of various lengths to extract temperature gradient variations.

REGRESS

The REGRESS option offers either:

(1) Polynomial regression up to fourth order; or

(2) Multiple linear regression with a maximum of ten independent variables.

The user is requested to nominate a channel as the dependent variable, followed by channel designation(s) of the independent variable(s). The number of independent variable channels automatically determines the type of regression performed. For one independent variable, polynomial regressions are computed; for several independent variables, a multiple linear regression.

The user may also elect to store computed regression estimates of the dependent variable. For a polynomial regression, these will be stored in channels 50-54. A multiple linear regression estimate will be stored in channel 50.

The output for a polynomial regression includes the coefficients for polynomials for "zeroth" (mean) through to fourth order, together with analysis of variance statistics (sample size, partitioned sums of squares, goodness of fit, correlation coefficient).

In the case of a multiple linear regression, coefficients are listed for both raw and standardized data. An analysis of variance is performed, with listings of sums of squares, degrees of freedom, mean squares and F-test statistic.

The application of either regression option is generally straightforward, provided that the unit magnitudes of the various variables are not excessively small, large, or grossly dissimilar. However, in common with all polynomial regression programs, computational "blow-ups" can occur at higher orders if this is not the case. An example is the execution of a polynomial regression using fractional porosity as the dependent variable and depth (in thousands of feet) as the independent variable. Situations of this type are easily remedied through "pretreatment" of input by ABACUS to rescale variables to reasonable ranges.

The most common applications of regression in log analysis focus on the extraction of prediction equations, which relate either the variation of logs or petrophysical transforms as a function of depth, or resolve relationships among logs and/or transforms. The analysis of variance statistics should not be neglected, since they provide valuable diagnostics concerning the validity of the computed relationships as robust predictor estimates. Examples of REGRESS option usage for both polynomial and multiple linear regression are given in Case Study 2.

RMA

RMA provides a "reduced major axis" or "maximum likelihood regression" of two variables which correspond to channels specified by the user. Output of RMA consists of means, variances and standard deviations of the two variables, together with their correlation coefficient and the intercept and slope of the reduced major axis.

The reduced major axis differs from a conventional linear regression in several important respects. Linear regression is rooted in a formal statistical model which stipulates that the dependent variable is comprised of a systematic component which is confounded by an element of random error, and is a function of an independent variable, measured without error. This model may be assessed by the classical inference of analysis of variance.

In many cases, both variable measurements are subject to some source of error, although it is often possible to equate the independent variable with the data source of more precise measurement. In more equivocal cases, the choice is less obvious, with the result that two alternative linear regressions may be computed, depending on the choice of the dependent/independent variable. Although both regressions will pass through the bivariate mean, the angle between them is determined by the correlation coefficient.

If the aim of the regression is to produce a useable prediction equation, several choices are available. If the intent of the equation is to predict a value of a second variable given (without error) the value of a first variable, a linear regression using the second variable as the dependent quantity is

the orthodox approach. If, however, a generalized equation which "fits" the joint variation is preferred, the reduced major axis may be a reasonable alternative. In common with the regression lines, the reduced major axis passes through the bivariate mean, but its slope is determined by the ratio of the standard deviations of the two variables, with a sign corresponding to the sign of the correlation coefficient. The reduced major axis closely approximates a visual perception of a "best-fit line," but has no roots in formal statistical inference.

PCA

PCA is a principal components analysis option which computes eigenvectors and eigenvalues of both a variance-covariance matrix and a correlation matrix of user-specified variables. The user may designate up to ten channels as input variables. As output, PCA generates means, variances and standard deviations of the input variables, a variance-covariance matrix and correlation matrix, together with their associated eigenvectors (principal components) and eigenvalues.

The user is asked whether he wishes to compute and store principal component scores. If scores are requested, the user further stipulates whether the scores will be based on the variance-covariance matrix (raw data) or correlation matrix (standardized data), and how many components will be used. The scores are stored in channels 50 onwards.

Principal component analysis is a valuable method for the dissection of complex interrelationships of multiple variables, and the generation of synthetic variables which express the major variation in the total set of variables. Unlike regression analysis, principal components are not dictated by a theoretical statistical model, but are a geometric reduction of total data variability. If the multivariate values of sample points are conceived as a "cloud" of locations in multidimensional space, the principal components match major orthogonal axes of this cloud.

Both the variance-covariance and correlation matrices, and their associated eigenvectors and eigenvalues, are appropriate data for the interpretation of fundamental variable interrelationships. The eigenvectors can be considered from the viewpoint of a simple factor analysis, in which the composite "identity" of each principal component is indicated by the relative loadings of the raw variables. The contribution of the component to the total variation is given by its associated eigenvalue. In cases where several raw variables give varying estimations of a common causal variable (e.g. "shale indicators"), which may be identified with one of the principal components, the scores from this component provide a new "composite log" which may be useful in analysis by other KOALA options. An example of the use of PCA is given in Case Study 2.

DISCRIM

The DISCRIM option executes a linear discriminant function analysis of two input sample groups. Prior to the application of DISCRIM, the user should identify depth zones which can be unequivocally assigned to either a "Group A" or "Group B." The "A" and "B" characteristics are defined by the user, but should correspond to two mutually exclusive categories of interest. For example, the two groups could be productive and nonproductive zones, marine and freshwater shales, bituminous and anthracitic coals, etc.

The use of a discriminant function is appropriate in situations where the user can classify some zones with certainty (as a result of core analysis, drill-stem tests, or other information), and wishes to assign other, unknown zones to one or other of the groups.

On the basis of log measurements made in the known zones, an equation may be computed that collectively weights the separate log responses in such a manner that there is a maximum differentiation between zones which relate to Group A and those which are drawn from Group B. In geometrical terms, zones from the two groups can be visualized as two clouds of points located in a multidimensional space in which each axis represents a log response. The function equation defines an axis through this space, along which there is both a maximum separation and a minimum dispersion of the two clouds.

On entering the DISCRIM option, the user is first requested to nominate the logs to be used in discriminant analysis (with an upper limit of ten). The logs chosen should have properties which might aid in discrimination. However, decisions can be flexible, in the sense that logs which fail to discriminate significantly will not adversely affect the analysis, and their failure will be highlighted in the associated diagnostics. Since the analysis is a linear operation, some prior remedial work on non-linear log responses through ABACUS may be useful.

Situations will commonly occur where zones preassigned to the two groups occur in multiple intervals. DISCRIM asks the user how many intervals are assigned to the two groups, and the depth ranges of these various intervals.

As output, DISCRIM tabulates the number of observations assigned to the two groups, and the depth ranges of the intervals from which these are drawn. For each of the logs used as input, the means for groups A and B are listed, together with their computed coefficient on the linear discriminant function, and a proportional estimate of their relative contribution to the total discrimination. This contribution statistic is a useful interpretative aid in identifying the key logs which are especially diagnostic in differentiating Group A from Group B zones.

Discriminant index statistics are listed which itemize the discriminant scores of the two group multivariate means and the midpoint between them. Discriminant scores may be computed by application of the discriminant function equation and represent the projections of the multivariate group clouds onto the discriminant axis.

An inferential statistical summary is printed which includes Mahalanobis' distance, t-test and F-test statistics, and associated degrees of freedom. These values are useful for an assessment regarding whether the computed discriminant function is statistically significant. This is equivalent to a judgement concerning whether there is any real separation between the two groups in terms of logs used. However, strict application of statistical tests can only be made when conditions of multivariate normality, independence and equivalent dispersion matrices are met.

The user may elect to compute discriminant scores for a specified depth interval, and these are stored in channel 50. These values should be considered as a "synthetic log," which is keyed to the differentiation of the two groups.

Discriminant functions have been widely used by oil companies for exploration studies and have had occasional applications in log analysis (Heseldin, 1976). Their relative mathematical and conceptual simplicity, combined with their "robust" operational characteristics, make them an excellent medium for problems where the user wishes to classify unknown intervals on the basis of "hard" information from limited zones.

FOURIER

FOURIER performs a simple Fourier analysis of a single log specified by the user. Harmonics from zero to 50 are computed and listings printed of a and b coefficients, raw power spectrum, power spectrum smoothed by a Hanning filter, amplitude, and phase angle. The raw power spectrum is also presented graphically.

Fourier analysis is not an operation routinely performed by log analysts, although its potential is occasionally demonstrated by geophysicists who stray into the area. Lindseth (1969) describes an interesting example where the power spectra of logged sections can be viewed as fundamental "signatures" which aid in the differentiation of reef and off-reef environments and their transitional intermediates.

There is no doubt that Fourier analysis provides an extra dimension to conventional log analysis, since all other techniques are confined to the "time domain," whereas the power spectrum is a transformation to the "frequency domain."

COSPECT

COSPECT is an extension of FOURIER to consideration of the cospectrum of two logs stipulated by the user (one as dependent variable, the other as independent). The design of this option has been hampered by the openly admitted conflicts of terminology and usage that abound in the literature of cospectral analysis.

A useful introductory analogy can be drawn between correlation and cospectral analysis. Correlation attempts to determine the degree of interrelation between two variables from determinations of variances and covariances. The aim of cospectral analysis is to coordinate the power spectra of two variables (variances) with their cospectrum (covariance) in a synthesis which expresses their interrelation in terms of frequency.

However, the analogy is not direct, since the error analysis in each instance is based on the number of degrees of freedom; for simple correlation, this is controlled by the sample size, but for cospectral analysis it is determined by the number of time series used. Since only two logs are used by COSPECT, the error is as large as the quantity estimated.

As a partial resolution of this problem, a "smoothing window" is applied to both the power spectrum and the cross spectrum. This operation increases the number of degrees of freedom, but has the drawback that it reduces the resolution of the frequency components.

In the application of COSPECT, the user specifies the log channel numbers for the independent and dependent variables. The user may also elect to remove a linear trend from the input data. This step is useful in extracting any simple long-term drift and conditioning the data towards "stationarity," which is a prerequisite for classical spectral analysis. The user is asked to select an appropriate smoothing window. The choices are: Hann-Tukey (3 points), Hamming (3 points), Bartlett (3 points), moving average (3 points), Hamming (5 points), Bartlett (5 points), moving average (5 points).

As initial output, COSPECT lists Fourier analyses of the two logs for zero through to 50 harmonics (a and b coefficients, power spectrum, phase angle and smoothed spectrum). This is followed by a listing of the cospectral analysis with gain and phase of the cross-spectrum, coherence function and amplitude ratio. A graphic presentation is made of variation of the phase angle indexed with a digit corresponding to the coherence function.

The graphic presentation is a condensation of information which is most likely to be immediately useful to the log analyst in diagnostic interpretation. Three fundamental variables are expressed: frequency (vertical axis), phase angle (horizontal axis) and coherence function (digital number). The coherence function is analogous to the correlation coefficient, but is scaled between extremes of zero (dissimilar) to one (similar). The frequency is given by the range of the analytical interval (specified by DEPTH) divided by the harmonic number (listed in the LAG column). Collectively, the trace expresses the degree of "correlation" between two logs as a function of frequency content.

Although cospectral analysis has not been widely used in the petrophysical literature, the potential for such methods is clearly apparent, particularly since quasi-periodicities in the rock succession has been recognized by many geologists as shown by the proliferation of papers on cyclic sedimentation over the last half century.

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THE KOALA CASE STUDIES

Stratigraphic intervals from four wells in Kansas were selected as examples of diverse subsurface associations to demonstrate the operation and output of the various KOALA options. In each case, digitized log suites are tabulated as test data in order for the user to familiarize himself with the operation of the KOALA system. Collectively, the case studies involve some of the more common problems encountered by the industrial log analyst and the academic subsurface stratigrapher. Their themes are indicated by their titles:

1: Evaporites;

2: Complex carbonate;

3: "Clean" sandstone;

4: "Shaly" sandstone;

5: Dipmeter analysis;

6: Synthetic seismic modeling.

It is beyond the scope of the manual to consider all possible applications of the KOALA system, although some further suggestions are made in the Manual Postscript.

The analysis of each interval is documented as a case study, with an initial consideration of its context and intrinsic characteristics. Wherever possible, external sources of "hard" data have been supplied in the form of core analyses and ancillary information. This material is useful in the evaluation of the KOALA example output and may encourage the user to attempt independent experimentation with the KOALA options.

Each case study introduction is followed by a commentary, which is keyed to a reproduction of a KOALA run, devised as a reasonable strategy of analysis performed in a logical sequence of option usage. The analyses are slightly artificial, in the sense that an attempt has been made to include the broadest variety of options within the case study material.

Each numbered point of the commentary is matched with the corresponding number on the KOALA output. These segments correspond with KOALA "pages," whose separation is indicated by bold dashed lines. "Returns" are indicated by solid squares. The GOPHER control module menu is displayed on frequent occasions in the development of these examples. In order to conserve space, this menu is abbreviated to a heavy caption together with the "prompt" used as a response.

These analyses are neither unique nor definitive KOALA solutions. Poor decisions by the user (in this case, the authors) based on intermediate KOALA output will result in poor analyses. Satisfactory results indicate intelligent coordination of user skills with the computational power and flexibility of the KOALA system.

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CASE STUDY I: EVAPORITES

In 1970, the U.S. Atomic Energy Commission drilled Test Hole No. 2 (C-N/2-N/2 35-19S-8W) in Lyons County, central Kansas. The test hole was part of a study of the potential for storage of high-level radioactive wastes in salt beds in Kansas. In this case, the target horizon was the Hutchinson Salt (Wellington Formation, Permian), which was both continuously cored and logged for stratigraphic and engineering evaluatons.

A 50-foot subsection of the log suite was chosen for analysis by KOALA. This interval straddles the base of the Hutchinson Salt and the anhydrite, shale and sandstone beds of the lower Wellington (Fig. 18). A graphic reproduction of the core lithologies is shown in Figure 19. The heterogeneity of the section and the distinctive log responses of its components make the sequence a useful subject for demonstration of KOALA options. Experiments to resolve the mineralogical variation of the section were reviewed by Doveton and Cable (1979), using log combinations with different degrees of information determinancy.

The log suite data set is listed in Table 4 and lists readings at 1-foot increments for gamma ray (API units), density (gm/cc), sonic (microsec/ft) and SNP neutron (porosity units) logs.

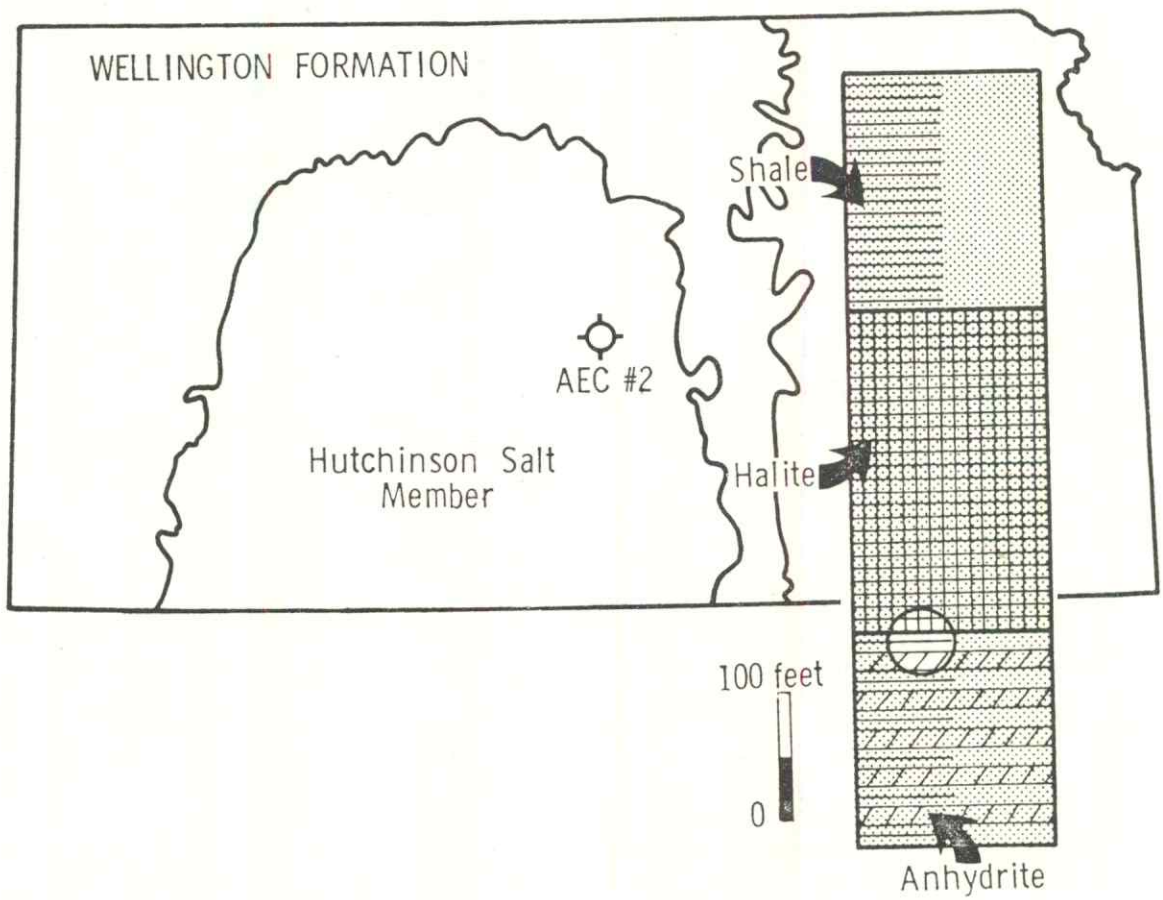


FIGURE 18: Wellington Formation section containing Hutchinson Salt Member in the AEC No. 2 test hole. Case-study interval is circled.

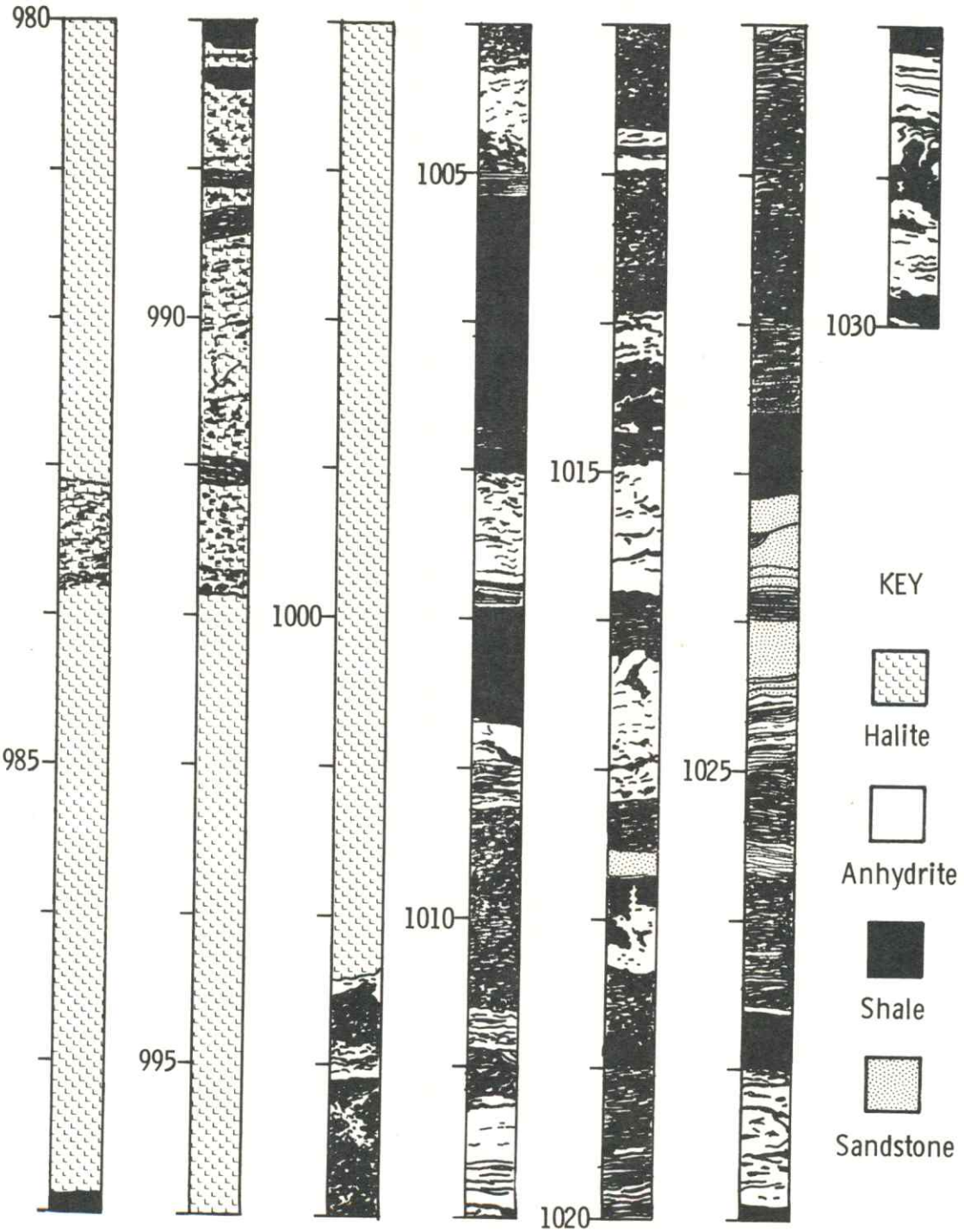


FIGURE 19: Core lithologies from the AEC No. 2 test hole, from the Hutchinson Salt Member at the top to the lower Wellington Formation.

OUTPUT COMMENTARY

1 Access to the KOALA system. Coordination of KOALA with the AEC well data file.

2 GOPHER control module menu. (Note that all future appearances of this menu in these case studies will be symbolized by a bold caption). "ECHO" prompt.

3 ECHO option: Request for numerical values of depth, gamma ray, density, sonic and SNP neutron channels for the entire interval.

4 ECHO option output. Further ECHO usage is declined.

5 GOPHER control module menu. "STATISTICS" prompt.

6 STATISTICS option: Channel summaries requested for entire interval.

7 STATISTICS option output.

8 STATISTICS option: Further statistical summaries are declined. Histogram production is rejected. (See Case Study No. 3 for example of histogram output.)

9 GOPHER control module menu. "LOGPLOT" prompt.

10 LOGPLOT option: Selection of depth interval, logs, track positions, scaling conventions, scale ranges, line weights, treatment of data outside ranges, and optional shading between logs. (Note that the choice of logs and their associated ranges is aided by review of the STATISTICS output.)

11 LOGPLOT output. Further LOGPLOT usage declined. (Note that the gross stratigraphy of the section is clearly indicated by the LOGPLOT presentation, and shows the Hutchinson Salt above interbedded shales and anhydrites.)

12 GOPHER menu. "COMMENT" prompt.

13 COMMENT option: Entry of stratigraphic identifiers and dashed boundary which marks base of Hutchinson Salt.

14 GOPHER menu. "CROSSPLOT" prompt.

15 CROSSPLOT option: Sonic versus density logs with user-stipulated scales. (Note that maximum and minimum values are given by STATISTICS output.) The choice of zero for the Z-axis parameter dictates that frequencies will be crossplotted. The interval selected coincides with the entire section.

16 CROSSPLOT output: Frequency plot. Joint frequencies of log values with respect to the two axes, marginal totals of rows and columns, and summaries of the number of points which lie both within and outside the bounds of the crossplot. The sides of the fundamental halite-anhydrite-shale composition triangle have been added manually. (Note that, although KOALA does not have a hardware "zoom" option, the same result may be achieved by multiple use of CROSSPLOT with expanded and translated scales of the two axes.)

17 GOPHER menu. "CROSSPLOT" prompt.

18 CROSSPLOT option: SNP neutron versus density logs with user-defined scales. Stipulation of the gamma ray log as a third "Z" axis, with integer presentation scaled between limits of 0 and 100 API units. Depth range equated with entire section.

19 CROSSPLOT output: Z-plot. Crossplotted points are denoted by average integer transforms of the associated gamma ray readings. A systematic increase in radioactivity across the (manually drafted) triangle towards the shale vertex clearly matches expectations. As with the frequency CROSSPLOT, the marginal quantities represent row and column frequency totals.

20 GOPHER menu. "PETRA" prompt.

21 PETRA option: Specifications for provisional resolution of the composition of the entire section in terms of the components of halite, anhydrite and shale, using the density, sonic and SNP neutron logs. Review of the default coefficients. Modification of the shale density, sonic and neutron coefficients to values which conform to estimations drawn from the LOGPLOT and CROSSPLOT output results. No modification is made to the component key.

22 PETRA output. Key with well identifier, analytical interval, solution logs and components, component graphic representation.

23 PETRA output. Summary of log-component coefficients to be used. Indication of solution algorithm. Since equations exceed unknowns in this PETRA run, the system is overdetermined and will be resolved as a least-squares solution. The summary information is accepted as correct.

24 PETRA output. Graphic presentation of component proportions in polygonal convention, comment track flags, diagnostics. As an overdetermined system, all three diagnostics of proportional variance, sum deviation and error are actively computed. The virtually consistent null sum deviation values indicate that almost all points lie within the triangular composition plane. Error values (limestone porosity units) are acceptably low, but the highest deviations occur most commonly in the Wellington Formation below the Salt. The authors suggest that these observations are explained by sandstone and silty horizons in the lower unit. A "sandstone line" would be located within the halite-anhydrite-shale composition space. As a consequence, the sum deviations would be insensitive to sandy zones, although these would be detected to some degree by the error diagnostic. The component proportions are stored in the appropriate work channels, as requested by the user, and further work with PETRA is initiated.

25 PETRA option: Specifications for a revision of the lower part of the section, using the same logs, but nominating anhydrite, shale, sandstone (quartz) and porosity as components. Modifications of porosity, density, and sonic coefficients to conform with a salt-saturated mud filtrate.

26 PETRA output. Log-component coefficients and method of solution. Since equations match unknowns on this run, a direct matrix inversion algorithm will be employed.

27 PETRA output. Graphic presentation with diagnostics. The error diagnostic is defaulted. The user decides to store these new component proportion values, which are "overwritten" on earlier values. More work with PETRA is requested.

28 PETRA option. Stipulation of a graphic presentation of the contents of the component channels as a review of the current solution.

29 PETRA output. Graphic presentation without diagnostics. (Note that diagnostic values are stored in the Greek "scratch file" area of channels 50, 51, 52 where they are available for review, unless overwritten by output from other KOALA options.) The ordering of components may be changed, and a block, rather than polygonal, convention selected for alternative forms of presentation. More work with PETRA is requested.

30 PETRA option. Since the compositional variation in mineralogy of the section retrieved by PETRA is, in some sense, a "moving average" of the "real composition," the user elects to try the sharpening filter option, which will accentuate bed differentiation.

31 PETRA output. The inverse filtered component proportions are automatically presented in block, rather than polygonal mode, to further emphasize bedding characteristics. The user may choose to store the results of this operation, although this is not encouraged as a general rule. Further work with PETRA is declined.

32 GOPHER menu. "BYE" prompt. Exit from the KOALA system.

Table 4
CASE STUDY #I
EVAPORITES

WELL NAME: A.E.C. TEST HOLE 2
LOCATION: RICE COUNTY, KANSAS
DATE: 1970

01-DEPTH	03-GR	04-DENSITY	05-SONIC	06-GNT/SNP %
980.000	4.594	2.095	67.364	3.546
981.000	5.001	2.095	67.071	3.535
982.000	5.938	2.108	66.878	3.724
983.000	8.123	2.110	66.595	5.238
984.000	13.422	2.118	73.323	6.802
985.000	13.186	2.091	70.919	5.287
986.000	8.339	2.073	68.064	4.090
987.000	10.368	2.121	68.262	5.322
988.000	28.131	2.165	70.895	9.122
989.000	43.525	2.224	77.579	13.470
990.000	47.025	2.241	87.753	18.967
991.000	37.287	2.234	85.870	15.006
992.000	22.768	2.185	77.709	8.717
993.000	10.628	2.159	69.217	4.844
994.000	7.923	2.140	68.722	4.093
995.000	6.211	2.109	67.146	3.785
996.000	7.554	2.107	66.904	3.939
997.000	7.124	2.123	68.171	3.940
998.000	5.983	2.113	67.384	3.816
999.000	4.665	2.092	67.143	3.450
1000.000	5.104	2.144	67.114	3.516
1001.000	6.400	2.184	67.686	3.817
1002.000	15.307	2.225	67.837	4.942
1003.000	27.154	2.318	71.623	10.669
1004.000	43.330	2.430	79.985	16.037
1005.000	49.884	2.511	78.447	15.668
1006.000	66.090	2.485	98.843	22.077
1007.000	67.003	2.459	112.068	28.486
1008.000	56.555	2.466	102.012	26.246
1009.000	52.283	2.473	101.772	24.005
1010.000	50.853	2.480	89.193	21.766
1011.000	53.411	2.572	87.931	16.452
1012.000	45.782	2.624	77.476	14.215
1013.000	51.608	2.583	93.102	18.337
1014.000	59.416	2.570	98.464	23.688
1015.000	55.058	2.620	88.612	21.137
1016.000	44.944	2.647	78.551	16.840
1017.000	40.149	2.656	77.329	12.544
1018.000	43.083	2.556	88.986	18.042
1019.000	52.126	2.456	93.338	23.920
1020.000	57.087	2.437	97.780	26.614
1021.000	50.708	2.553	94.703	20.336
1022.000	37.577	2.593	81.150	15.676
1023.000	35.721	2.633	67.598	13.561
1024.000	44.559	2.536	84.278	24.713
1025.000	48.786	2.396	94.506	25.922
1026.000	52.004	2.477	87.758	18.330
1027.000	55.797	2.599	81.011	17.738
1028.000	58.967	2.544	96.650	23.564
1029.000	47.909	2.551	89.957	17.518
1030.000	40.159	2.675	75.792	11.509

```
: KOALA

KOALA
DO YOU HAVE A SEPARATE FILE CONTAINING
WELL LOG AND CONSTANT NAMES - YES, NO, SAME
NO
DO YOU HAVE A USER DEFINED INPUT OR
OUTPUT FILE - YES, NO, SAME
NO
DO YOU HAVE A KOALA DATA FILE - YES, NO, SAME
YES
ENTER FILE NAME
CASESTUDY1
```

(1)

---

(2)

```
GOPHER CONTROL MODULE

DATA ENTRY AND MODIFICATION
        FILES ---------- DEFINE EXTERNAL INPUT, OUTPUT, AND
                         DATA FILES
        DATABASE ------- INITIALIZE KOALA WELL LOG FILE
                         ADD, DELETE, AND MODIFY CHANNELS
                         CHANGE LABEL AND CONSTANTS
        ECHO ----------- LIST CONSTANTS AND CHANNEL CONTENTS
        STORE ---------- COPY CHANNEL ONTO EXTERNAL FILE
        ABACUS --------- RESCALE OR TRANSFER CHANNEL
                         MULTIPLEX TWO CHANNELS
                         SUM CONTENTS OF CHANNEL
        LEXICON -------- CHANGE ASSUMED NAMES FOR CHANNELS
                         OR CONSTANTS
        SHIFT ---------- DEPTH SHIFT CHANNEL
        COMMENT -------- ADD, DELETE, OR RETRIEVE DEPTH-INDEXED
                         COMMENT INFORMATION

DATA DISPLAY
        STATISTICS ----- LIST STATUS OF ALL CHANNELS AND
                         CONSTANTS, WITH MINIMUM, MAXIMUM
                         AND AVERAGE VALUES.  PLOT HISTOGRAMS
                         FOR DESIRED CHANNELS
        LOGPLOT -------- PLOT CONTENTS OF SPECIFIED CHANNELS
                         IN CONVENTIONAL WELL LOG FORMAT ON
                         TERMINAL SCREEN
        AUTOPLOT ------- FIXED-FRAME FREQUENCY CROSSPLOTS OF
                         COMBINATIONS OF GAMMA RAY, DENSITY,
                         SONIC, AND NEUTRON LOGS
        CROSSPLOT ------ CROSSPLOT ANY TWO CHANNELS WITH USER
                         SPECIFIED FRAME EITHER AS FREQUENCY
                         OR Z-PLOT
        MNP ------------ COMPUTE, LIST, AND STORE ALL POSSIBLE
                         M, N, AND P VALUES

EXTERNAL PLOTTER OPTIONS
        XYPLOT --------- TRANSFER OF LOGPLOT TO PLOTTER
        XYPETRA -------- TRANSFER OF PETRA OUTPUT TO PLOTTER

ACCESS TO KOALA SATELLITE MODULES
        PETRA ---------- MINERALOGY, LITHOLOGY, AND POROSITY
                         RESOLUTION
        KOBRA ---------- RESERVOIR ANALYSIS FUNCTIONS
        KERMIT --------- DIPMETER ANALYSIS
        SNARK ---------- SYNTHETIC SEISMIC MODELLING
        MERLIN --------- MULTIVARIATE STATISTICS AND TIME SERIES
                         ANALYSIS
        BYE ------------ EXIT KOALA SYSTEM

INPUT NAME OF DESIRED OPTION
ECHO
```

```
ECHO PRINT WELL LOG DATA ON FILE
TOTAL INTERVAL AVAILABLE   980.00 TO  1030.00
DO YOU WANT THE TOTAL INTERVAL - YES OR NO
YES
DO YOU WANT CONSTANTS LISTED - YES OR NO
NO
FOR EACH LOG DESIRED, INPUT ITS TWO DIGIT
TRACK NUMBER - A MAXIMUM OF 15 LOGS CAN BE PRINTED
    ENTER 0 WHEN FINISHED
    01=DEPTH              02=SP                 03=GR
    04=DENSITY            05=SONIC              06=GNT/SNP %
    07=CNL %              08=NEUTRON COUNT      09=LL8
    10=ILM                11=ILD                12=DEEP LATEROLOG
    13=MICRORESISTIVITY   14=AZIMUTH            15=DIP
    16=TEMPERATURE        17=INTEGRATED SONIC   18=CALIPER
    19=                   20=                   21=PETRA SS
    22=PETRA LS           23=PETRA DOL          24=PETRA SH
    25=PETRA AN           26=PETRA HL           27=PETRA CL
    28=PETRA POR          29=PETRA 2POR         30=PHIRA
    31=SX0                32=SW                 33=K
    34=DI                 35=RT                 36=RX0
    37=RWA                38=M                  39=N
    40=P                  41=ARCHIE M           42=SYNTH SEISM
    43=MODEL SONIC        44=MODEL INT SONIC    45=
    46=                   47=                   48=
    49=                   50=ALPHA              51=BETA
    52=GAMMA              53=DELTA              54=EPSILON
    55=OMEGA
01
03
04
05
06
0
```

WELL NAME: A.E.C. TEST HOLE 2
LOCATION: RICE COUNTY, KANSAS
DATE: 1970

01-DEPTH	03-GR	04-DENSITY	05-SONIC	06-GNT/SNP %
980.000	4.593	2.094	67.364	3.545
981.000	5.001	2.094	67.071	3.534
982.000	5.938	2.108	66.877	3.723
983.000	8.123	2.109	66.594	5.237
984.000	13.421	2.118	73.323	6.801
985.000	13.186	2.090	70.919	5.287
986.000	8.339	2.073	68.064	4.089
987.000	10.368	2.121	68.261	5.322
988.000	28.131	2.164	70.895	9.121
989.000	43.524	2.223	77.579	13.470
990.000	47.025	2.240	87.752	18.967
991.000	37.287	2.234	85.869	15.006
992.000	22.767	2.184	77.708	8.717
993.000	10.628	2.158	69.216	4.844
994.000	7.923	2.140	68.722	4.093
995.000	6.211	2.109	67.145	3.785
996.000	7.553	2.107	66.904	3.938
997.000	7.123	2.123	68.171	3.940
998.000	5.982	2.113	67.384	3.815
999.000	4.664	2.092	67.142	3.450
1000.000	5.103	2.144	67.113	3.515
1001.000	6.400	2.184	67.685	3.816
1002.000	15.307	2.224	67.836	4.941
1003.000	27.154	2.318	71.623	10.669
1004.000	43.330	2.430	79.985	16.036
1005.000	49.883	2.511	78.446	15.667
1006.000	66.089	2.485	98.843	22.077
1007.000	67.003	2.459	112.068	28.486
1008.000	56.554	2.466	102.012	26.246
1009.000	52.283	2.473	101.772	24.005
1010.000	50.852	2.479	89.193	21.765
1011.000	53.411	2.571	87.931	16.451
1012.000	45.782	2.623	77.476	14.215
1013.000	51.607	2.582	93.102	18.336
1014.000	59.416	2.569	98.464	23.688
1015.000	55.058	2.620	88.612	21.137
1016.000	44.944	2.646	78.551	16.840
1017.000	40.149	2.655	77.329	12.543
1018.000	43.082	2.556	88.986	18.041
1019.000	52.126	2.456	93.338	23.920
1020.000	57.087	2.437	97.780	26.613
1021.000	50.708	2.553	94.702	20.336
1022.000	37.577	2.593	81.150	15.676
1023.000	35.721	2.633	67.597	13.561
1024.000	44.559	2.536	84.278	24.712
1025.000	48.786	2.396	94.505	25.922
1026.000	52.003	2.477	87.758	18.329
1027.000	55.796	2.599	81.010	17.738
1028.000	58.967	2.544	96.650	23.564
1029.000	47.908	2.551	89.957	17.518
1030.000	40.159	2.675	75.792	11.508

IS MORE INFORMATION TO BE PRINTED - YES OR NO
NO

5

gopher menu

INPUT NAME OF DESIRED OPTION
STATISTICS

6

SUMMARY STATISTICS AND HISTOGRAMS
TOTAL INTERVAL AVAILABLE 980.00 TO 1030.00
DO YOU WANT THE TOTAL INTERVAL - YES OR NO
YES

WELL NAME: A.E.C. TEST HOLE 2
LOCATION: RICE COUNTY, KANSAS
DATE: 1970
INTERVAL: 980.00 TO 1030.00

LOG NUMBER	AVAILABILITY FOR USAGE AVAILABLE	NUMBER OF VALUES	NUMBER OF VALUES DEFAULTED	MINIMUM VALUE	MAXIMUM VALUE	AVERAGE VALUE
01=DEPTH	YES	51	0	980.00	1030.00	1005.00
02=SP	NO					
03=GR	YES	51	0	4.59	67.00	33.58
04=DENSITY	YES	51	0	2.07	2.67	2.35
05=SONIC	YES	51	0	66.59	112.06	80.28
06=GNT/SNP %	YES	51	0	3.45	28.48	13.50
07=CNL %	NO					
08=NEUTRON COUNT	NO					
09=LL8	NO					
10=ILM	NO					
11=ILD	NO					
12=DEEP LATEROLOG	NO					
13=MICRORESISTIVITY	NO					
14=AZIMUTH	NO					
15=DIP	NO					
16=TEMPERATURE	NO					
17=INTEGRATED SONIC	NO					
18=CALIPER	NO					
19=	NO					
20=	NO					
21=PETRA SS	NO					
22=PETRA LS	NO					
23=PETRA DOL	NO					
24=PETRA SH	NO					
25=PETRA AN	NO					
26=PETRA HL	NO					
27=PETRA CL	NO					
28=PETRA POR	NO					
29=PETRA 2POR	NO					
30=PHIRA	NO					
31=SX0	NO					
32=SW	NO					
33=K	NO					
34=DI	NO					
35=RT	NO					
36=RX0	NO					
37=RWA	NO					
38=M	NO					
39=N	NO					
40=P	NO					
41=ARCHIE M	NO					
42=SYNTH SEISM	NO					
43=MODEL SONIC	NO					
44=MODEL INT SONIC	NO					
45=	NO					
46=	NO					
47=	NO					
48=	NO					
49=	NO					
50=ALPHA	NO					
51=BETA	NO					
52=GAMMA	NO					
53=DELTA	NO					
54=EPSILON	NO					
55=OMEGA	NO					

CONSTANTS	VALUE
01=MINIMUM DEPTH	980.00
02=MAXIMUM DEPTH	1030.00
03=INCREMENT	1.00
04=ELEVATION	1704.00
05=LATITUDE	-9999.00
06=LONGITUDE	-9999.00
07=RM	0.08
08=TRM	65.00
09=RMF	0.07
10=TRMF	70.00
11=RMC	-9999.00
12=TRMC	-9999.00
13=BHT	75.80
14=MEAN-T	55.00
15=T-GRADIENT	-9999.00
16=TIME-C-GR	-9999.00
17=TIME-C-N	-9999.00
18=LOG SPEED GR	-9999.00
19=LOG SPEED N	-9999.00
20=TD	1216.00
21=	-9999.00
22=	-9999.00
23=	-9999.00
24=	-9999.00
25=	-9999.00
26=	-9999.00
27=	-9999.00
28=	-9999.00
29=	-9999.00
30=	-9999.00
31=	-9999.00
32=	-9999.00
33=	-9999.00
34=	-9999.00
35=	-9999.00
36=	-9999.00
37=	-9999.00
38=	-9999.00
39=	-9999.00
40=	-9999.00
41=	-9999.00
42=	-9999.00
43=	-9999.00
44=	-9999.00
45=	-9999.00
46=	-9999.00
47=	-9999.00
48=TOP VIOLA	-9999.00
49=TOP SIMPSON	-9999.00
50=TOP ARBUCKLE	-9999.00
51=	-9999.00
52=	-9999.00
53=	-9999.00
54=	-9999.00
55=	-9999.00
56=	-9999.00
57=	-9999.00
58=	-9999.00
59=	-9999.00
60=	-9999.00

8

```
DO YOU WANT ANOTHER DEPTH INTERVAL- YES OR NO
NO
DO YOU WANT A HISTOGRAM PRODUCED - YES OR NO
NO
```

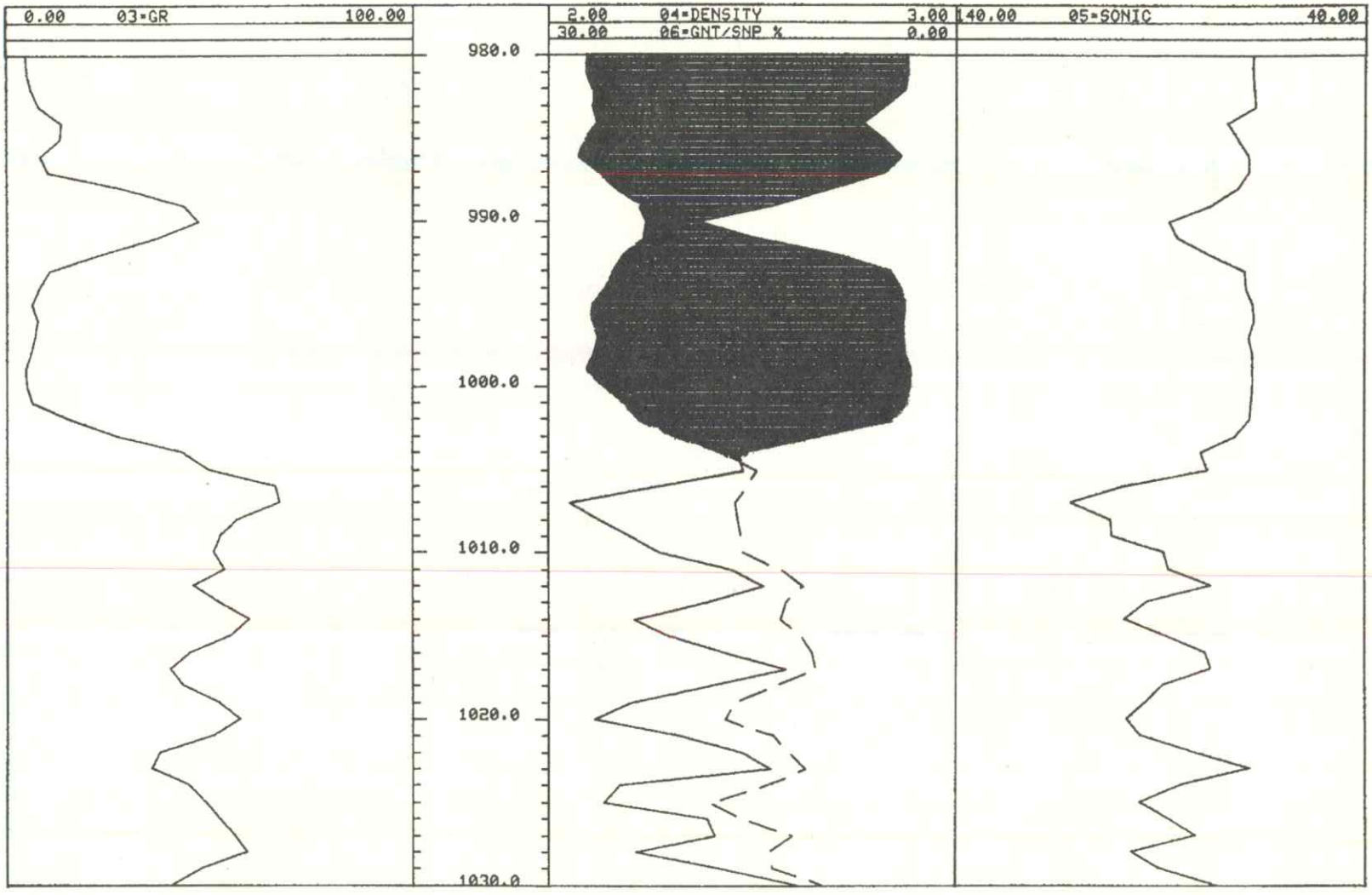
9

gopher menu

```
INPUT NAME OF DESIRED OPTION
LOGPLOT
```

```
PROGRAM TO PLOT WELL LOGS
TOTAL INTERVAL AVAILABLE   980.00 TO  1030.00
DO YOU WANT THE ENTIRE INTERVAL - YES OR NO
YES
WELL LOGS
 01=DEPTH                02=SP                   03=GR
 04=DENSITY              05=SONIC                06=GNT/SNP %
 07=CNL %                08=NEUTRON COUNT        09=LL8
 10=ILM                  11=ILD                  12=DEEP LATEROLOG
 13=MICROPESISTIVITY     14=AZIMUTH              15=DIP
 16=TEMPERATURE          17=INTEGRATED SONIC     18=CALIPER
 19=                     20=                     21=PETRA SS
 22=PETRA LS             23=PETRA DOL            24=PETRA SH
 25=PETRA AN             26=PETRA HL             27=PETRA CL
 28=PETRA POR            29=PETRA 2POR           30=PHIRA
 31=SX0                  32=SW                   33=K
 34=DI                   35=RT                   36=RX0
 37=RWA                  38=M                    39=N
 40=P                    41=ARCHIE M             42=SYNTH SEISM
 43=MODEL SONIC          44=MODEL INT SONIC      45=
 46=                     47=                     48=
 49=                     50=ALPHA                51=BETA
 52=GAMMA                53=DELTA                54=EPSILON
 55=OMEGA
WILL TRACK 1 AND POSITION 1
BE USED - YES OR NO
YES
ENTER LOG NUMBER - 01 TO 55
03
ENTER TYPE OF SCALING
    1=LINEAR
    2=LOGARITHMIC BASE 10
    3=LOGARITHMIC BASE E
    4=EXPONENTIAL BASE 10
    5=EXPONENTIAL BASE E
1
ENTER LEFTMOST VALUE TO BE PLOTTED
0.
ENTER RIGHTMOST VALUE TO BE PLOTTED
100.
ENTER LINE WEIGHT TO BE USED
        1=SOLID LINE
        2=DASHED LINE
        3=DOTTED LINE
1
ENTER METHOD OF HANDLING OFF-SCALE DATA
    1=CLIP
    2=REFLECT
1
WILL TRACK 1 AND POSITION 2
BE USED - YES OR NO
NO
WILL TRACK 2 AND POSITION 1
BE USED - YES OR NO
YES
ENTER LOG NUMBER - 01 TO 55
04
ENTER TYPE OF SCALING
    1=LINEAR
    2=LOGARITHMIC BASE 10
    3=LOGARITHMIC BASE E
    4=EXPONENTIAL BASE 10
    5=EXPONENTIAL BASE E
1
ENTER LEFTMOST VALUE TO BE PLOTTED
2.0
ENTER RIGHTMOST VALUE TO BE PLOTTED
3.0
ENTER LINE WEIGHT TO BE USED
        1=SOLID LINE
        2=DASHED LINE
        3=DOTTED LINE
2
ENTER METHOD OF HANDLING OFF-SCALE DATA
    1=CLIP
    2=REFLECT
1
WILL TRACK 2 AND POSITION 2
BE USED - YES OR NO
YES
ENTER LOG NUMBER - 01 TO 55
06
ENTER TYPE OF SCALING
    1=LINEAR
    2=LOGARITHMIC BASE 10
    3=LOGARITHMIC BASE E
    4=EXPONENTIAL BASE 10
    5=EXPONENTIAL BASE E
1
ENTER LEFTMOST VALUE TO BE PLOTTED
30.
ENTER RIGHTMOST VALUE TO BE PLOTTED
0.
ENTER LINE WEIGHT TO BE USED
        1=SOLID LINE
        2=DASHED LINE
        3=DOTTED LINE
1
ENTER METHOD OF HANDLING OFF-SCALE DATA
    1=CLIP
    2=REFLECT
1
WILL TRACK 2 AND POSITION 3
BE USED - YES OR NO
NO
WILL TRACK 3 AND POSITION 1
BE USED - YES OR NO
YES
ENTER LOG NUMBER - 01 TO 55
05
ENTER TYPE OF SCALING
    1=LINEAR
    2=LOGARITHMIC BASE 10
    3=LOGARITHMIC BASE E
    4=EXPONENTIAL BASE 10
    5=EXPONENTIAL BASE E
1
ENTER LEFTMOST VALUE TO BE PLOTTED
140.
ENTER RIGHTMOST VALUE TO BE PLOTTED
40.
ENTER LINE WEIGHT TO BE USED
        1=SOLID LINE
        2=DASHED LINE
        3=DOTTED LINE
1
ENTER METHOD OF HANDLING OFF-SCALE DATA
    1=CLIP
    2=REFLECT
1
WILL TRACK 3 AND POSITION 2
BE USED - YES OR NO
NO
DO YOU WANT SHADING BETWEEN LOGS - YES OR NO
YES
INPUT LEFTMOST LOG NUMBER - 02 TO 55
04
INPUT RIGHTMOST LOG NUMBER - 02 TO 55
06
SHADING WILL BE PERFORMED
DO YOU WANT SHADING BETWEEN LOGS - YES OR NO
NO
```

WELL NAME: A.E.C. TEST HOLE 2



DO YOU WANT A DIFFERENT DEPTH - YES OR NO
NO

(12)

gopher menu

```
INPUT NAME OF DESIRED OPTION
COMMENT
```

---

(13)

```
COMMENT - AVAILABLE OPTIONS
    BLANK ----- INITIALIZE ALL COMMENTS TO BLANKS
    LIST ------ LIST COMMENTS ON AN INTERVAL
    INSERT ---- ADD COMMENTS TO AN INTERVAL
    DELETE ---- DELETE COMMENTS FROM AN INTERVAL
    STOP ------ FINISHED
BLANK
COMMENT - AVAILABLE OPTIONS
    BLANK ----- INITIALIZE ALL COMMENTS TO BLANKS
    LIST ------ LIST COMMENTS ON AN INTERVAL
    INSERT ---- ADD COMMENTS TO AN INTERVAL
    DELETE ---- DELETE COMMENTS FROM AN INTERVAL
    STOP ------ FINISHED
INSERT
COMMENTS MAY BE A MAXIMUM OF 10 CHARACTERS
ENTER STARTING DEPTH - ENTER 0 IF FINISHED
986.
DEPTH  986.00 - ENTER RETURN IF FINISHED
HUTCHINSON
DEPTH  987.00 - ENTER RETURN IF FINISHED
   SALT
DEPTH  988.00 - ENTER RETURN IF FINISHED
  MEMBER
DEPTH  989.00 - ENTER RETURN IF FINISHED

COMMENTS MAY BE A MAXIMUM OF 10 CHARACTERS
ENTER STARTING DEPTH - ENTER 0 IF FINISHED
1003.
DEPTH 1003.00 - ENTER RETURN IF FINISHED
----------
DEPTH 1004.00 - ENTER RETURN IF FINISHED

COMMENTS MAY BE A MAXIMUM OF 10 CHARACTERS
ENTER STARTING DEPTH - ENTER 0 IF FINISHED
1018.
DEPTH 1018.00 - ENTER RETURN IF FINISHED
WELLINGTON
DEPTH 1019.00 - ENTER RETURN IF FINISHED
 FORMATION
DEPTH 1020.00 - ENTER RETURN IF FINISHED
  BELOW
DEPTH 1021.00 - ENTER RETURN IF FINISHED
   SALT
DEPTH 1022.00 - ENTER RETURN IF FINISHED

COMMENTS MAY BE A MAXIMUM OF 10 CHARACTERS
ENTER STARTING DEPTH - ENTER 0 IF FINISHED
0
COMMENT - AVAILABLE OPTIONS
    BLANK ----- INITIALIZE ALL COMMENTS TO BLANKS
    LIST ------ LIST COMMENTS ON AN INTERVAL
    INSERT ---- ADD COMMENTS TO AN INTERVAL
    DELETE ---- DELETE COMMENTS FROM AN INTERVAL
    STOP ------ FINISHED
STOP
```

(14)

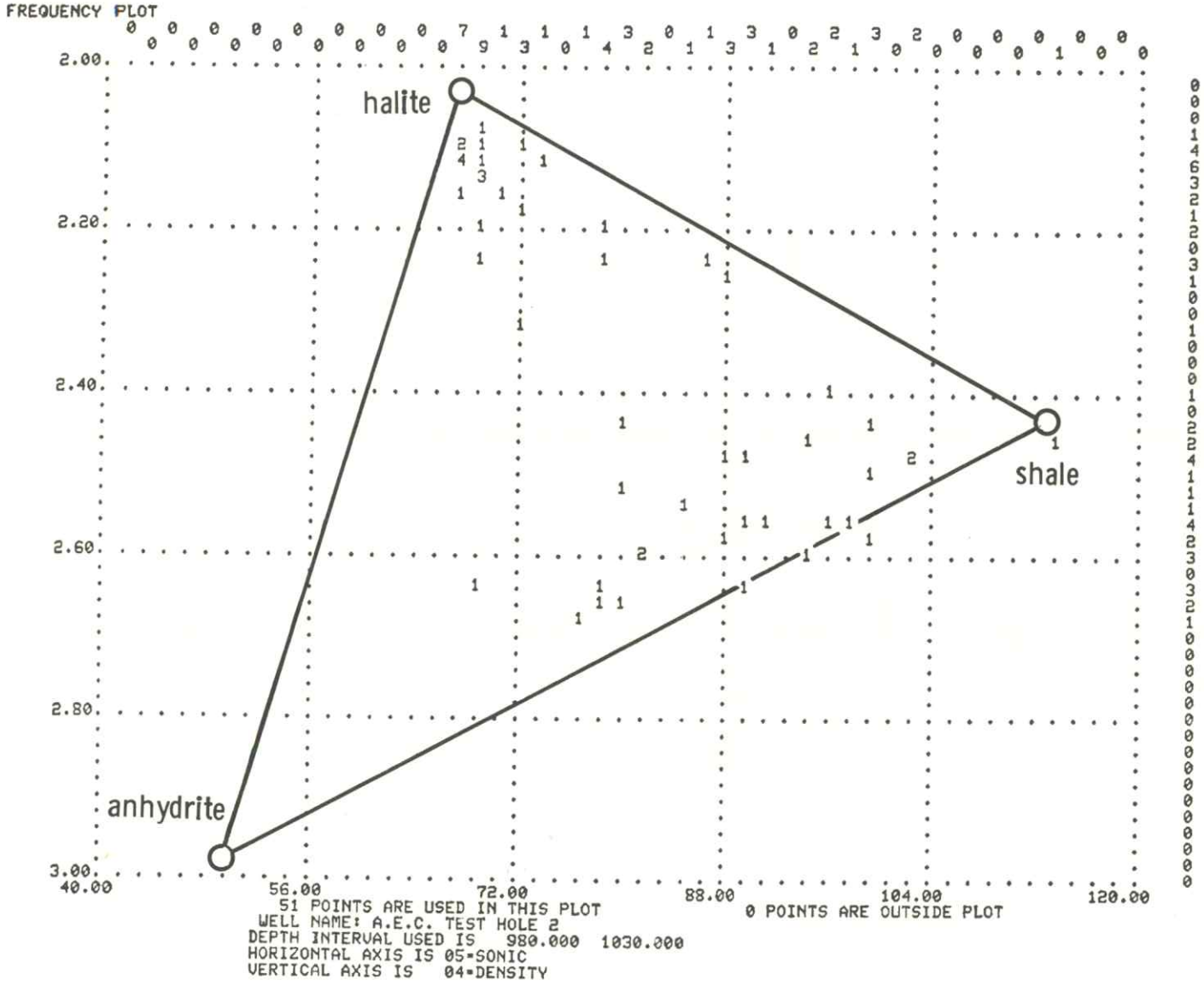
gopher menu

```
INPUT NAME OF DESIRED OPTION
CROSSPLOT
```

---

(15)

```
CROSSPLOT PROGRAM
01-DEPTH                02-SP                   03-GR
04-DENSITY              05-SONIC                06-GNT/SNP %
07-CNL %                08-NEUTRON COUNT        09-LL8
10-ILM                  11-ILD                  12-DEEP LATEROLOG
13-MICROPESISTIVITY     14-AZIMUTH              15-DIP
16-TEMPERATURE          17-INTEGRATED SONIC     18-CALIPER
19-                     20-                     21-PETRA SS
22-PETPA LS             23-PETRA DOL            24-PETRA SH
25-PETRA AN             26-PETRA HL             27-PETRA CL
28-PETRA POR            29-PETRA 2POR           30-PHIRA
31-SX0                  32-SW                   33-K
34-DI                   35-RT                   36-RX0
37-RWA                  38-M                    39-N
40-P                    41-ARCHIE M             42-SYNTH SEISM
43-MODEL SONIC          44-MODEL INT SONIC      45-
46-                     47-                     48-
49-                     50-ALPHA                51-BETA
52-GAMMA                53-DELTA                54-EPSILON
55-OMEGA
CROSSPLOT PROGRAM
    PARAMETERS FOR HORIZONTAL AXIS
         LOG NUMBER (01-55)
05
         LEFTMOST VALUE
40.
         RIGHTMOST VALUE
120.
    PARAMETERS FOR VERTICAL AXIS
         LOG NUMBER (01-55)
04
         BOTTOMMOST VALUE
3.0
         TOPMOST VALUE
2.0
    PARAMETERS FOR Z AXIS
         CROSSPLOT -- LOG NUMBER 0
         ZPLOT ------ LOG NUMBER 01-55
0
    ENTER MINIMUM DEPTH DESIRED
980.
    ENTER MAXIMUM DEPTH DESIRED
1030.
```


FREQUENCY PLOT
halite
shale
anhydrite
2.00
2.20
2.40
2.60
2.80
3.00
40.00
56.00
72.00
88.00
104.00
120.00
51 POINTS ARE USED IN THIS PLOT
WELL NAME: A.E.C. TEST HOLE 2
DEPTH INTERVAL USED IS 980.000 1030.000
HORIZONTAL AXIS IS 05=SONIC
VERTICAL AXIS IS 04=DENSITY
0 POINTS ARE OUTSIDE PLOT

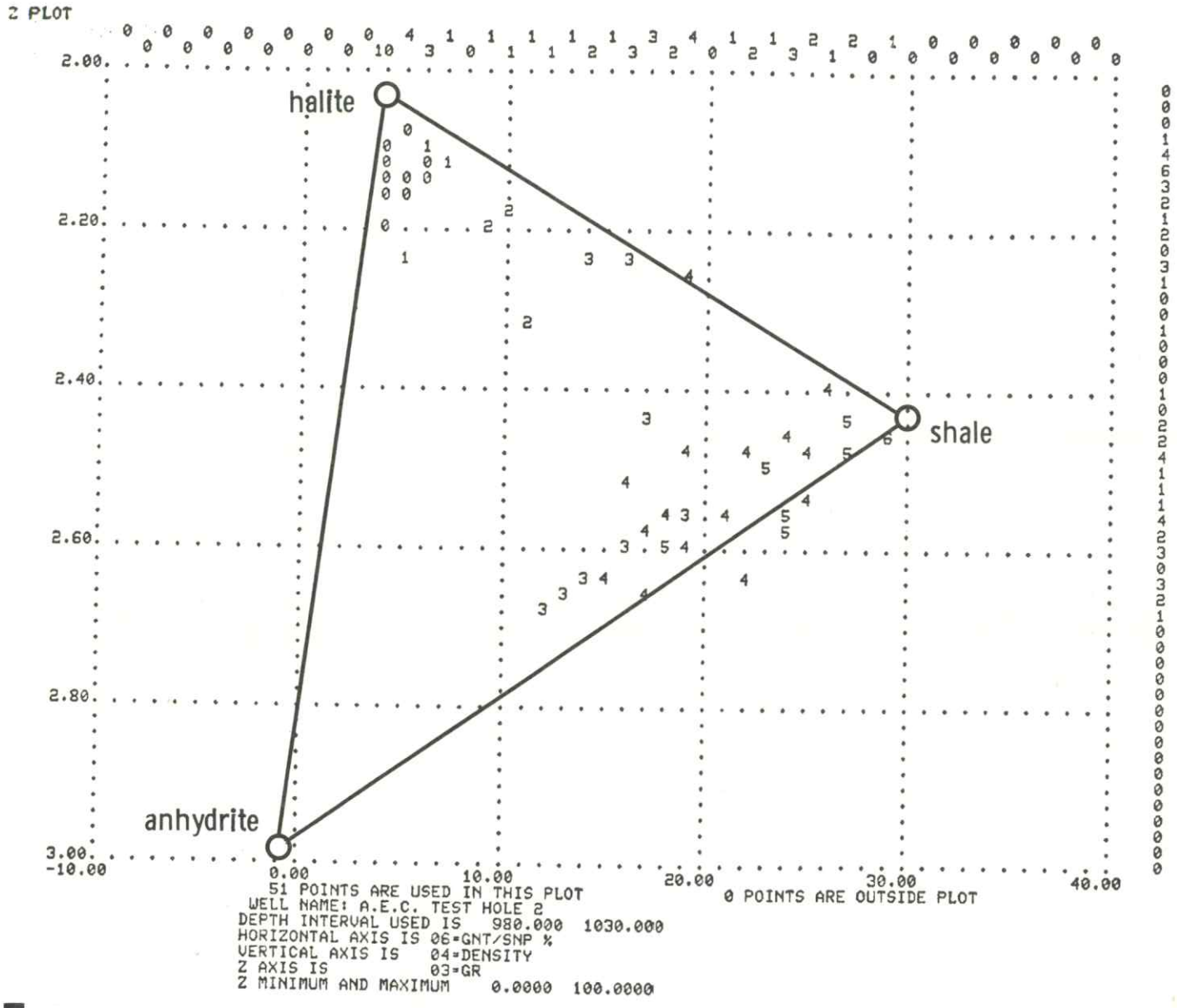
(17)

gopher menu

```
INPUT NAME OF DESIRED OPTION
CROSSPLOT
```

(18)

```
CROSSPLOT PROGRAM
01=DEPTH                02=SP                   03=GR
04=DENSITY              05=SONIC                06=GNT/SNP %
07=CNL %                08=NEUTRON COUNT        09=LL8
10=ILM                  11=ILD                  12=DEEP LATEROLOG
13=MICRORESISTIVITY     14=AZIMUTH              15=DIP
16=TEMPERATURE          17=INTEGRATED SONIC     18=CALIPER
19=                     20=                     21=PETRA SS
22=PETRA LS             23=PETRA DOL            24=PETRA SH
25=PETRA AN             26=PETRA HL             27=PETRA CL
28=PETRA POR            29=PETRA 2POR           30=PHIRA
31=SX0                  32=SW                   33=K
34=DI                   35=RT                   36=RX0
37=RWA                  38=M                    39=N
40=P                    41=ARCHIE M             42=SYNTH SEISM
43=MODEL SONIC          44=MODEL INT SONIC      45=
46=                     47=                     48=
49=                     50=ALPHA                51=BETA
52=GAMMA                53=DELTA                54=EPSILON
55=OMEGA
CROSSPLOT PROGRAM
    PARAMETERS FOR HORIZONTAL AXIS
        LOG NUMBER (01-55)
06
        LEFTMOST VALUE
-10.
        RIGHTMOST VALUE
40.
    PARAMETERS FOR VERTICAL AXIS
        LOG NUMBER (01-55)
04
        BOTTOMMOST VALUE
3.0
        TOPMOST VALUE
2.0
    PARAMETERS FOR Z AXIS
        CROSSPLOT -- LOG NUMBER 0
        ZPLOT ------ LOG NUMBER 01-55
03
        ENTER MINIMUM Z VALUE
0.
        ENTER MAXIMUM Z VALUE
100.
    ENTER MINIMUM DEPTH DESIRED
980.
    ENTER MAXIMUM DEPTH DESIRED
1030.
```


Z PLOT
halite
shale
anhydrite
2.00
2.20
2.40
2.60
2.80
3.00
-10.00
0.00
10.00
20.00
30.00
40.00
51 POINTS ARE USED IN THIS PLOT
0 POINTS ARE OUTSIDE PLOT
WELL NAME: A.E.C. TEST HOLE 2
DEPTH INTERVAL USED IS 980.000 1030.000
HORIZONTAL AXIS IS 06=GNT/SNP %
VERTICAL AXIS IS 04=DENSITY
Z AXIS IS 03=GR
Z MINIMUM AND MAXIMUM 0.0000 100.0000

(20)

gopher menu

```
INPUT NAME OF DESIRED OPTION
PETRA
```

---

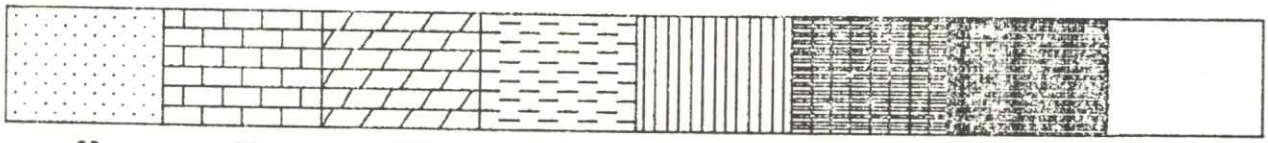
(21)

```
PROGRAM PETRA: MINERALOGICAL/LITHOLOGICAL COMPONENT
    ESTIMATION FOR PETROPHYSICAL WELL LOGS
TOTAL INTERVAL AVAILABLE   980.00 TO  1030.00
DO YOU WANT THE ENTIRE INTERVAL - YES OR NO
YES
SELECT DESIRED CALCULATION/PLOTTING
    1=PLOT EXISTING VALUES
    2=CALCULATE AND PLOT NEW VALUES
    3=CALCULATE NEW VALUES
    4=APPLY INVERSE SHARPENING FILTER
2
SELECT PLOTTING OPTION
    1=POLYGON
    2=BLOCK
1
THE FOLLOWING WELL LOGS ARE AVAILABLE
    GAMMA
    DENSITY
    SONIC
    NEUTRON
NUMBER OF LOGS - MAXIMUM OF 5
3
NUMBER OF COMPONENTS - MAXIMUM OF 9
3
TYPE OF LOGS LISTED BY INPUT ORDER
    CAN USE DENSITY,NEUTRON,SONIC,GAMMA,SP
LOG 1
DEN
LOG 2
SON
LOG 3
NEU
TYPE OF COMPONENTS DESIRED
    CAN USE SS,LS,DOL,SH,AN,HL,CL,POR,2POR
COMPONENT 1
HL
COMPONENT 2
AN
COMPONENT 3
SH
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
LIST
              HL       AN       SH
DENSITY     2.03     2.98     2.50
SONIC      67.00    50.00   100.00
NEUTRON     4.00    -0.50    40.00
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
DEN
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
SH
ENTER NEW COEFFICIENT VALUE
2.43
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
SON
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
SH
ENTER NEW COEFFICIENT VALUE
113.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
NEU
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
SH
ENTER NEW COEFFICIENT VALUE
30.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
DONE
INPUT ANY MODIFICATIONS TO COMPONENT KEY
```

(22)

WELL NAME: A.E.C. TEST HOLE 2
LOCATION: RICE COUNTY, KANSAS 1970
INTERVAL: 980.00 TO 1030.00 BY 1.00
LOGS: DENSITY SONIC NEUTRON
COMPONENTS: HL AN SH

KEY



SS LS DOL SH AN HL CL POR 2POR

■

(23)

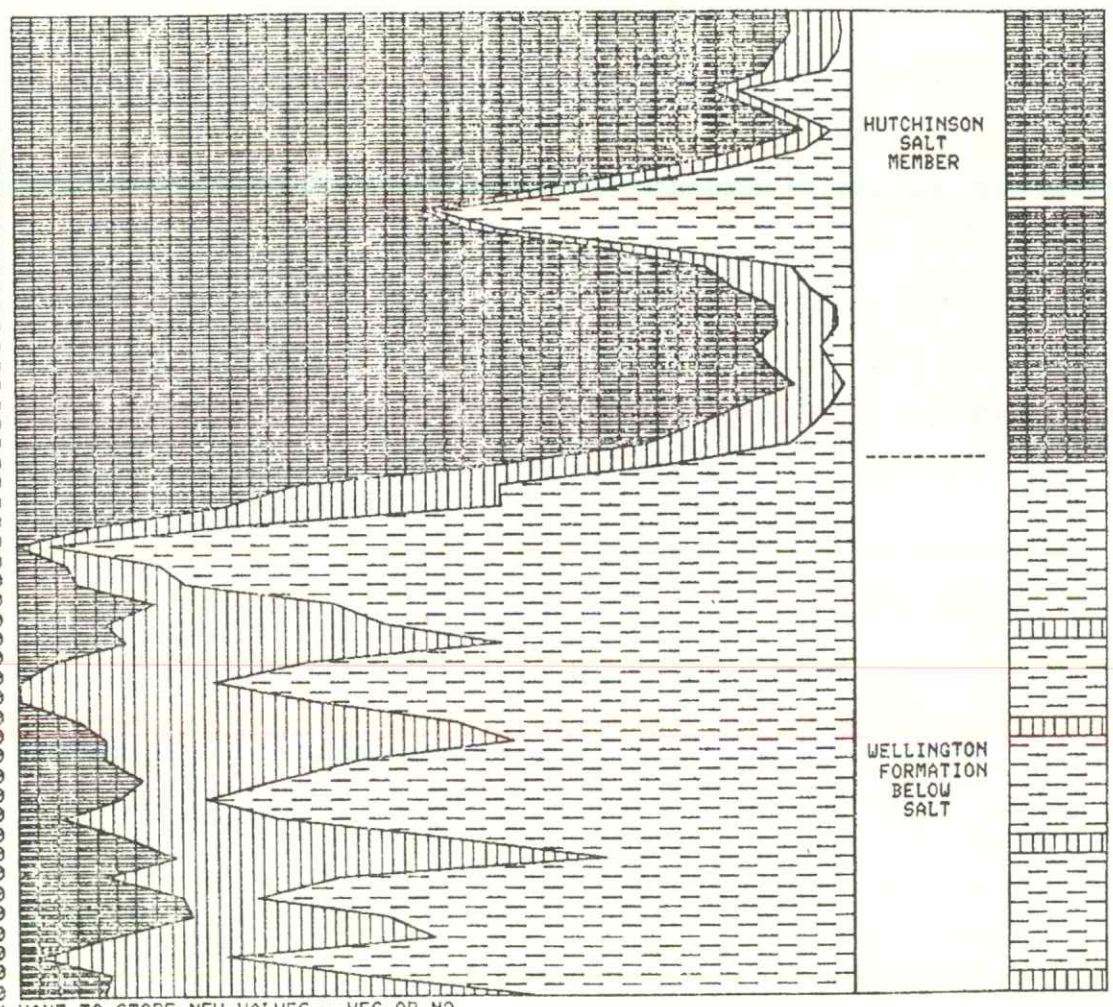
INPUT COEFFICIENTS:

	HL	AN	SH
DENSITY	2.03	2.98	2.43
SONIC	67.00	50.00	113.00
NEUTRON	4.00	-0.50	30.00

EQUATIONS EXCEED UNKNOWNS N+1>M

SOLUTION CALCULATED BY LEAST SQUARES
IS THE ABOVE INFORMATION CORRECT - YES OR NO
YES

WELL NAME: A.E.C. TEST HOLE 2



DEPTH	PROP VAR	SUM DEV	ERROR
980.0	0.21	0.00	0.36
981.0	0.20	0.00	0.30
982.0	0.25	0.00	0.22
983.0	0.28	0.00	0.42
984.0	0.44	0.00	0.35
985.0	0.29	0.00	0.40
986.0	0.17	0.00	0.25
987.0	0.35	0.00	0.09
988.0	0.56	0.00	0.95
989.0	0.78	0.00	1.17
990.0	0.76	0.00	1.21
991.0	0.79	0.00	0.06
992.0	0.66	0.00	0.62
993.0	0.46	0.00	0.35
994.0	0.38	0.00	0.51
995.0	0.26	0.00	0.25
996.0	0.25	0.00	0.13
997.0	0.32	0.00	0.42
998.0	0.27	0.00	0.29
999.0	0.20	0.00	0.35
1000.0	0.35	0.00	0.41
1001.0	0.48	0.00	0.48
1002.0	0.59	0.00	0.15
1003.0	0.87	0.00	1.13
1004.0	0.97	0.00	1.31
1005.0	0.97	0.00	1.33
1006.0	0.61	0.00	0.28
1007.0	0.11	1.19	0.44
1008.0	0.44	0.00	0.72
1009.0	0.50	0.00	0.11
1010.0	0.81	0.00	1.57
1011.0	0.84	0.00	0.40
1012.0	0.90	0.00	0.76
1013.0	0.71	0.00	0.75
1014.0	0.53	1.06	0.26
1015.0	0.68	0.00	1.19
1016.0	0.84	0.00	1.52
1017.0	0.87	0.00	0.08
1018.0	0.81	0.00	0.02
1019.0	0.70	0.00	1.60
1020.0	0.55	0.00	1.78
1021.0	0.68	0.00	0.24
1022.0	0.90	0.00	0.63
1023.0	0.91	0.00	2.51
1024.0	0.79	0.00	3.62
1025.0	0.66	0.00	2.25
1026.0	0.88	0.00	0.53
1027.0	0.87	0.00	1.46
1028.0	0.57	0.00	0.63
1029.0	0.81	0.00	0.36
1030.0	0.86	0.00	0.04

DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES
ARE YOU FINISHED WITH PETRA - YES OR NO
NO

```
PROGRAM PETRA: MINERALOGICAL/LITHOLOGICAL COMPONENT
     ESTIMATION FOR PETROPHYSICAL WELL LOGS
TOTAL INTERVAL AVAILABLE    980.00 TO  1030.00
DO YOU WANT THE ENTIRE INTERVAL - YES OR NO
NO
TOP OF INTERVAL (FEET)
1006.
BOTTOM OF INTERVAL (FEET)
1030.
SELECT DESIRED CALCULATION/PLOTTING
     1=PLOT EXISTING VALUES
     2=CALCULATE AND PLOT NEW VALUES
     3=CALCULATE NEW VALUES
     4=APPLY INVERSE SHARPENING FILTER
2
SELECT PLOTTING OPTION
     1=POLYGON
     2=BLOCK
1
THE FOLLOWING WELL LOGS ARE AVAILABLE
     GAMMA
     DENSITY
     SONIC
     NEUTRON
NUMBER OF LOGS - MAXIMUM OF 5
3
NUMBER OF COMPONENTS - MAXIMUM OF 9
4
TYPE OF LOGS LISTED BY INPUT ORDER
     CAN USE DENSITY,NEUTRON,SONIC,GAMMA,SP
LOG 1
DEN
LOG 2
SON
LOG 3
NEU
TYPE OF COMPONENTS DESIRED
     CAN USE SS,LS,DOL,SH,AN,HL,CL,POR,2POR
COMPONENT 1
AN
COMPONENT 2
SH
COMPONENT 3
SS
COMPONENT 4
POR
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
LIST
              AN      SH      SS      POR
DENSITY       2.98    2.43    2.65    1.00
SONIC        50.00  113.00   55.50  189.00
NEUTRON      -0.50   30.00   -4.00  100.00
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
DEN
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
POR
ENTER NEW COEFFICIENT VALUE
1.01
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
SON
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
POR
ENTER NEW COEFFICIENT VALUE
185.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
DONE
INPUT ANY MODIFICATIONS TO COMPONENT KEY
```

26

INPUT COEFFICIENTS:

	AN	SH	SS	POR
DENSITY	2.98	2.43	2.65	1.01
SONIC	50.00	113.00	55.50	185.00
NEUTRON	-0.50	30.00	-4.00	100.00

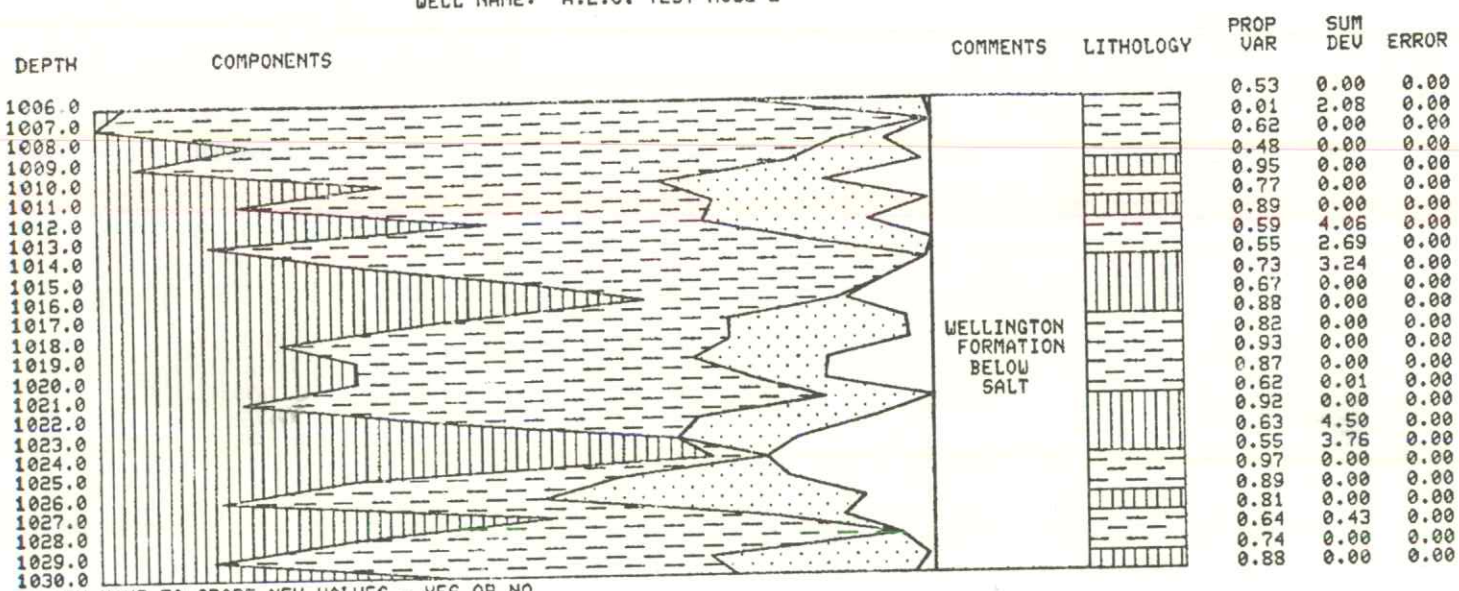
EQUATIONS EQUAL UNKNOWNS N+1=M

SOLUTION CALCULATED BY MATRIX INVERSION

IS THE ABOVE INFORMATION CORRECT - YES OR NO
YES

27

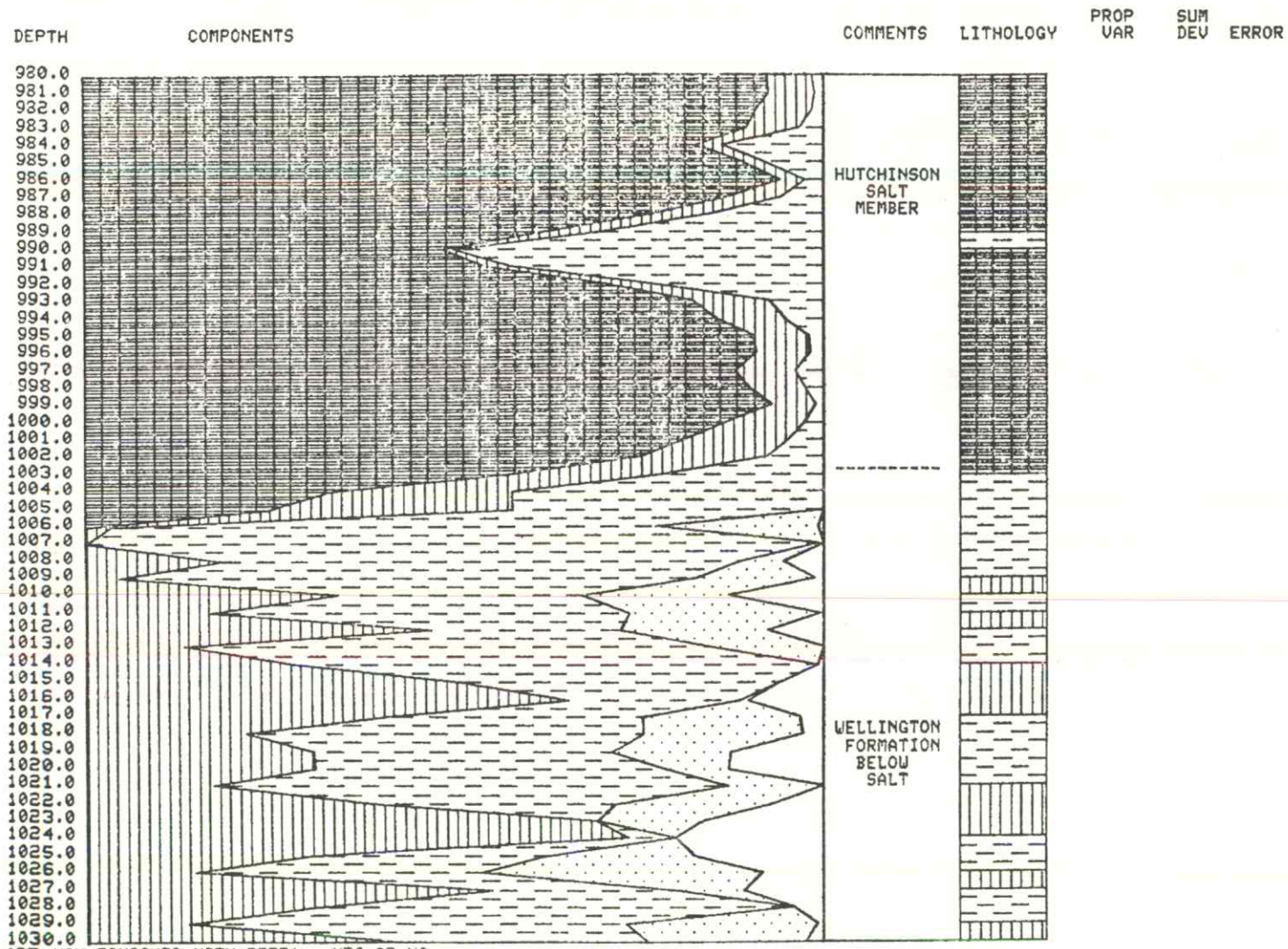
WELL NAME: A.E.C. TEST HOLE 2



DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES
ARE YOU FINISHED WITH PETRA - YES OR NO
NO

```
PROGRAM PETRA: MINERALOGICAL/LITHOLOGICAL COMPONENT
    ESTIMATION FOR PETROPHYSICAL WELL LOGS
TOTAL INTERVAL AVAILABLE   980.00 TO  1030.00
DO YOU WANT THE ENTIRE INTERVAL - YES OR NO
YES
SELECT DESIRED CALCULATION/PLOTTING
    1=PLOT EXISTING VALUES
    2=CALCULATE AND PLOT NEW VALUES
    3=CALCULATE NEW VALUES
    4=APPLY INVERSE SHARPENING FILTER
1
SELECT PLOTTING OPTION
    1=POLYGON
    2=BLOCK
1
THE FOLLOWING COMPONENTS HAVE BEEN COMPUTED
    SS
    SH
    AN
    HL
    POR
NUMBER OF COMPONENTS - MAXIMUM OF 9
5
TYPE OF COMPONENTS DESIRED
    CAN USE SS,LS,DOL,SH,AN,HL,CL,POR,2POR
COMPONENT 1
HL
COMPONENT 2
AN
COMPONENT 3
SH
COMPONENT 4
SS
COMPONENT 5
POR
INPUT ANY MODIFICATIONS TO COMPONENT KEY
■
```

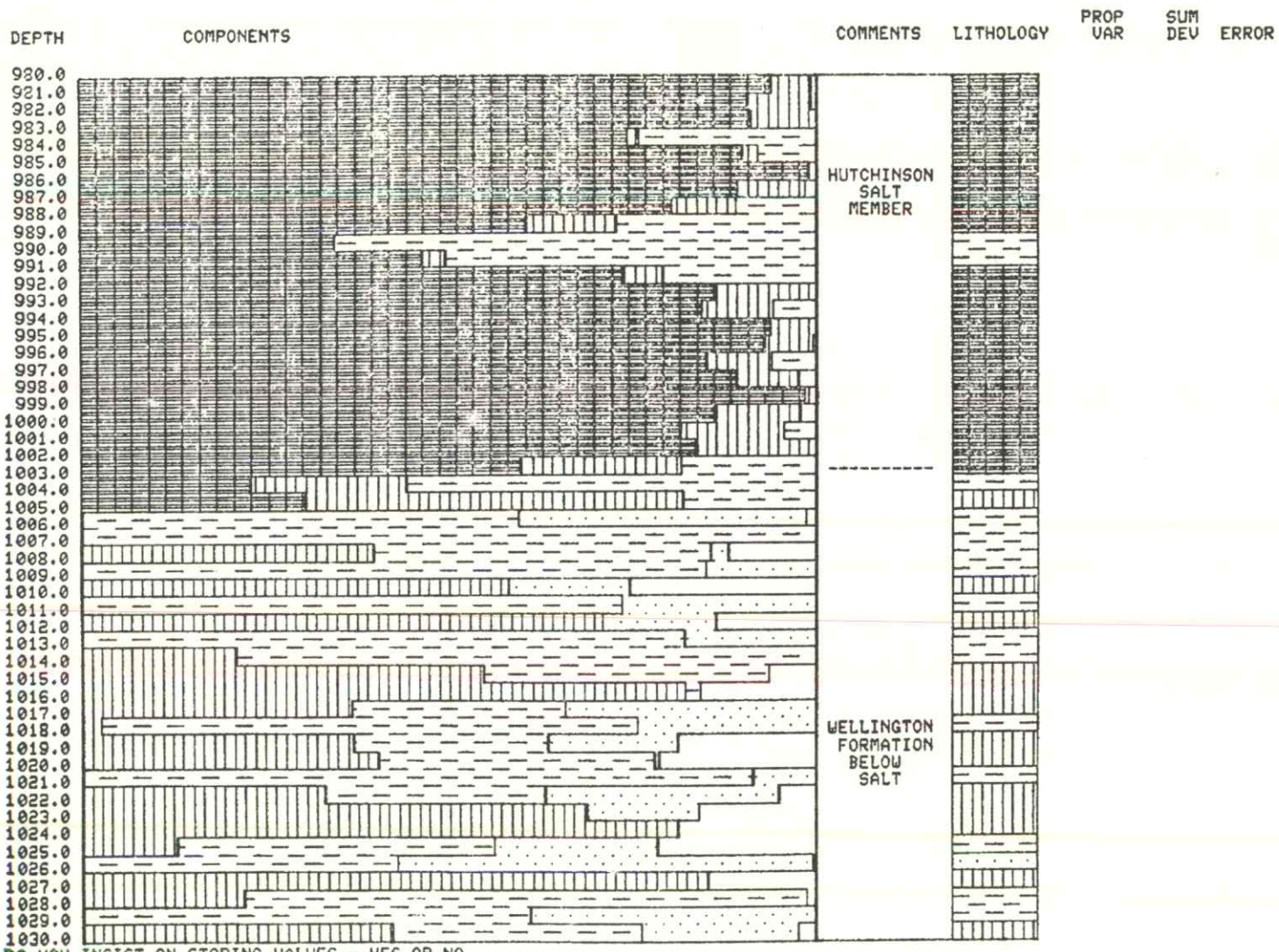
WELL NAME: A.E.C. TEST HOLE 2



ARE YOU FINISHED WITH PETRA - YES OR NO
NO

```
PROGRAM PETRA: MINERALOGICAL/LITHOLOGICAL COMPONENT
    ESTIMATION FOR PETROPHYSICAL WELL LOGS
TOTAL INTERVAL AVAILABLE   980.00 TO  1030.00
DO YOU WANT THE ENTIRE INTERVAL - YES OR NO
YES
SELECT DESIRED CALCULATION/PLOTTING
    1=PLOT EXISTING VALUES
    2=CALCULATE AND PLOT NEW VALUES
    3=CALCULATE NEW VALUES
    4=APPLY INVERSE SHARPENING FILTER
4
THE FOLLOWING COMPONENTS HAVE BEEN COMPUTED
    SS
    SH
    AN
    HL
    POR
NUMBER OF COMPONENTS - MAXIMUM OF 9
5
TYPE OF COMPONENTS DESIRED
    CAN USE SS,LS,DOL,SH,AN,HL,CL,POR,2POR
COMPONENT 1
HL
COMPONENT 2
AN
COMPONENT 3
SH
COMPONENT 4
SS
COMPONENT 5
POR
INPUT ANY MODIFICATIONS TO COMPONENT KEY
```

WELL NAME: A.E.C. TEST HOLE 2



DO YOU INSIST ON STORING VALUES - YES OR NO
NO
ARE YOU FINISHED WITH PETRA - YES OR NO
YES

(32)

gopher menu

INPUT NAME OF DESIRED OPTION
BYE

CASE STUDY 2: COMPLEX CARBONATE

The Middle Ordovician Viola Limestone is found throughout much of the subsurface of Kansas and shows broad regional changes in composition from limestone to dolomite. In eastern Kansas, the unit is predominantly limestone, but changes to dolomite in the west and to the north (Cole, 1975). Although the Viola contains little sand and few shale beds, chert horizons are commonly developed and are used widely for stratigraphic subdivision of the formation.

McQueen and Greene (1938) divided the correlative Kimmswick Limestone of northwestern Missouri into three divisions: a lower unit of dolomite, with small amounts of chert, a middle unit of very cherty dolomite, and an upper unit of sparsely cherty dolomite. In northeastern Kansas, these same divisions can be recognized, although the Viola contains both limestone and dolomite. The lateral transition from dolomite to limestone is generally marked by a progressive change, either from bottom upwards or from top downwards (Lee, 1943).

Many oil reservoirs occur in the Viola of both Oklahoma and Kansas. The drilling of Cities Service Beck A-1 (SW-SE-SE 14-5S-12E) in Nemaha County, northeast Kansas, resulted in the discovery of a small oil field with production from an interval in the upper Viola.

The log suite data set for the Viola section (2448-2566) are listed (Table 5) for spontaneous potential, gamma ray, density, sonic, CNL neutron, laterolog-8, medium and deep induction logs, as well as values for the CONSTANTS area.

OUTPUT COMMENTARY

1 GOPHER menu. "COMMENT" prompt.

2 COMMENT option: Initial erasure of COMMENT track, followed by insertion of Viola stratigraphic top.

3 GOPHER menu. "PETRA" prompt. Note that, in order to save space, the "diagnosis" options of GOPHER have been bypassed (e.g., LOGPLOT, MNP, CROSSPLOT). It is presumed that the fundamental composition of the Viola has been identified as variation in the system dolomite-chert-calcite-porosity.

4 PETRA option: Specifications for a provisional PETRA solution for the entire Viola section, utilizing density, sonic and neutron logs to resolve porosity, dolomite, "sandstone" (chert), limestone (calcite). Default coefficients are accepted for this initial run, but the component key is modified to signal that SS represents chert rather than sand.

5 PETRA output. "Header" and graphic key with modification statement.

6 PETRA output. Listing of log-component coefficients. Since unknowns are matched by equations, the PETRA solution will be computed by a simple matrix inversion algorithm. The information is accepted as correct.

7 PETRA output. Graphic presentation of the provisional PETRA solution of the Viola composition, together with diagnostics (error values are defaulted).
The solution indicates a fundamental subdivision of three major units: a lower, sparsely cherty, low-porosity limestone; a middle, low-porosity, cherty dolomite; and an upper, porous unit, which is dominantly limestone in aspect.
The sum deviation diagnostic suggests that the composition is consistent with the log information in the middle and lower units (with minor local aberrations). However, the upper part (2448-2480) is marked by significantly higher sum deviation values, which signal systematic inconsistencies in the solution.
The user requests storage of the compositional proportions and leaves PETRA for some diagnostic analysis of the upper unit.

8 GOPHER menu. "MNP" prompt.

9 MNP option. Computation of M, N and P values are requested for the upper, problematical part of Viola, using a fresh-water mud filtrate.

MNP output, with automatic storage of calculated values. Further work with MNP declined.

10 GOPHER menu. "CROSSPLOT" prompt.

11 CROSSPLOT option. A Z-plot is requested for the upper Viola (2448-2480), using M (channel 38) and N (channel 39) as fundamental axes. A Z-axis is equated with the gamma ray log, setting 0 and 100 API units as scaling extremes. (Note that the STATISTICS option could be used as an aid in defining the range extremes for the M, N and gamma ray values.)

12 CROSSPLOT output. Z-plot of M-N-gamma ray. A calcite-dolomite-chert composition triangle has been drafted manually, to aid diagnosis.
The systematic increase in gamma ray values towards the base of the plot clearly indicates the influence of a "shale point" which would lie in this direction. Zones which are located below the triangle would register non-zero sum deviation values, which can be attributed to the neglect of shale as a component in the initial PETRA solution. Zones which lie above the triangle may be interpreted as reflecting the influence of "secondary porosity" (vugs and fractures). Again these anomalous zones will be associated with non-zero sum deviations on the PETRA solution.
A comprehensive solution of the upper Viola should therefore be resolved in terms of six components: porosity, secondary porosity, dolomite, chert, calcite, and shale. Since only three logs (density, sonic, neutron) have been utilized, the full suite of unknowns now dominates the available log equations. The use of at least another log is clearly desirable, and the obvious choice is the gamma ray. However, although an appropriate gamma ray reading may be assigned to a shale component based on readings from shales overlying the Viola, no distinctive values may be attributed to the dolomite, chert, calcite and pore components from direct inspection of the log traces. The MERLIN module is summoned to aid in this problem.

13 GOPHER menu. "MERLIN" prompt.

14 MERLIN option. Analysis by MERLIN is restricted to the interval 2481-2566, through use of the DEPTH command. This interval corresponds to the part of the Viola section (middle and lower units) for which generally consistent solutions were generated by the initial PETRA solution.
The REGRESS option is used to compute a multiple regression of gamma ray (as dependent variable) in terms of chert, calcite, dolomite and porosity as dependent variables. Storage of the regression estimates is declined.

15 REGRESS output. Statistics of the multiple regression. The F-test value indicates that the computed regression is highly significant (at the $\alpha = 0.01$ level). Gamma ray values for the pure end-member components may be computed from the equation constants and are:

chert	39.991
calcite	14.729
dolomite	-6.536
porosity	212.094

Since the component proportions constitute a closed system, the regression violates the tenets of orthodox statistical procedure. However, the method is applied here as a "bootstrap" procedure to obtain "reasonable" gamma ray values for compositional analysis.
Low values are suggested for calcite and dolomite, in contrast with a higher value for chert. ("Hot" cherts are well known in the Kansas Pennsylvanian.)
The extremely high value for pore fluid can be attributed to two factors:

(i) Porosity variation is generally restricted to a narrow range while the other components are marked by wide variations in compositional proportions. As a result the estimate of the pore fluid gamma ray value is extremely sensitive.

(ii) Since no account has been made of shale content in the provisional PETRA solution, any minor shale streaks will be resolved mainly as "porosity," enhancing gamma ray values associated with the porosity component.

16 MERLIN menu. "STOP" prompt.

17 GOPHER menu. "STATISTICS" prompt.

18 STATISTICS option. Request for channel summaries for the upper Viola (2448-2480). The reason for this step is to ascertain the average composition of the upper Viola from the provisional PETRA solution. PETRA revisions will now utilize four logs to resolve six components as an underdetermined system. Rather than run with an unconstrained maximum variance solution, the average composition will provide a reasonable guidepoint for a guided minimum variance solution.

19 STATISTICS output. Average composition indicated by hand symbol.

20 STATISTICS option. Further work with STATISTICS and histogram production are declined.

21 GOPHER menu. "PETRA" prompt.

22 PETRA option. Revision of upper Viola (2448-2480), using gamma ray, density, sonic, and neutron logs to resolve porosity, secondary porosity, dolomite, chert, calcite, and shale. Gamma ray coefficients for components are modified in accordance with REGRESS option results. Shale coefficients are entered as external estimates from the overlying Maquoketa Shale. The secondary porosity sonic coefficient is equated with the transit time of the average matrix composition.

23 PETRA output. "Header" and graphic key.

24 PETRA output. Listing of log-component coefficients. The system is defined to be underdetermined. The information is accepted as correct. A guided minimum variance solution is requested. Guidepoint coordinates are entered which match the compositional average of the provisional PETRA solution retrieved by STATISTICS. Proportions for secondary porosity and shale are set to zero.

25 PETRA output. Graphic solution and diagnostics for composition of the upper Viola. The results represent estimates under some degree of uncertainty, which is reflected in the broad trend of variation. The sum deviation diagnostic is generally more subdued than its equivalent in the provisional solution, but is riddled with zones which have non-zero values. These zones correspond to solutions for which "negative components" have been computed, and are located as closest approaches to the guidepoint, but outside the fundamental composition space. The revised compositions were requested to be stored, thereby overwriting the earlier solution. Each problem zone was resolved by further PETRA runs which, for reasons of space, are omitted here. In each case, the negative component (set by PETRA to zero proportion) was dropped from the component system. For these runs, the solution system is now fully determined. In cases where positive sum deviations were generated, a further revision was made, dropping yet another negative component.

26 The final composition of the upper Viola which resulted from these multiple runs is listed as it was stored in the PETRA channels.

27 PETRA output. A graphic review of the final resolution of the upper Viola as a result of multiple PETRA runs. (It should be noted that similar remedial work could be made on the minor anomalous zones in the middle and lower Viola, but these are neglected in this case study.)

28 GOPHER menu. "KOBRA" prompt.

29 KOBRA menu. "TORNADO" prompt. A "small slam" is initiated, using the laterolog-8, medium and deep induction logs. The PETRA POR channel will be used as porosity indicator and, where no porosity values occur, a default zone of 3% will be used.

30 TORNADO output. Graphic representation of invasion diameter, formation resistivity and flushed zone resistivity. Particularly noteworthy are the problematical zones, where the flushed-zone resistivities are markedly lower than the formation resistivities. The most systematic anomaly occurs in the interval 2470-75, which coincides approximately with the interval of maximum secondary porosity deduced from PETRA runs. This observation matches conventional log analysis wisdom that suggests that these anomalies are caused by significant fracturing in carbonates. The user requests storage for true estimates of R_t (channel 35) and R_{xo} (channel 36).

31 KOBRA menu. "RWA" prompt. Selection of small slam formation resistivity estimates as input. Specification of the generalized "carbonate equation" for the Archie equation constants.

32 RWA output. Shale proportions, porosity, secondary porosity, total porosity (from PETRA channels), selected resistivity, computed reconnaissance water resistivity, and R_{wa} graphic presentation for the entire Viola section. The oil-productive zone in the upper Viola is clearly indicated. Elucidation of a representative formation water resistivity from the middle and lower Viola is almost certainly complicated by variations in "cementation exponent" from the input value and by aberrations introduced by shale streaks. A request is made to store the R_{wa} values (in channel 37).

33 KOBRA menu. "STOP" prompt.

34 GOPHER menu. "STATISTICS" prompt.

35 STATISTICS option. A review of channel contents is requested for the interval 2480-2540 in an effort to isolate a reasonable estimate of formation water resistivity for the RWA channel 37.

36 STATISTICS output. An average reconnaissance water resistivity of 0.25 ohm-m is listed for this interval.

37 STATISTICS option. Further STATISTICS summaries are declined, but a histogram presentation of the R_{wa} values is requested.

38. STATISTICS output. Histogram of R_{wa} values. The average R_{wa} value coincides with the principal mode and is accepted as a reasonable estimate of the formation water resistivity. Further histogram production is declined.

39 GOPHER menu. "KOBRA" prompt.

40 KOBRA menu. "RPPLOT" prompt. A Pickett plot is requested for the entire Viola, using the small slam estimate of formation resistivity and a water line, determined by the "carbonate form" of the Archie equation in conjunction with the estimated formation water resistivity.

41 RPPLOT output. The match of the water line is good for values where porosity exceeds 3%.

42 KOBRA menu. "DEPTH" prompt. Reservoir analysis is directed to the potential oil-productive zone of the upper Viola section. KOBRA menu. "CLSAT" prompt. Selection of the small slam estimate of formation resistivity, in conjunction with the "limestone form" of the Archie equation, and a saturation exponent of two.

43 CLSAT output. Values for shale proportion, total porosity (from PETRA channels), formation resistivity and water saturation, together with graphic profile of water saturation. An oil-productive zone is clearly delineated in the upper Viola and provided the discovery for the well, which was subsequently completed for production.

The computed water saturation proportions should be viewed as "implicit diagnostics" which may be used to evaluate the input parameters (a, m, n, R_w, etc.) as reasonable estimates of their "true" values. Clearly, water saturations are limited to a range between zero and one and significant aberrations should alert the user to possible problems. Many anomalous values occur in the water zone below the productive interval, but may be attributed to the fact that porosities are typically on the order of 2%. At this low range, estimations of water saturation are highly sensitive to minor changes in parameter values and cannot reasonably be expected to closely approximate unity. The highly anomalous values of the upper 2 feet in the section are almost certainly caused by significant conductivity effects introduced by the immediately overlying Maquoketa Shale.
The user requests storage of the computed water saturations (in channel 32).

44 KOBRA menu. "STOP" prompt.

45 MERLIN menu. "ABACUS" prompt.

46 ABACUS menu. "SCALE" prompt. A transformed depth scale is created and stored in the vacant channel 49 by subtracting the average depth of the interval (2507) and dividing the result by 100.
The purpose of this ABACUS operation is to "standardize" the depth variable in preparation for a polynomial regression of chert content as a function of depth in the Viola. If regression was performed on the raw variables, with depth in unit thousands and chert in proportional units, severe round-off errors would occur in the matrix algebra computations.

47 ABACUS menu. "STOP" prompt.

48 GOPHER menu. "MERLIN" prompt.

49 MERLIN menu. "REGRESS" prompt. A polynomial regression is computed for the entire Viola section, using chert as the dependent variable and "standardized" depth as independent variable. Request for storage of regression estimates (Greek channels).

50 REGRESS output. Polynomial regression coefficients for first through fourth orders, together with analysis of variance statistics.
The goodness-of-fit values show a weak upward trend in the lower orders and a dramatic increase at fourth order. Since a fourth-order polynomial has three extrema (maxima/minima), the broad trend in chert values strongly suggests a fundamental tripartite subdivision of the Viola section. This observation matches the stratigraphy of McQueen and Greene (1938) in the correlative Kimmswick Limestone in nearby northwest Missouri, which is also keyed to chert variation, but based on cuttings.
If a fourth-order polynomial is double-differentiated and the resulting quadratic is equated to zero, the two roots of this equation correspond to the depths of the inflection points which separate the three subdivisions. These inflections may be computed easily by hand from the regression coefficients of the fourth-order polynomial noted on the REGRESS output. The inflection points occur at depths of 2479 and 2530 feet. The regression method has zoned the Viola into three units, which may be indexed on the PETRA graphic output and show good visual correspondence to overall component variation, as well as to chert content. Collectively, the zonation may be characterized as:

(i) Upper Viola (2448-2479): porous (fractured and vuggy, in part) interbedded limestones and dolomites, with minor chert and minor but significant amounts of shale;

(ii) Middle Viola (2479-2530): low porosity dolomites and cherts;

(iii) Lower Viola (2530-2566): low porosity limestone with minor chert and dolomite.

If the user requires something more visual than the theoretical aspects of calculus, it should be recalled that the regression estimates from all four polynomial fits were requested to be stored (Greek channels 50-53). These polynomials may be plotted together

with raw chert variation (channel 21) in "standard" log format by use of the GOPHER option, LOGPLOT.

51 MERLIN menu. "DEPTH" prompt. Analysis is focused on a restricted section of the Viola (2480-2540).
MERLIN menu. "PCA" prompt. A principal components analysis is requested of the variables chert, calcite, dolomite, porosity, and reconnaissance water resistivity. The last variable is proposed as an estimate of pore tortuosity/fabric geometry, which would account for changes in the "cementation exponent" discussed earlier in relation to RWA output. The choice of this variable also dictates the DEPTH range restriction, since oil saturations in the upper Viola would dominate R_{wa} variation.

52 PCA output. Statistical moments of input variables, variance-covariance matrix and associated eigenvectors and eigenvalues, correlation matrix and associated eigenvectors and eigenvalues. Interpretation should be focused on the correlation matrix and its eigen characteristics, since R_{wa} and the component proportions are scaled in incompatible units and will unduly influence the variance-covariance matrix.
The dominant values of the correlation matrix suggest a strong dolomite-chert association which (obviously) is inversely related with calcite content. Porosity shows no strong correlation with mineralogy, although slightly enhanced porosities are suggested to be associated with higher degrees of dolomitization. However, an alternative explanation is that minor shale streaks (not accounted for by the PETRA solution) would be resolved as slight enhancements in both dolomite and porosity. (Some weak support for this latter argument is offered by the gamma ray multiple regression analysis used earlier.)
The reconnaissance water resistivity shows strong correlations with mineralogy, with increase matched with increasing calcite, decrease with increasing dolomite-chert. In terms of the dual hypotheses proposed in the previous paragraph, this relationship is explained most simply by either a reduction in tortuosity associated with an increase in porosity, both of which are caused by dolomitization, or a reflection of a conductivity contribution introduced by contaminating shale.
The eigenvectors of the correlation matrix lend themselves to a basic interpretation, if considered as a "factor analysis." The first component (accounting for 67% of the total variation) may be identified as "mineralogical variation." The second component (24%) is largely equated with "pore volume." The third component (7%), with its high loading on reconnaissance water resistivity, registers either "pore tortuosity" or "shale content" or both.
The user elects to store scores from the first four principal components in the Greek channels. Further speculations on cause and effect among these variables may be made by graphing the component score profiles through use of LOGPLOT and comparing these with output from PETRA and other modules.

53 MERLIN menu. "STOP" prompt.

54 GOPHER menu. "XYPETRA" prompt.

55 XYPETRA. Specifications are made for a file to draft PETRA results of the Viola section on a plotter. A polygonal convention is requested for six components, which are entered in the order that they will appear on the plot (left to right). A lithology track is also requested. A color plot is also chosen and a shading line density stipulated. (Colored presentations on the Kansas Geological Survey's Xynetics plotter are made by line shading, using colored ball-point pens.)

56 GOPHER menu. "BYE" prompt.

57 Plotter presentation of Viola composition stored on tape by XYPETRA.

REMARKS

A prime objective of this case study development has been to demonstrate the operation of KOALA by the log analyst as wrangler, rather than as zombie. The procedure used is emphatically not the KOALA method for complex carbonates, but merely an illustration of a chain of option usage, dictated both by the overall aim of the user and

hypotheses suggested by intermediate option output.

In reviewing this case study, the reader will be made strongly aware of the authors' (current) thought processes. It is hoped that at various points in the speculation, alternative methods of attacking the problems will suggest themselves.

o-o-o

Table 5

CASE STUDY #2
COMPLEX CARBONATE DATA

CONSTANTS	VALUE
01-MINIMUM DEPTH	2448.00
02-MAXIMUM DEPTH	2566.00
03-INCREMENT	1.00
04-ELEVATION	1278.00
05-LATITUDE	-9999.00
06-LONGITUDE	-9999.00
07-RM	-9999.00
08-TRM	-9999.00
09-RMF	2.14
10-TRMF	58.00
11-RMC	-9999.00
12-TRMC	-9999.00
13-BHT	92.00
14-MEAN-T	54.00
15-T-GRADIENT	-9999.00
16-TIME-C-GR	-9999.00
17-TIME-C-N	-9999.00
18-LOG SPEED GR	-9999.00
19-LOG SPEED N	-9999.00
20-TD	2757.00

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
LOCATION: NEMAHA CO., KANSAS
DATE: JAN. 11, 1978

01-DEPTH	02-SP	03-GR	04-DENSITY	05-SONIC	07-CNL %	09-LL8	10-ILM	11-ILD
2448.000	46.000	22.847	2.722	54.776	6.594	436.510	48.305	41.304
2449.000	50.000	22.504	2.721	54.083	7.060	685.495	84.722	73.113
2450.000	52.000	29.651	2.678	52.238	7.410	405.515	145.881	118.031
2451.000	53.750	33.225	2.624	56.385	8.682	260.613	175.389	129.419
2452.000	55.500	28.388	2.591	60.531	8.342	296.480	169.044	120.227
2453.000	57.000	24.819	2.623	59.492	7.195	387.251	159.956	122.461
2454.000	59.000	24.361	2.622	58.339	6.509	334.191	180.300	136.772
2455.000	60.250	25.516	2.660	58.683	6.284	301.996	210.863	162.930
2456.000	62.000	24.138	2.706	55.227	4.102	608.124	325.087	183.654
2457.000	64.000	19.996	2.643	53.500	3.878	711.238	340.414	220.799
2458.000	66.750	17.813	2.646	52.578	3.884	642.673	440.548	237.682
2459.000	69.000	16.897	2.641	52.348	4.696	619.425	401.784	235.504
2460.000	70.000	16.786	2.619	54.650	5.623	487.519	285.755	218.775
2461.000	71.750	16.676	2.608	56.606	8.506	366.434	226.989	170.607
2462.000	72.250	15.185	2.564	56.375	9.893	265.463	161.436	131.825
2463.000	72.750	19.332	2.606	62.587	10.589	139.316	107.646	104.713
2464.000	73.750	22.673	2.551	66.497	11.860	89.536	86.298	96.382
2465.000	74.000	20.952	2.560	62.931	10.946	136.772	87.902	91.200
2466.000	74.000	19.232	2.602	57.181	11.643	155.596	91.200	91.200
2467.000	74.000	20.042	2.603	56.031	13.489	134.276	93.755	92.896
2468.000	73.500	18.553	2.548	60.400	16.369	96.382	86.298	86.298
2469.000	73.750	19.593	2.623	61.780	15.800	87.902	77.267	80.168
2470.000	72.750	18.335	2.601	43.620	13.507	91.200	67.297	76.559
2471.000	71.000	18.570	2.623	57.528	12.135	100.000	73.113	77.267
2472.000	68.750	18.232	2.628	59.482	11.108	104.713	75.858	84.722
2473.000	64.250	20.650	2.682	60.057	9.851	119.124	93.755	98.174
2474.000	61.500	24.792	2.670	61.092	9.054	145.881	108.642	112.719
2475.000	60.500	24.223	2.667	58.795	9.062	134.276	109.647	124.738
2476.000	58.750	23.769	2.652	58.911	8.151	129.419	121.338	131.825
2477.000	57.500	26.646	2.666	58.912	7.125	159.956	135.519	147.232
2478.000	56.000	31.588	2.698	58.799	5.871	229.084	181.970	195.882
2479.000	56.250	27.920	2.690	57.308	3.468	424.628	272.896	275.421
2480.000	57.000	23.335	2.716	53.866	1.641	895.335	420.733	444.622
2481.000	56.750	20.701	2.721	51.000	1.191	847.242	666.800	642.673
2482.000	57.750	17.954	2.725	51.003	1.315	862.962	717.772	586.132
2483.000	59.000	18.191	2.704	50.547	1.210	744.713	487.519	478.629
2484.000	59.500	20.952	2.693	51.926	1.450	405.515	366.434	409.266
2485.000	60.000	20.959	2.707	53.421	2.033	398.105	343.560	369.822
2486.000	60.750	21.081	2.719	53.653	2.616	398.105	337.291	340.414
2487.000	60.500	16.387	2.718	53.886	2.741	436.510	331.125	331.125
2488.000	61.750	16.510	2.705	53.430	3.554	340.414	304.785	356.455
2489.000	61.500	16.633	2.746	53.090	4.481	353.182	343.560	340.414
2490.000	62.000	18.819	2.698	52.979	4.835	394.461	343.560	343.560
2491.000	61.500	17.452	2.720	52.868	4.730	356.455	307.607	331.125
2492.000	60.000	16.773	2.719	52.757	5.199	285.755	272.896	301.996
2493.000	59.500	19.990	2.699	53.105	5.095	296.480	255.859	280.544
2494.000	57.000	21.832	2.677	53.682	3.845	291.070	246.603	275.421
2495.000	56.500	20.924	2.693	53.801	3.512	296.480	255.859	285.755
2496.000	55.500	18.756	2.718	53.805	3.065	293.763	270.394	291.070
2497.000	55.000	18.307	2.728	54.038	2.847	383.700	270.394	275.421
2498.000	54.750	19.920	2.696	53.699	3.316	280.544	251.186	291.070
2499.000	54.000	23.707	2.695	53.933	3.786	265.463	280.544	307.607
2500.000	54.000	23.258	2.710	54.510	2.996	420.733	319.152	363.082
2501.000	54.000	20.291	2.708	53.828	2.206	554.631	398.105	452.898
2502.000	53.500	19.614	2.711	52.917	2.332	549.541	394.461	544.514
2503.000	52.000	19.852	2.679	52.623	2.001	529.661	554.631	619.425
2504.000	52.250	22.036	2.707	52.470	1.670	613.760	544.514	619.425
2505.000	52.500	21.245	2.700	52.476	1.568	630.954	510.516	619.425

2506.000	52.500	22.284	2.698	52.138	1.695	570.158	529.661	691.850
2507.000	51.500	21.493	2.702	52.716	1.478	630.954	666.800	666.800
2508.000	51.750	21.617	2.688	52.722	1.491	862.962	613.760	685.495
2509.000	52.250	23.343	2.678	52.385	1.504	575.440	524.796	660.677
2510.000	52.750	24.724	2.680	52.162	1.745	666.800	510.516	597.051
2511.000	52.500	23.248	2.677	52.626	1.644	519.993	496.598	575.440
2512.000	51.000	25.087	2.696	52.975	1.772	544.514	505.817	529.661
2513.000	50.750	24.412	2.719	53.210	1.785	554.631	474.248	496.598
2514.000	50.750	23.851	2.712	53.102	1.798	554.631	409.266	487.519
2515.000	50.500	25.004	2.676	52.880	1.926	461.318	405.515	469.903
2516.000	50.750	30.041	2.697	52.887	1.940	444.622	413.052	492.029
2517.000	51.000	32.221	2.707	53.237	1.725	496.598	398.105	519.993
2518.000	51.750	31.431	2.670	53.472	1.396	544.514	478.629	613.760
2519.000	52.000	29.729	2.677	53.251	0.954	570.158	619.425	855.066
2520.000	52.750	30.310	2.686	53.372	1.082	824.130	685.4951096.490	
2521.000	52.250	30.434	2.686	52.581	0.868	990.786	963.8551555.930	
2522.000	52.250	32.842	2.702	51.447	0.9971419.0401180.3501599.480			
2523.000	53.500	35.135	2.692	51.112	1.1251737.9201472.3201599.480			
2524.000	55.500	30.124	2.688	51.006	1.0261706.1901472.3201599.480			
2525.000	56.000	26.484	2.667	51.471	1.0411584.7801472.3201599.480			
2526.000	56.500	23.073	2.696	51.593	0.8281555.9301472.3201599.480			
2527.000	59.000	22.287	2.713	51.830	0.8431644.4601472.3201599.480			
2528.000	59.000	18.878	2.698	51.610	0.8581614.4601472.3201599.480			
2529.000	59.000	19.689	2.668	51.390	1.1021419.0401485.8801599.480			
2530.000	60.000	22.210	2.667	51.171	1.2311737.9201485.8801599.480			
2531.000	60.750	21.881	2.666	50.724	1.2471737.9201485.8801599.480			
2532.000	60.750	20.982	2.664	50.961	1.1481737.9201485.8801614.460			
2533.000	60.750	20.767	2.667	50.856	1.0501737.9201499.7001614.460			
2534.000	60.750	21.920	2.679	50.296	0.8381770.2201499.7001614.460			
2535.000	61.000	24.213	2.683	50.647	0.7401770.2201485.8801614.460			
2536.000	61.750	23.542	2.656	50.771	0.7571770.2201485.8801614.460			
2537.000	61.500	24.011	2.649	50.325	0.8871555.9301472.3201614.460			
2538.000	**61.000**	**20.835**	**2.660**	**50.334**	1.2451037.5501472.3201599.480			
2539.000	61.000	15.952	2.651	50.800	1.6031599.4801076.4201330.490			
2540.000	61.000	14.715	2.653	52.518	1.7341056.8501191.1801527.650			
2541.000	62.000	14.047	2.654	53.097	1.6371367.8001472.3201584.780			
2542.000	61.000	11.216	2.656	51.400	1.3121737.9201485.8801584.780			
2543.000	61.000	10.549	2.672	51.069	0.8741770.2201485.8801599.480			
2544.000	61.000	11.930	2.683	51.534	0.6641786.3501485.8801599.480			
2545.000	60.500	11.491	2.683	50.407	0.7951770.2201499.7001599.480			
2546.000	59.000	12.759	2.702	50.418	0.8121770.2201499.7001599.480			
2547.000	59.000	13.343	2.676	50.884	0.7161737.9201499.7001599.480			
2548.000	59.000	13.473	2.672	50.554	0.7341770.2201499.7001599.480			
2549.000	59.500	14.513	2.672	49.882	0.6381786.3501499.7001599.480			
2550.000	60.000	15.098	2.675	50.462	0.7701737.9201499.7001599.480			
2551.000	59.750	18.184	2.698	50.588	1.0151770.2201499.7001541.780			
2552.000	59.000	23.202	2.695	50.372	1.8291721.7601367.800 862.962			
2553.000	59.500	24.126	2.712	50.497	2.757 847.242 744.713 461.318			
2554.000	57.500	24.483	2.657	50.964	3.002 731.154 366.434 285.755			
2555.000	56.750	27.453	2.656	51.544	2.339 272.896 218.775 242.101			
2556.000	53.500	29.172	2.638	53.601	1.108 201.373 226.989 212.815			
2557.000	50.750	27.710	2.686	52.363	0.786 570.158 244.343 195.882			
2558.000	49.500	26.931	2.701	52.148	1.032 356.455 272.896 224.906			
2559.000	46.750	25.015	2.688	53.182	0.824 363.082 363.082 272.896			
2560.000	45.750	22.079	2.696	51.945	0.5021737.920 613.760 319.152			
2561.000	44.250	14.828	2.711	50.027	0.5221737.920 666.800 363.082			
2562.000	44.000	15.527	2.691	49.586	0.5411419.040 685.495 424.628			
2563.000	42.750	16.794	2.680	50.280	0.4471737.920 981.740 416.875			
2564.000	41.000	16.925	2.699	50.293	0.4671770.2201076.420 356.455			
2565.000	39.750	16.148	2.719	50.080	0.6011770.220 855.066 201.373			
2566.000	39.000	17.301	2.725	49.526	0.6211599.480 195.882 84.722			

(1)

gopher menu

```
INPUT NAME OF DESIRED OPTION
COMMENT
```

---

(2)

```
COMMENT - AVAILABLE OPTIONS
    BLANK ----- INITIALIZE ALL COMMENTS TO BLANKS
    LIST ------ LIST COMMENTS ON AN INTERVAL
    INSERT ---- ADD COMMENTS TO AN INTERVAL
    DELETE ---- DELETE COMMENTS FROM AN INTERVAL
    STOP ------ FINISHED
BLANK
COMMENT - AVAILABLE OPTIONS
    BLANK ----- INITIALIZE ALL COMMENTS TO BLANKS
    LIST ------ LIST COMMENTS ON AN INTERVAL
    INSERT ---- ADD COMMENTS TO AN INTERVAL
    DELETE ---- DELETE COMMENTS FROM AN INTERVAL
    STOP ------ FINISHED
INSERT
COMMENTS MAY BE A MAXIMUM OF 10 CHARACTERS
ENTER STARTING DEPTH - ENTER 0 IF FINISHED
2448.
DEPTH 2448.00 - ENTER RETURN IF FINISHED
----------
DEPTH 2449.00 - ENTER RETURN IF FINISHED
  VIOLA
DEPTH 2450.00 - ENTER RETURN IF FINISHED

COMMENTS MAY BE A MAXIMUM OF 10 CHARACTERS
ENTER STARTING DEPTH - ENTER 0 IF FINISHED
0
COMMENT - AVAILABLE OPTIONS
    BLANK ----- INITIALIZE ALL COMMENTS TO BLANKS
    LIST ------ LIST COMMENTS ON AN INTERVAL
    INSERT ---- ADD COMMENTS TO AN INTERVAL
    DELETE ---- DELETE COMMENTS FROM AN INTERVAL
    STOP ------ FINISHED
STOP
```

(3)

gopher menu

```
INPUT NAME OF DESIRED OPTION
PETRA
```

---

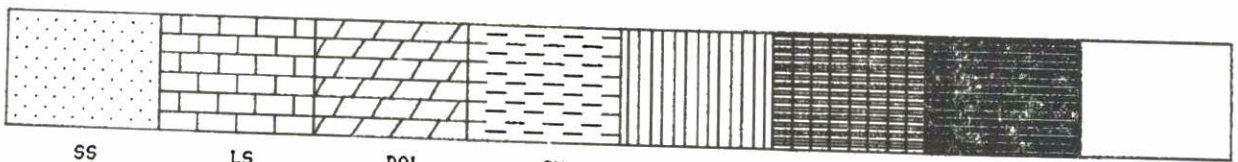
(4)

```
PROGRAM PETRA: MINERALOGICAL/LITHOLOGICAL COMPONENT
    ESTIMATION FOR PETROPHYSICAL WELL LOGS
TOTAL INTERVAL AVAILABLE  2448.00 TO  2566.00
DO YOU WANT THE ENTIRE INTERVAL - YES OR NO
YES
SELECT DESIRED CALCULATION/PLOTTING
     1=PLOT EXISTING VALUES
     2=CALCULATE AND PLOT NEW VALUES
     3=CALCULATE NEW VALUES
     4=APPLY INVERSE SHARPENING FILTER
2
SELECT PLOTTING OPTION
     1=POLYGON
     2=BLOCK
1
THE FOLLOWING WELL LOGS ARE AVAILABLE
     SP
     GAMMA
     DENSITY
     SONIC
     NEUTRON
NUMBER OF LOGS - MAXIMUM OF 5
3
NUMBER OF COMPONENTS - MAXIMUM OF 9
4
TYPE OF LOGS LISTED BY INPUT ORDER
     CAN USE DENSITY,NEUTRON,SONIC,GAMMA,SP
LOG 1
DEN
LOG 2
SON
LOG 3
NEU
TYPE OF COMPONENTS DESIRED
     CAN USE SS,LS,DOL,SH,AN,HL,CL,POR,2POR
COMPONENT 1
POR
COMPONENT 2
DOL
COMPONENT 3
SS
COMPONENT 4
LS
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
LIST
                POR      DOL      SS       LS
DENSITY        1.00     2.87     2.65     2.71
SONIC        189.00    43.50    55.50    47.50
NEUTRON      100.00     7.50    -5.00     0.00
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
DONE
INPUT ANY MODIFICATIONS TO COMPONENT KEY
SS = CHERT
```

5

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
LOCATION: NEMAHA CO., KANSAS JAN. 11, 1978
INTERVAL: 2448.00 TO 2566.00 BY 1.00
LOGS: DENSITY SONIC NEUTRON
COMPONENTS: POR DOL SS LS

KEY



MODIFICATIONS: SS = CHERT

■

6

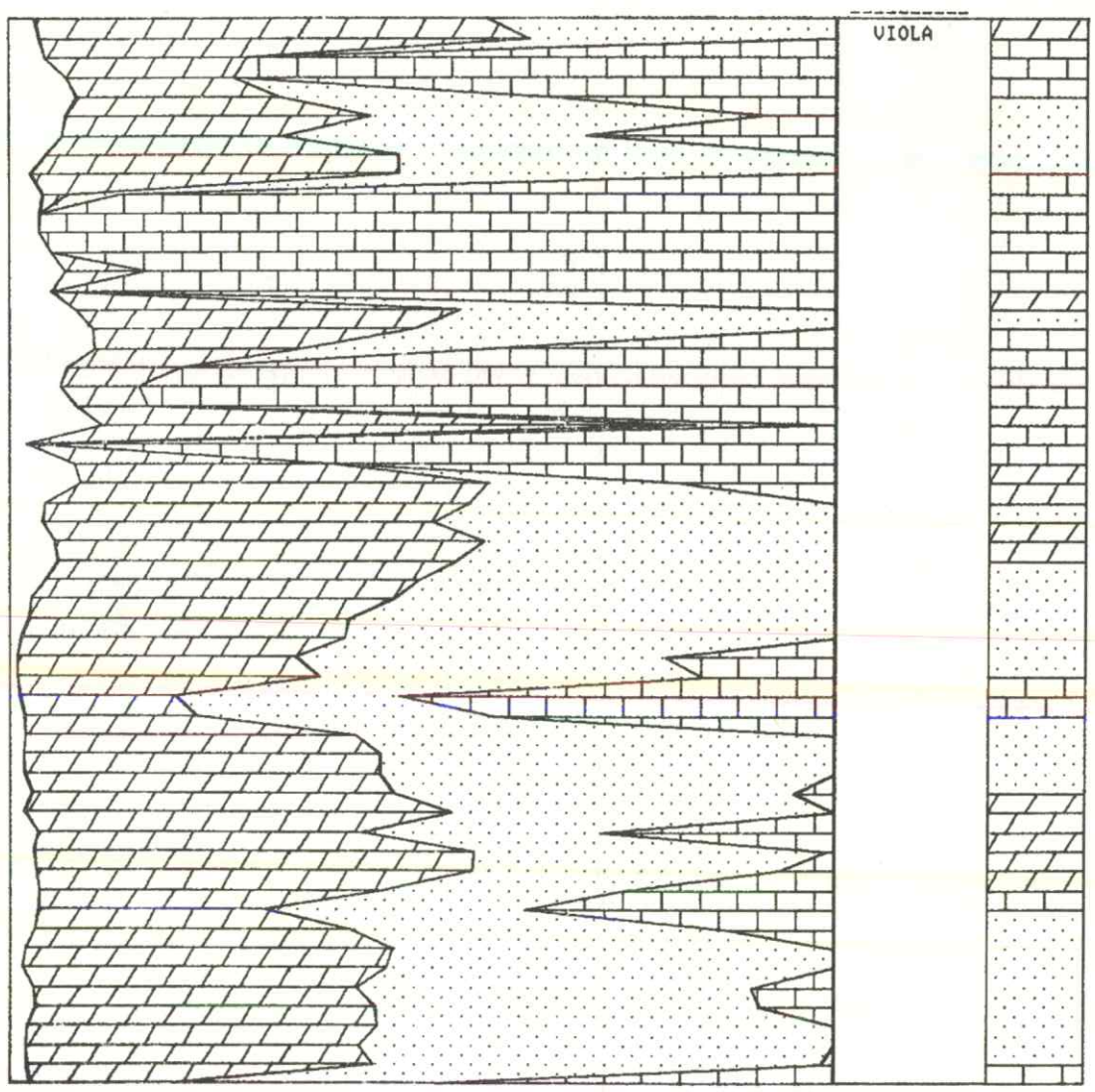
INPUT COEFFICIENTS:

	POR	DOL	SS	LS
DENSITY	1.00	2.87	2.65	2.71
SONIC	189.00	43.50	55.50	47.50
NEUTRON	100.00	7.50	-5.00	0.00

EQUATIONS EQUAL UNKNOWNS N+1=M

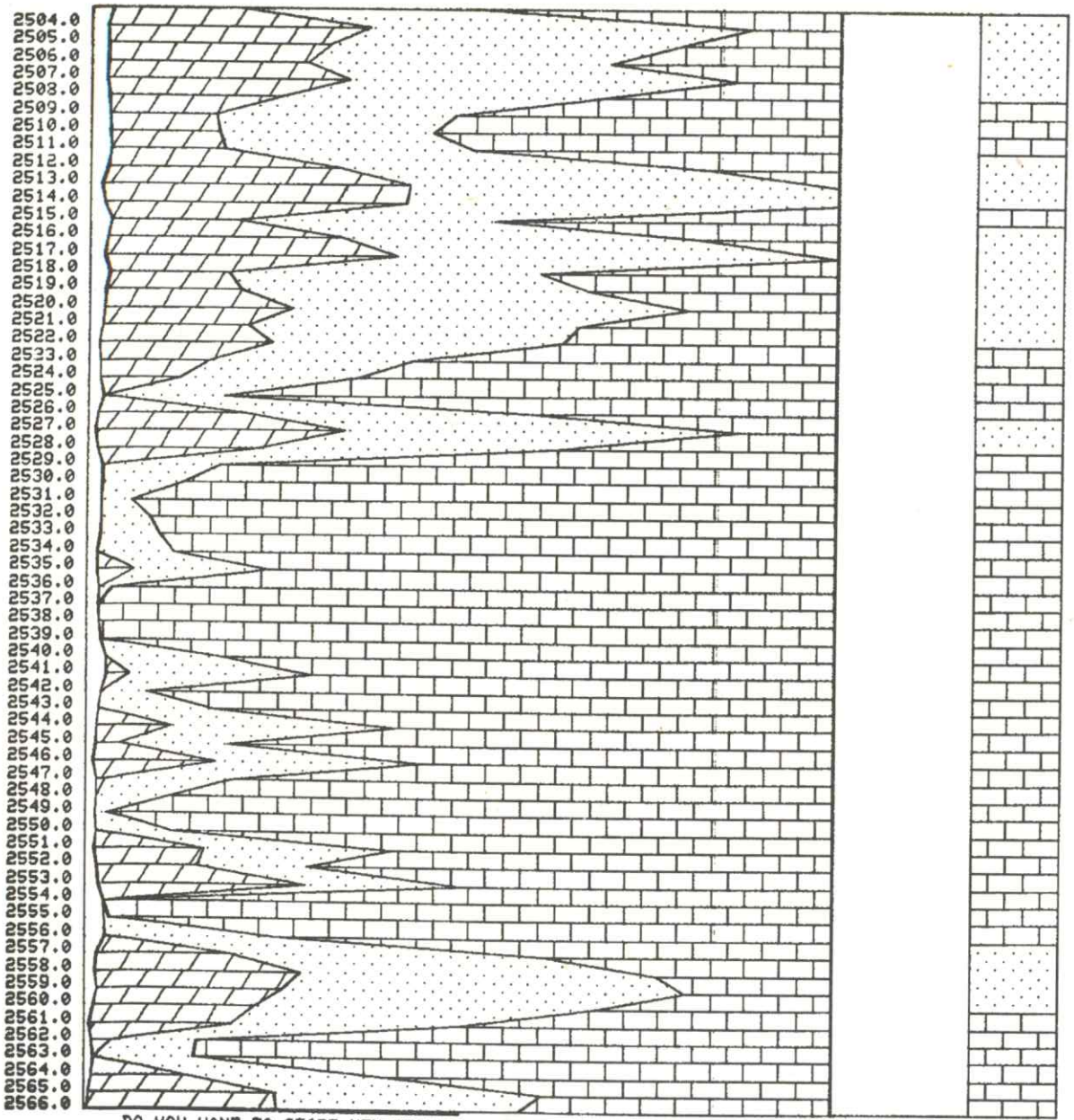
SOLUTION CALCULATED BY MATRIX INVERSION
IS THE ABOVE INFORMATION CORRECT - YES OR NO
YES

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E



DEPTH	PROP VAR	SUM DEV	ERROR
2448.0	0.69	1.99	0.00
2449.0	0.68	1.10	0.00
2450.0	0.57	1.34	0.00
2451.0	0.56	0.32	0.00
2452.0	0.94	0.00	0.00
2453.0	0.83	0.00	0.00
2454.0	0.93	0.00	0.00
2455.0	0.71	2.33	0.00
2456.0	0.69	1.57	0.00
2457.0	0.32	0.00	0.00
2458.0	0.09	0.29	0.00
2459.0	0.09	1.26	0.00
2460.0	0.12	0.70	0.00
2461.0	0.38	1.13	0.00
2462.0	0.12	5.95	0.00
2463.0	0.76	2.09	0.00
2464.0	0.77	2.42	0.00
2465.0	0.93	0.00	0.00
2466.0	0.46	3.69	0.00
2467.0	0.36	6.67	0.00
2468.0	0.39	7.96	0.00
2469.0	0.59	0.00	0.00
2470.0	0.05	13.20	0.00
2471.0	0.70	1.99	0.00
2472.0	0.87	0.00	0.00
2473.0	0.71	5.42	0.00
2474.0	0.71	5.83	0.00
2475.0	0.72	2.61	0.00
2476.0	0.73	1.44	0.00
2477.0	0.71	2.98	0.00
2478.0	0.69	4.48	0.00
2479.0	0.66	2.70	0.00
2480.0	0.65	1.01	0.00
2481.0	0.85	0.00	0.00
2482.0	0.83	0.00	0.00
2483.0	0.81	0.00	0.00
2484.0	0.87	0.00	0.00
2485.0	0.66	0.21	0.00
2486.0	0.67	0.93	0.00
2487.0	0.67	1.06	0.00
2488.0	0.75	0.00	0.00
2489.0	0.68	1.77	0.00
2490.0	0.90	0.00	0.00
2491.0	0.70	0.00	0.00
2492.0	0.76	0.00	0.00
2493.0	0.89	0.00	0.00
2494.0	0.90	0.00	0.00
2495.0	0.83	0.00	0.00
2496.0	0.68	0.99	0.00
2497.0	0.67	1.59	0.00
2498.0	0.80	0.00	0.00
2499.0	0.80	0.00	0.00
2500.0	0.68	1.21	0.00
2501.0	0.66	0.57	0.00
2502.0	0.69	0.00	0.00
2503.0	0.84	0.00	0.00

(7)



0.79	0.00	0.00
0.85	0.00	0.00
0.88	0.00	0.00
0.80	0.00	0.00
0.87	0.00	0.00
0.81	0.00	0.00
0.79	0.00	0.00
0.83	0.00	0.00
0.83	0.00	0.00
0.66	0.65	0.00
0.66	0.25	0.00
0.85	0.00	0.00
0.84	0.00	0.00
0.66	0.08	0.00
0.85	0.00	0.00
0.85	0.00	0.00
0.82	0.00	0.00
0.86	0.00	0.00
0.87	0.00	0.00
0.77	0.00	0.00
0.69	0.00	0.00
0.40	0.05	0.00
0.86	0.00	0.00
0.79	0.00	0.00
0.87	0.00	0.00
0.39	0.00	0.00
0.29	0.27	0.00
0.14	0.79	0.00
0.20	0.78	0.00
0.22	0.62	0.00
0.27	0.08	0.00
0.52	0.00	0.00
0.08	1.75	0.00
0.03	2.18	0.00
0.04	1.36	0.00
0.05	1.59	0.00
0.40	0.19	0.00
0.59	0.00	0.00
0.19	1.04	0.00
0.38	0.03	0.00
0.73	0.00	0.00
0.42	0.00	0.00
0.78	0.00	0.00
0.42	0.00	0.00
0.26	0.49	0.00
0.07	1.09	0.00
0.27	0.32	0.00
0.75	0.00	0.00
0.61	0.00	0.00
0.84	0.00	0.00
0.06	0.81	0.00
0.08	0.60	0.00
0.52	0.94	0.00
0.85	0.00	0.00
0.85	0.00	0.00
0.81	0.00	0.00
0.86	0.00	0.00
0.82	0.00	0.00
0.34	0.00	0.00
0.33	0.12	0.00
0.73	0.00	0.00
0.87	0.00	0.00
0.87	0.00	0.00

DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES
ARE YOU FINISHED WITH PETRA - YES OR NO
YES

8

gopher menu

```
INPUT NAME OF DESIRED OPTION
MNP
```

9

```
M-N-P PROGRAM
TOTAL INTERVAL AVAILABLE  2448.00 TO  2566.00
DO YOU WANT THE TOTAL INTERVAL - YES OR NO
NO
ENTER MINIMUM DEPTH DESIRED
2448.
ENTER MAXIMUM DEPTH DESIRED
2480.
DO YOU WANT FRESH MUD OR SALT MUD - F OR S
F
```

DEPTH	M	N	P
2448.0	0.779	0.542	0.695
2449.0	0.783	0.539	0.688
2450.0	0.814	0.551	0.677
2451.0	0.816	0.561	0.688
2452.0	0.807	0.575	0.713
2453.0	0.797	0.571	0.716
2454.0	0.805	0.576	0.715
2455.0	0.784	0.564	0.719
2456.0	0.783	0.562	0.716
2457.0	0.824	0.584	0.709
2458.0	0.828	0.583	0.704
2459.0	0.832	0.580	0.697
2460.0	0.829	0.582	0.702
2461.0	0.823	0.568	0.691
2462.0	0.847	0.576	0.679
2463.0	0.786	0.556	0.707
2464.0	0.789	0.568	0.719
2465.0	0.807	0.570	0.706
2466.0	0.822	0.551	0.670
2467.0	0.829	0.539	0.650
2468.0	0.830	0.539	0.650
2469.0	0.783	0.518	0.661
2470.0	0.907	0.540	0.594
2471.0	0.809	0.541	0.668
2472.0	0.795	0.545	0.686
2473.0	0.766	0.535	0.699
2474.0	0.765	0.544	0.711
2475.0	0.781	0.545	0.698
2476.0	0.787	0.555	0.706
2477.0	0.780	0.557	0.713
2478.0	0.766	0.554	0.722
2479.0	0.779	0.571	0.733
2480.0	0.787	0.573	0.727

```
DO YOU WANT A DIFFERENT DEPTH - YES OR NO
NO
```

(10)

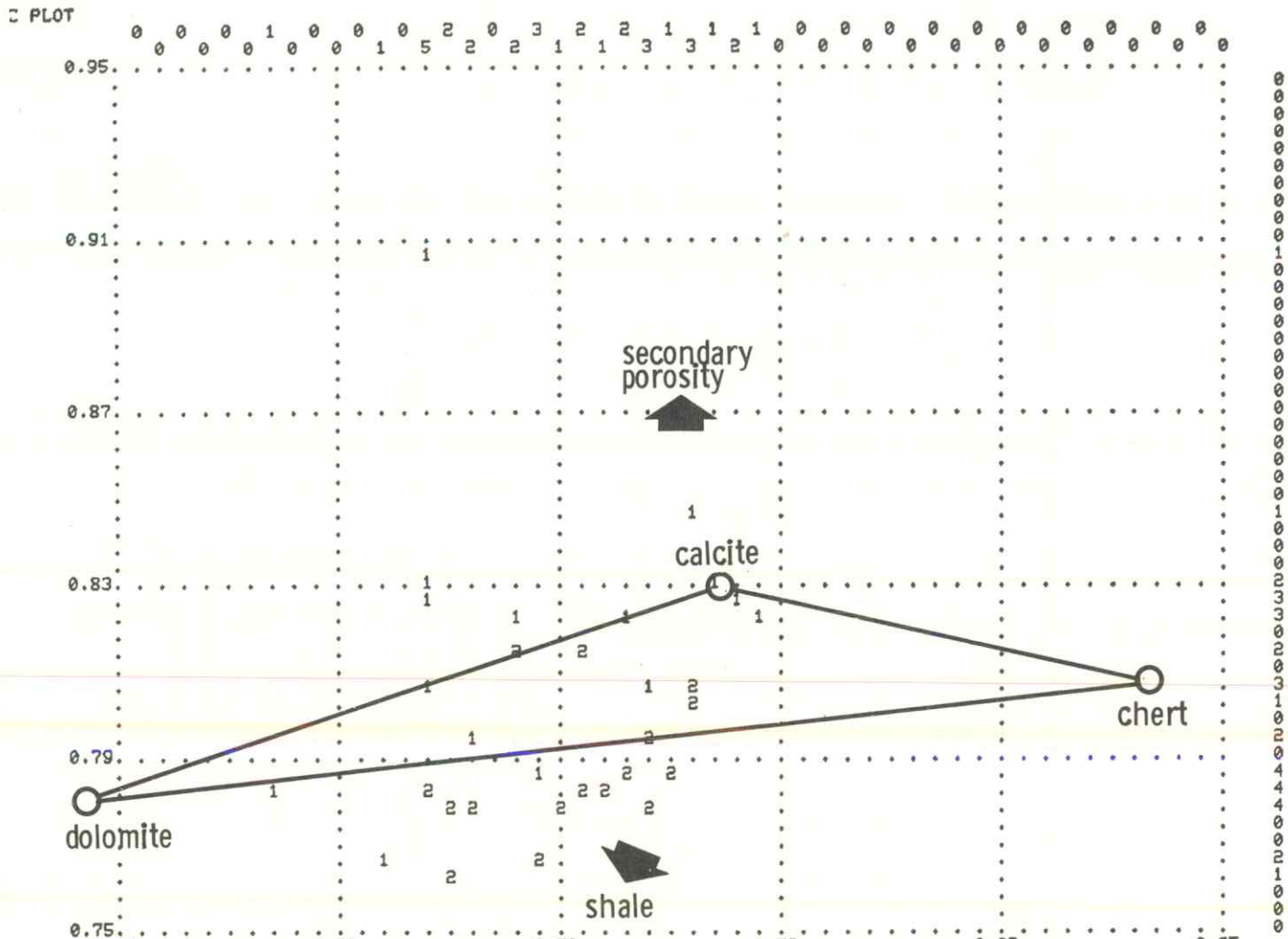
gopher menu

```
INPUT NAME OF DESIRED OPTION
CROSSPLOT
```

(11)

```
CROSSPLOT PROGRAM
01=DEPTH                02=SP                   03=GR
04=DENSITY              05=SONIC                06=GNT/SNP %
07=CNL %                08=NEUTRON COUNT        09=LL8
10=ILM                  11=ILD                  12=DEEP LATEROLOG
13=MICRORESISTIVITY     14=AZIMUTH              15=DIP
16=TEMPERATURE          17=INTEGRATED SONIC     18=CALIPER
19=                     20=                     21=PETRA SS
22=PETRA LS             23=PETRA DOL            24=PETRA SH
25=PETRA AN             26=PETRA HL             27=PETRA CL
28=PETRA POR            29=PETRA 2POR           30=PHIRA
31=SX0                  32=SW                   33=K
34=DI                   35=RT                   36=RX0
37=RWA                  38=M                    39=N
40=P                    41=ARCHIE M             42=SYNTH SEISM
43=MODEL SONIC          44=MODEL INT SONIC      45=
46=                     47=                     48=
49=                     50=ALPHA                51=BETA
52=GAMMA                53=DELTA                54=EPSILON
55=OMEGA
CROSSPLOT PROGRAM
    PARAMETERS FOR HORIZONTAL AXIS
         LOG NUMBER (01-55)
39
         LEFTMOST VALUE
0.5
         RIGHTMOST VALUE
0.65
    PARAMETERS FOR VERTICAL AXIS
         LOG NUMBER (01-55)
38
         BOTTOMMOST VALUE
0.75
         TOPMOST VALUE
0.95
    PARAMETERS FOR Z AXIS
         CROSSPLOT -- LOG NUMBER 0
         ZPLOT ------ LOG NUMBER 01-55
03
         ENTER MINIMUM Z VALUE
0.
         ENTER MAXIMUM Z VALUE
100.
   ENTER MINIMUM DEPTH DESIRED
2448.
   ENTER MAXIMUM DEPTH DESIRED
2480.
```

(12)



33 POINTS ARE USED IN THIS PLOT 0 POINTS ARE OUTSIDE PLOT
WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
DEPTH INTERVAL USED IS 2448.000 2480.000
HORIZONTAL AXIS IS 39=N
VERTICAL AXIS IS 38=M
Z AXIS IS 03=GR
Z MINIMUM AND MAXIMUM 0.0000 100.0000

(13)

gopher menu

```
INPUT NAME OF DESIRED OPTION
MERLIN
```

---

(14)

```
MERLIN NUMERICAL PROCESSING MODULE
    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    FILTER ---- CONVOLVE WITH USER-DESIGNED FILTER
    REGRESS --- SIMPLE POLYNOMIAL OR MULTIPLE LINEAR
                REGRESSION
    RMA ------- REDUCED MAJOR AXIS
    PCA ------- PRINCIPAL COMPONENT ANALYSIS
    DISCRIM --- DISCRIMINANT FUNCTION ANALYSIS
    FOURIER --- SINGLE CHANNEL FOURIER ANALYSIS
    COSPECT --- MULTI-CHANNEL COSPECTRAL ANALYSIS
    STOP ------ EXIT FROM MERLIN
DEPTH
TOTAL INTERVAL AVAILABLE  2448.00 TO  2566.00
SELECTED INTERVAL 2448.00 TO  2566.00
DO YOU WANT THE SELECTED INTERVAL - YES OR NO
NO
ENTER MINIMUM DEPTH DESIRED
2481.
ENTER MAXIMUM DEPTH DESIRED
2566.
MERLIN NUMERICAL PROCESSING MODULE
    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    FILTER ---- CONVOLVE WITH USER-DESIGNED FILTER
    REGRESS --- SIMPLE POLYNOMIAL OR MULTIPLE LINEAR
                REGRESSION
    RMA ------- REDUCED MAJOR AXIS
    PCA ------- PRINCIPAL COMPONENT ANALYSIS
    DISCRIM --- DISCRIMINANT FUNCTION ANALYSIS
    FOURIER --- SINGLE CHANNEL FOURIER ANALYSIS
    COSPECT --- MULTI-CHANNEL COSPECTRAL ANALYSIS
    STOP ------ EXIT FROM MERLIN
REGRESS
REGRESSION ANALYSIS - LOGS AVAILABLE
01=DEPTH            02=SP               03=GR
04=DENSITY          05=SONIC            06=GNT/SNP %
07=CNL %            08=NEUTRON COUNT    09=LL8
10=ILM              11=ILD              12=DEEP LATEROLOG
13=MICRORESISTIVITY 14=AZIMUTH          15=DIP
16=TEMPERATURE      17=INTEGRATED SONIC 18=CALIPER
19=                 20=                 21=PETRA SS
22=PETRA LS         23=PETRA DOL        24=PETRA SH
25=PETRA AN         26=PETRA HL         27=PETRA CL
28=PETRA POR        29=PETRA 2POR       30=PHIRA
31=SX0              32=SW               33=K
34=DI               35=RT               36=RX0
37=RWA              38=M                39=N
40=P                41=ARCHIE M         42=SYNTH SEISM
43=MODEL SONIC      44=MODEL INT SONIC  45=
46=                 47=                 48=
49=                 50=ALPHA            51=BETA
52=GAMMA            53=DELTA            54=EPSILON
55=OMEGA
ENTER DEPENDENT LOG - 01 TO 55
03
ENTER INDEPENDENT LOGS - 01 TO 55
SIMPLE REGRESSION UP TO ORDER 4 FOR SINGLE LOG
MULTIPLE REGRESSION FOR 2 TO 10 LOGS
ENTER 0 WHEN FINISHED
21
22
23
28
0
WILL COMPUTED REGRESSION VALUES BE
STORED - YES OR NO
NO
```

(15)

```
REGRESSION ANALYSIS
    WELL NAME : CITIES SERVICE BECK A-1      SW-SE-SE 14-5S-12E
    LOCATION  : NEMAHA CO., KANSAS
    DATE      : JAN. 11, 1978
    DEPTH INTERVAL : 2481.00 TO  2566.00
    DEPENDENT VARIABLE : 03=GR

MULTIPLE REGRESSION

CONSTANT                16.175      0.000
21=PETRA SS             23.816      0.803
22=PETRA LS             -1.446     -0.090
23=PETRA DOL           -22.711     -0.701
28=PETRA POR           195.919      0.234

          SUM-OF-SQUARES   DEGREES-OF-FREEDOM   MEAN-SQUARES   F-TEST
REGRESSION      524.30            4                131.075     5.617
DEVIATION      1890.14           81                 23.335
TOTAL          2414.44           85
```

■

---

(16)

```
MERLIN NUMERICAL PROCESSING MODULE
    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    FILTER ---- CONVOLVE WITH USER-DESIGNED FILTER
    REGRESS --- SIMPLE POLYNOMIAL OR MULTIPLE LINEAR
                REGRESSION
    RMA ------- REDUCED MAJOR AXIS
    PCA ------- PRINCIPAL COMPONENT ANALYSIS
    DISCRIM --- DISCRIMINANT FUNCTION ANALYSIS
    FOURIER --- SINGLE CHANNEL FOURIER ANALYSIS
    COSPECT --- MULTI-CHANNEL COSPECTRAL ANALYSIS
    STOP ------ EXIT FROM MERLIN
STOP
```

---

(17)

gopher menu

INPUT NAME OF DESIRED OPTION
STATISTICS

---

(18)

```
SUMMARY STATISTICS AND HISTOGRAMS
TOTAL INTERVAL AVAILABLE  2448.00 TO 2566.00
DO YOU WANT THE TOTAL INTERVAL - YES OR NO
NO
ENTER MINIMUM DEPTH DESIRED
2442.
ENTER MAXIMUM DEPTH DESIRED
2480.
```

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
LOCATION: NEMAHA CO., KANSAS
DATE: JAN. 11, 1978
INTERVAL: 2448.00 TO 2480.00

LOG NUMBER	AVAILABILITY FOR USAGE AVAILABLE	NUMBER OF VALUES	NUMBER OF VALUES DEFAULTED	MINIMUM VALUE	MAXIMUM VALUE	AVERAGE VALUE
01=DEPTH	YES	33	0	2448.00	2480.00	2464.00
02=SP	YES	33	0	46.00	74.00	63.91
03=GR	YES	33	0	15.18	33.22	22.34
04=DENSITY	YES	33	0	2.54	2.72	2.63
05=SONIC	YES	33	0	43.62	66.49	57.32
06=GNT/SNP %	NO					
07=CNL %	YES	33	0	1.64	16.36	8.49
08=NEUTRON COUNT	NO					
09=LL8	YES	33	0	87.90	895.33	308.55
10=ILM	YES	33	0	48.30	440.54	171.13
11=ILD	YES	33	0	41.30	444.62	142.88
12=DEEP LATEROLOG	NO					
13=MICRORESISTIVITY	NO					
14=AZIMUTH	NO					
15=DIP	NO					
16=TEMPERATURE	NO					
17=INTEGRATED SONIC	NO					
18=CALIPER	NO					
19=	NO					
20=	NO					
21=PETRA SS	YES	33	0	0.00	0.59	0.26
22=PETRA LS	YES	33	0	0.00	0.98	0.37
23=PETRA DOL	YES	33	0	0.00	0.71	0.30
24=PETRA SH	NO					
25=PETRA AN	NO					
26=PETRA HL	NO					
27=PETRA CL	NO					
28=PETRA POR	YES	33	0	0.01	0.11	0.05
29=PETRA 2POR	NO					
30=PHIRA	NO					
31=SX0	NO					
32=SW	NO					
33=K	NO					
34=DI	NO					
35=RT	NO					
36=RX0	NO					
37=RWA	NO					
38=M	YES	33	0	0.76	0.90	0.80
39=N	YES	33	0	0.51	0.58	0.55
40=P	YES	33	0	0.59	0.73	0.69
41=ARCHIE M	NO					
42=SYNTH SEISM	NO					
43=MODEL SONIC	NO					
44=MODEL INT SONIC	NO					
45=	NO					
46=	NO					
47=	NO					
48=	NO					
49=	NO					
50=ALPHA	YES	33	0	0.05	0.94	0.58
51=BETA	YES	33	0	0.00	13.20	2.50
52=GAMMA	YES	33	0	0.00	0.00	0.00
53=DELTA	NO					
54=EPSILON	NO					
55=OMEGA	NO					

CONSTANTS	VALUE
01=MINIMUM DEPTH	2448.00
02=MAXIMUM DEPTH	2566.00
03=INCREMENT	1.00
04=ELEVATION	1278.00
05=LATITUDE	-9999.00
06=LONGITUDE	-9999.00
07=RM	-9999.00
08=TRM	-9999.00
09=RMF	2.14
10=TRMF	58.00
11=RMC	-9999.00
12=TRMC	-9999.00
13=BHT	92.00
14=MEAN-T	54.00
15=T-GRADIENT	-9999.00
16=TIME-C-GR	-9999.00
17=TIME-C-N	-9999.00
18=LOG SPEED GR	-9999.00
19=LOG SPEED N	-9999.00
20=TD	2757.00
21=	-9999.00
22=	-9999.00
23=	-9999.00
24=	-9999.00
25=	-9999.00
26=	-9999.00
27=	-9999.00
28=	-9999.00
29=	-9999.00
30=	-9999.00
31=	-9999.00
32=	-9999.00
33=	-9999.00
34=	-9999.00
35=	-9999.00
36=	-9999.00
37=	-9999.00
38=	-9999.00
39=	-9999.00
40=	-9999.00
41=	-9999.00
42=	-9999.00
43=	-9999.00
44=	-9999.00
45=	-9999.00
46=	-9999.00
47=	-9999.00
48=TOP VIOLA	-9999.00
49=TOP SIMPSON	-9999.00
50=TOP ARBUCKLE	-9999.00
51=	-9999.00
52=	-9999.00
53=	-9999.00
54=	-9999.00
55=	-9999.00
56=	-9999.00
57=	-9999.00
58=	-9999.00
59=	-9999.00
60=	-9999.00

19

DO YOU WANT ANOTHER DEPTH INTERVAL- YES OR NO
NO
DO YOU WANT A HISTOGRAM PRODUCED - YES OR NO
NO

20

(22)

```
PROGRAM PETRA: MINERALOGICAL/LITHOLOGICAL COMPONENT
    ESTIMATION FOR PETROPHYSICAL WELL LOGS
TOTAL INTERVAL AVAILABLE  2448.00 TO  2566.00
DO YOU WANT THE ENTIRE INTERVAL - YES OR NO
NO
TOP OF INTERVAL (FEET)
2443.
BOTTOM OF INTERVAL (FEET)
2420.
SELECT DESIRED CALCULATION/PLOTTING
     1=PLOT EXISTING VALUES
     2=CALCULATE AND PLOT NEW VALUES
     3=CALCULATE NEW VALUES
     4=APPLY INVERSE SHARPENING FILTER
2
SELECT PLOTTING OPTION
     1=POLYGON
     2=BLOCK
1
THE FOLLOWING WELL LOGS ARE AVAILABLE
     SP
     GAMMA
     DENSITY
     SONIC
     NEUTRON
NUMBER OF LOGS - MAXIMUM OF 5
4
NUMBER OF COMPONENTS - MAXIMUM OF 9
6
TYPE OF LOGS LISTED BY INPUT ORDER
     CAN USE DENSITY,NEUTRON,SONIC,GAMMA,SP
LOG 1
GAMMA
LOG 2
DEN
LOG 3
SON
LOG 4
NEU
TYPE OF COMPONENTS DESIRED
     CAN USE SS,LS,DOL,SH,AN,HL,CL,POR,2POR
COMPONENT 1
POR
COMPONENT 2
2POR
COMPONENT 3
DOL
COMPONENT 4
SS
COMPONENT 5
LS
COMPONENT 6
SH
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
LIST
                POR     2POR     DOL      SS      LS      SH
GAMMA         10.00    10.00    20.00   30.00   20.00  100.00
DENSITY        1.00     1.00     2.87    2.65    2.71    2.50
SONIC        189.00     0.00    43.50   55.50   47.50  100.00
NEUTRON      100.00   100.00     7.50   -5.00    0.00   40.00
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
GAMMA
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
DOL
```

(21)

gopher menu

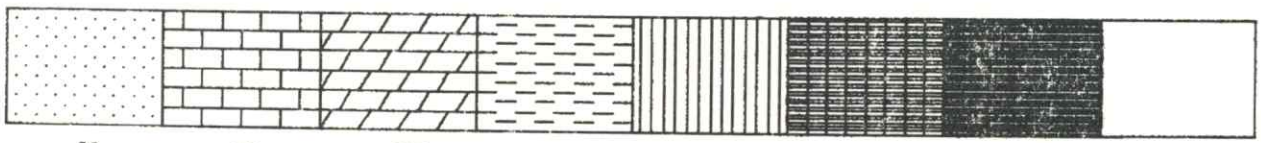
```
INPUT NAME OF DESIRED OPTION
PETRA
```

```
ENTER NEW COEFFICIENT VALUE
0.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
GAMMA
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
SS
ENTER NEW COEFFICIENT VALUE
40.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
GAMMA
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
LS
ENTER NEW COEFFICIENT VALUE
15.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
GAMMA
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
SH
ENTER NEW COEFFICIENT VALUE
125.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
SONIC
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
2POR
ENTER NEW COEFFICIENT VALUE
46.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
NEU
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
SH
ENTER NEW COEFFICIENT VALUE
30.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
DONE
INPUT ANY MODIFICATIONS TO COMPONENT KEY
SS = CHERT
```

(23)

```
WELL NAME: CITIES SERVICE BECK A-1      SW-SE-SE 14-5S-12E
 LOCATION: NEMAHA CO., KANSAS     JAN. 11, 1978
 INTERVAL:  2448.00 TO  2480.00 BY 1.00
     LOGS: GAMMA      DENSITY   SONIC      NEUTRON
COMPONENTS: POR   2POR  DOL   SS    LS    SH
```

KEY



MODIFICATIONS: SS = CHERT

■

(24)

INPUT COEFFICIENTS:

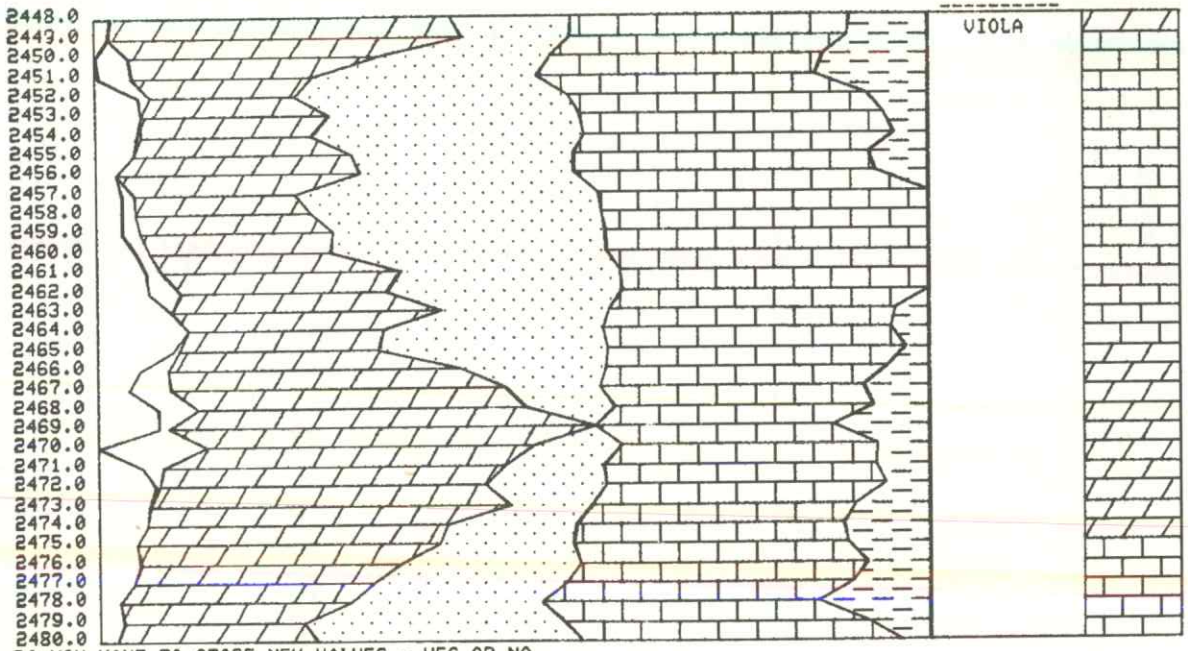
	POR	2POR	DOL	SS	LS	SH
GAMMA	10.00	10.00	0.00	40.00	15.00	125.00
DENSITY	1.00	1.00	2.87	2.65	2.71	2.50
SONIC	189.00	46.00	43.50	55.50	47.50	100.00
NEUTRON	100.00	100.00	7.50	-5.00	0.00	30.00

EQUATIONS LESS THAN UNKNOWNS N+1<M

SOLUTION CALCULATED BY MAXIMUM VARIANCE

```
IS THE ABOVE INFORMATION CORRECT - YES OR NO
YES
DO YOU WANT GUIDED MINIMUM VARIANCE - YES OR NO
YES
ENTER COORDINATE FOR POR
0.05
ENTER COORDINATE FOR 2POR
0.
ENTER COORDINATE FOR DOL
0.31
ENTER COORDINATE FOR SS
0.26
ENTER COORDINATE FOR LS
0.38
ENTER COORDINATE FOR SH
0.
```

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E



PROP VAR	SUM DEV	ERROR
0.83	0.72	0.00
0.81	0.00	0.00
0.89	2.75	0.00
0.89	0.00	0.00
0.86	0.00	0.00
0.86	0.00	0.00
0.84	0.00	0.00
0.87	1.26	0.00
0.85	1.57	0.00
0.80	0.64	0.00
0.81	1.60	0.00
0.82	1.63	0.00
0.82	1.85	0.00
0.84	0.11	0.00
0.85	1.61	0.00
0.87	1.26	0.00
0.88	1.07	0.00
0.87	0.00	0.00
0.86	0.00	0.00
0.85	0.00	0.00
0.86	0.00	0.00
0.76	0.04	0.00
0.86	7.04	0.00
0.84	0.00	0.00
0.84	0.00	0.00
0.82	2.44	0.00
0.87	2.52	0.00
0.86	0.36	0.00
0.87	0.40	0.00
0.87	1.04	0.00
0.88	2.09	0.00
0.85	2.41	0.00
0.82	2.30	0.00

DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES
ARE YOU FINISHED WITH PETRA - YES OR NO
NO

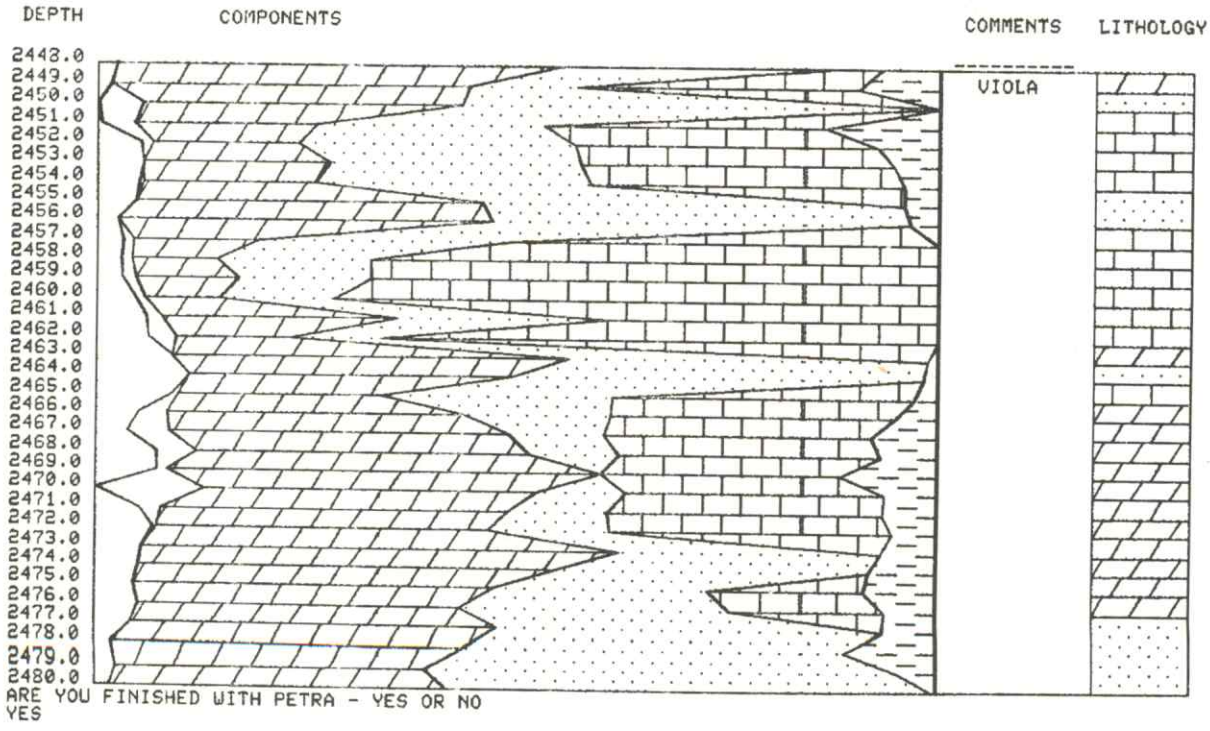
WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
LOCATION: NEMAHA CO., KANSAS
DATE: JAN. 11, 1978

26

01=DEPTH	21=PETRA SS	22=PETRA LS	23=PETRA DOL	24=PETRA SH	28=PETRA POR	29=PETRA 2POR
2448.000	0.326	0.056	0.525	0.069	0.021	0.000
2449.000	0.129	0.334	0.423	0.097	0.015	0.001
2450.000	0.569	0.000	0.377	0.000	0.000	0.052
2451.000	0.270	0.335	0.214	0.135	0.003	0.039
2452.000	0.328	0.360	0.172	0.073	0.051	0.013
2453.000	0.297	0.373	0.220	0.054	0.054	0.000
2454.000	0.326	0.374	0.203	0.041	0.048	0.005
2455.000	0.502	0.000	0.411	0.041	0.045	0.000
2456.000	0.498	0.000	0.443	0.034	0.023	0.000
2457.000	0.297	0.512	0.148	0.000	0.029	0.012
2458.000	0.181	0.676	0.101	0.000	0.028	0.011
2459.000	0.157	0.675	0.121	0.000	0.028	0.016
2460.000	0.135	0.719	0.088	0.000	0.045	0.010
2461.000	0.249	0.394	0.279	0.000	0.058	0.018
2462.000	0.107	0.662	0.135	0.000	0.060	0.033
2463.000	0.428	0.000	0.470	0.012	0.089	0.000
2464.000	0.491	0.000	0.382	0.016	0.109	0.000
2465.000	0.276	0.359	0.239	0.028	0.089	0.007
2466.000	0.174	0.338	0.352	0.050	0.050	0.033
2467.000	0.112	0.318	0.403	0.079	0.036	0.050
2468.000	0.106	0.311	0.395	0.067	0.071	0.047
2469.000	0.000	0.284	0.514	0.115	0.072	0.012
2470.000	0.105	0.308	0.394	0.062	0.000	0.129
2471.000	0.119	0.326	0.412	0.064	0.051	0.024
2472.000	0.144	0.335	0.393	0.053	0.067	0.004
2473.000	0.311	0.000	0.566	0.067	0.054	0.000
2474.000	0.373	0.000	0.494	0.081	0.050	0.000
2475.000	0.255	0.185	0.427	0.086	0.045	0.000
2476.000	0.321	0.185	0.381	0.061	0.050	0.000
2477.000	0.457	0.000	0.435	0.064	0.042	0.000
2478.000	0.454	0.000	0.415	0.110	0.019	0.000
2479.000	0.563	0.000	0.366	0.046	0.024	0.000
2480.000	0.578	0.000	0.400	0.004	0.016	0.000

27

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E



28

gopher menu

```
INPUT NAME OF DESIRED OPTION
KOBRA
```

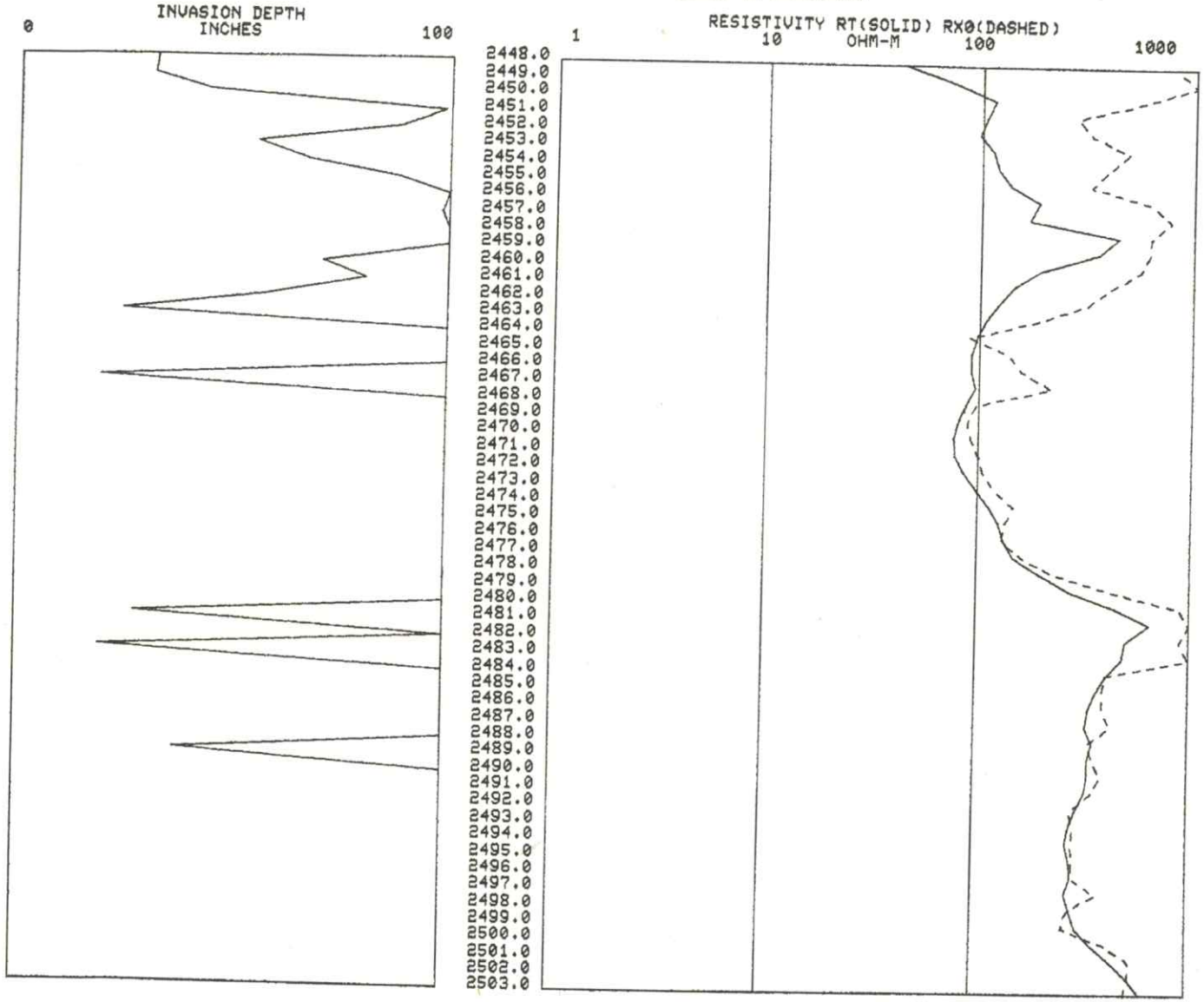
29

```
KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    PPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIPA ----- WATER-FILLED POROSITY
    PORGEO ---- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
TORNADO
IS A POROSITY LOG AVAILABLE - YES OR NO
YES
INPUT TRACK NUMBER OF POROSITY LOG (02-50)
28
ENTER DEFAULT VALUE FOR % POROSITY
3.
```

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E



2504.0
2505.0
2506.0
2507.0
2508.0
2509.0
2510.0
2511.0
2512.0
2513.0
2514.0
2515.0
2516.0
2517.0
2518.0
2519.0
2520.0
2521.0
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2525.0
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2530.0
2531.0
2532.0
2533.0
2534.0
2535.0
2536.0
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2539.0
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2541.0
2542.0
2543.0
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2551.0
2552.0
2553.0
2554.0
2555.0
2556.0
2557.0
2558.0
2559.0
2560.0
2561.0
2562.0
2563.0
2564.0
2565.0
2566.0
DO YOU WANT TO STORE NEW VALUES - YES OR NO

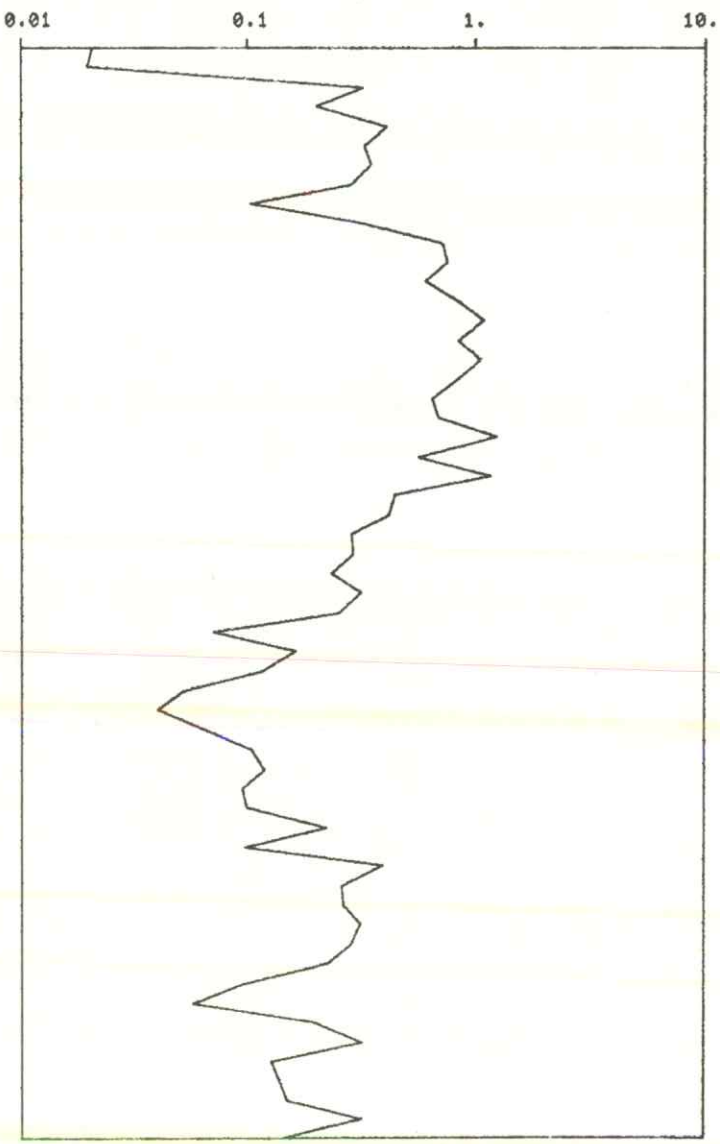
```
KOBRA RESERVOIR ANALYSIS MODULE

     DEPTH ----- SELECT DESIRED DEPTH INTERVAL
     TORNADO --- SMALL SLAM INVASION PARAMETERS
     RPPLOT ---- PICKETT PLOT
     SPRW ------ WATER RESISTIVITY FROM SP
     RWA ------- RECONNAISSANCE WATER RESISTIVITY
     PHIRA ----- WATER-FILLED POROSITY
     POREG ----- PORE GEOMETRY
     CLSAT ----- WATER SATURATION (SHALE-FREE)
     SHSAT ----- WATER SATURATION (SHALY MODELS)
     WASP ------ WAXMAN-SMITS MODEL
     PERM ------ PERMEABILITY INDEX
     CHERNOFF -- PHI.SW.SH.VSH.K FACES
     STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
RWA
RWA OPTION SELECTED
THE FOLLOWING RESISTIVITY LOGS ARE AVAILABLE
     09=LL8
     10=ILM
     11=ILD
     35=RT
     36=RX0
SELECT TRACK NUMBER OF RESISTIVITY TO BE USED
35
SPECIFY ARCHIE EQUATION CONSTANTS - A,M
1.
2.
```

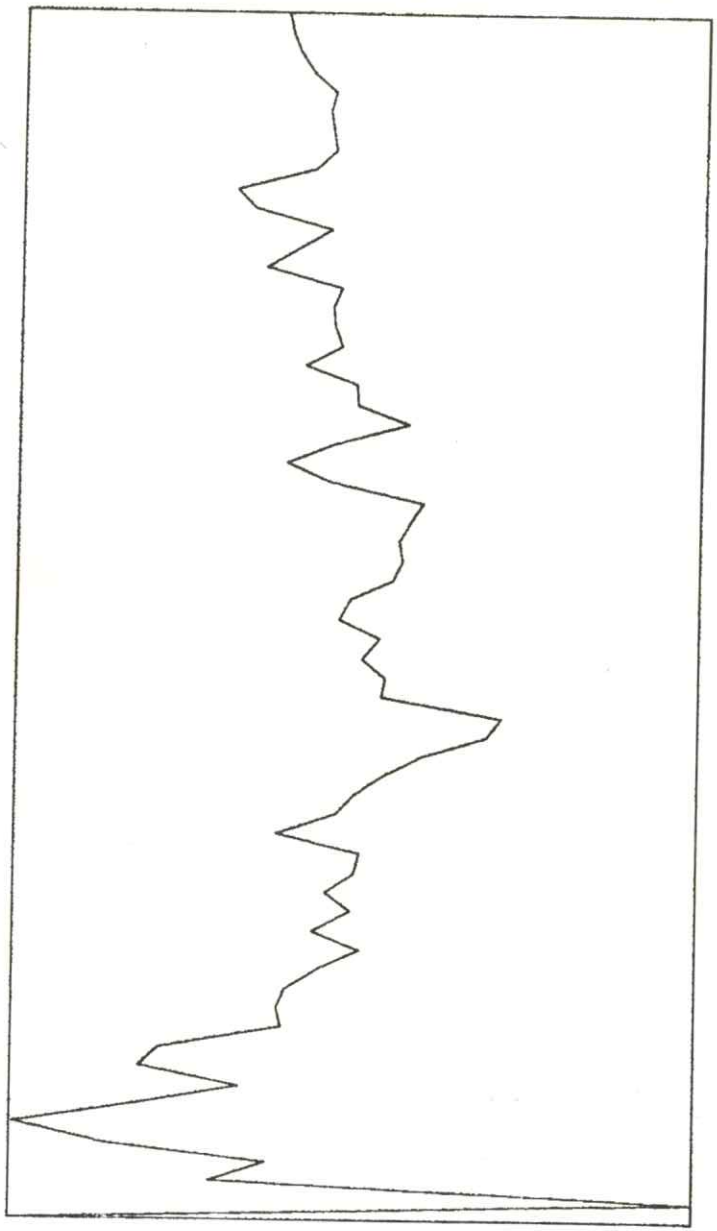
RWA COMPUTATION
WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
DEPTH INTERVAL: 2448.00 2566.00
RESISTIVITY LOG: 35-RT
A= 1.00 M= 2.00

DEPTH	VSH	POR	2POR	PHI	R	RWA
2448.0	0.069	0.021	0.000	0.021	42.40	0.020
2449.0	0.097	0.015	0.001	0.016	75.21	0.019
2450.0	0.000	0.000	0.052	0.052	114.42	0.319
2451.0	0.135	0.003	0.039	0.043	104.55	0.199
2452.0	0.073	0.051	0.013	0.064	96.67	0.405
2453.0	0.054	0.054	0.000	0.054	111.69	0.326
2454.0	0.041	0.048	0.005	0.053	119.10	0.344
2455.0	0.041	0.045	0.000	0.045	136.70	0.280
2456.0	0.034	0.023	0.000	0.023	185.36	0.102
2457.0	0.000	0.029	0.012	0.042	167.45	0.303
2458.0	0.000	0.028	0.011	0.040	440.41	0.715
2459.0	0.000	0.028	0.016	0.045	360.22	0.754
2460.0	0.000	0.045	0.010	0.056	189.45	0.602
2461.0	0.000	0.058	0.018	0.076	142.99	0.839
2462.0	0.000	0.060	0.033	0.094	121.72	1.078
2463.0	0.012	0.089	0.000	0.089	106.04	0.842
2464.0	0.016	0.109	0.000	0.109	86.29	1.042
2465.0	0.028	0.089	0.007	0.096	89.75	0.839
2466.0	0.050	0.050	0.033	0.083	91.20	0.635
2467.0	0.079	0.036	0.050	0.086	91.48	0.684
2468.0	0.067	0.071	0.047	0.119	86.29	1.224
2469.0	0.115	0.072	0.012	0.084	78.04	0.559
2470.0	0.062	0.000	0.129	0.129	68.52	1.143
2471.0	0.064	0.051	0.024	0.076	74.66	0.441
2472.0	0.053	0.067	0.004	0.072	77.47	0.409
2473.0	0.067	0.054	0.000	0.054	95.35	0.283
2474.0	0.081	0.050	0.000	0.050	110.57	0.286
2475.0	0.086	0.045	0.000	0.045	110.59	0.229
2476.0	0.061	0.050	0.000	0.050	121.40	0.311
2477.0	0.064	0.042	0.000	0.042	136.83	0.246
2478.0	0.110	0.019	0.000	0.019	184.97	0.069
2479.0	0.046	0.024	0.000	0.024	275.50	0.158
2480.0	0.004	0.016	0.000	0.016	434.01	0.112
2481.0	-1.000	0.008	-1.000	0.008	649.64	0.052
2482.0	-1.000	0.008	-1.000	0.008	501.45	0.039
2483.0	-1.000	0.011	-1.000	0.011	491.86	0.065
2484.0	-1.000	0.016	-1.000	0.016	366.98	0.103
2485.0	-1.000	0.018	-1.000	0.018	346.56	0.117
2486.0	-1.000	0.016	-1.000	0.016	339.52	0.093
2487.0	-1.000	0.017	-1.000	0.017	331.12	0.097
2488.0	-1.000	0.026	-1.000	0.026	305.00	0.220
2489.0	-1.000	0.016	-1.000	0.016	340.39	0.095
2490.0	-1.000	0.033	-1.000	0.033	343.55	0.383
2491.0	-1.000	0.028	-1.000	0.028	310.30	0.256
2492.0	-1.000	0.030	-1.000	0.030	272.90	0.262
2493.0	-1.000	0.034	-1.000	0.034	257.59	0.309
2494.0	-1.000	0.033	-1.000	0.033	248.28	0.280
2495.0	-1.000	0.029	-1.000	0.029	257.15	0.222
2496.0	-1.000	0.018	-1.000	0.018	270.96	0.093
2497.0	-1.000	0.014	-1.000	0.014	273.96	0.057
2498.0	-1.000	0.027	-1.000	0.027	251.40	0.193
2499.0	-1.000	0.030	-1.000	0.030	337.18	0.314
2500.0	-1.000	0.019	-1.000	0.019	324.16	0.125
2501.0	-1.000	0.018	-1.000	0.018	406.28	0.135
2502.0	-1.000	0.019	-1.000	0.019	396.80	0.146
2503.0	-1.000	0.023	-1.000	0.023	591.71	0.313
2504.0	-1.000	0.016	-1.000	0.016	545.50	0.140



2505.0	-1.000	0.016	-1.000	0.016	512.89	0.146
2506.0	-1.000	0.017	-1.000	0.017	529.66	0.158
2507.0	-1.000	0.016	-1.000	0.016	666.79	0.182
2508.0	-1.000	0.019	-1.000	0.019	627.72	0.228
2509.0	-1.000	0.020	-1.000	0.020	524.82	0.218
2510.0	-1.000	0.020	-1.000	0.020	516.67	0.224
2511.0	-1.000	0.021	-1.000	0.021	496.60	0.233
2512.0	-1.000	0.019	-1.000	0.019	507.64	0.189
2513.0	-1.000	0.013	-1.000	0.013	479.90	0.085
2514.0	-1.000	0.015	-1.000	0.015	414.83	0.103
2515.0	-1.000	0.023	-1.000	0.023	406.18	0.224
2516.0	-1.000	0.019	-1.000	0.019	413.07	0.162
2517.0	-1.000	0.017	-1.000	0.017	399.06	0.119
2518.0	-1.000	0.022	-1.000	0.022	478.75	0.253
2519.0	-1.000	0.019	-1.000	0.019	622.59	0.233
2520.0	-1.000	0.018	-1.000	0.018	685.61	0.236
2521.0	-1.000	0.016	-1.000	0.016	963.85	0.256
2522.0	-1.000	0.012	-1.000	0.012	1181.23	0.178
2523.0	-1.000	0.014	-1.000	0.014	1486.62	0.298
2524.0	-1.000	0.014	-1.000	0.014	1483.74	0.303
2525.0	-1.000	0.018	-1.000	0.018	1473.79	0.516
2526.0	-1.000	0.012	-1.000	0.012	1472.72	0.241
2527.0	-1.000	0.010	-1.000	0.010	1478.09	0.150
2528.0	-1.000	0.012	-1.000	0.012	1475.65	0.233
2529.0	-1.000	0.018	-1.000	0.018	1720.32	0.603
2530.0	-1.000	0.018	-1.000	0.018	1500.35	0.533
2531.0	-1.000	0.017	-1.000	0.017	1500.35	0.476
2532.0	-1.000	0.018	-1.000	0.018	1498.85	0.488
2533.0	-1.000	0.017	-1.000	0.017	1512.83	0.444
2534.0	-1.000	0.013	-1.000	0.013	1515.71	0.288
2535.0	-1.000	0.013	-1.000	0.013	1501.71	0.259
2536.0	-1.000	0.016	-1.000	0.016	1501.71	0.395
2537.0	-1.000	0.015	-1.000	0.015	1472.58	0.332
2538.0	-1.000	0.016	-1.000	0.016	1545.86	0.419
2539.0	-1.000	0.019	-1.000	0.019	1095.62	0.402
2540.0	-1.000	0.025	-1.000	0.025	2038.60	1.362
2541.0	-1.000	0.026	-1.000	0.026	1674.17	1.175
2542.0	-1.000	0.020	-1.000	0.020	1501.75	0.622
2543.0	-1.000	0.016	-1.000	0.016	1503.13	0.409
2544.0	-1.000	0.014	-1.000	0.014	1504.45	0.308
2545.0	-1.000	0.013	-1.000	0.013	1517.06	0.259
2546.0	-1.000	0.009	-1.000	0.009	1517.06	0.142
2547.0	-1.000	0.014	-1.000	0.014	1514.31	0.329
2548.0	-1.000	0.014	-1.000	0.014	1517.06	0.317
2549.0	-1.000	0.012	-1.000	0.012	1518.34	0.236
2550.0	-1.000	0.014	-1.000	0.014	1514.31	0.305
2551.0	-1.000	0.011	-1.000	0.011	1517.13	0.210
2552.0	-1.000	0.015	-1.000	0.015	1367.60	0.337
2553.0	-1.000	0.017	-1.000	0.017	744.71	0.221
2554.0	-1.000	0.024	-1.000	0.024	259.41	0.158
2555.0	-1.000	0.025	-1.000	0.025	221.69	0.148
2556.0	-1.000	0.026	-1.000	0.026	225.11	0.153
2557.0	-1.000	0.015	-1.000	0.015	185.98	0.045
2558.0	-1.000	0.013	-1.000	0.013	197.67	0.036
2559.0	-1.000	0.016	-1.000	0.016	363.08	0.101
2560.0	-1.000	0.011	-1.000	0.011	247.91	0.034
2561.0	-1.000	0.006	-1.000	0.006	269.26	0.010
2562.0	-1.000	0.009	-1.000	0.009	313.72	0.025
2563.0	-1.000	0.011	-1.000	0.011	981.73	0.135
2564.0	-1.000	0.008	-1.000	0.008	1076.41	0.076
2565.0	-1.000	0.005	-1.000	0.005	0.00*766.000	
2566.0	-1.000	0.003	-1.000	0.003	74.40	0.000

DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES



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KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    RPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
STOP
```

34

gopher menu

```
INPUT NAME OF DESIRED OPTION
STATISTICS
```

35

```
SUMMARY STATISTICS AND HISTOGRAMS
TOTAL INTERVAL AVAILABLE  2448.00 TO 2566.00
DO YOU WANT THE TOTAL INTERVAL - YES OR NO
NO
ENTER MINIMUM DEPTH DESIRED
2480.
ENTER MAXIMUM DEPTH DESIRED
2540.
```

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
LOCATION: NEMAHA CO., KANSAS
DATE: JAN. 11, 1978
INTERVAL: 2480.00 TO 2540.00

LOG NUMBER	AVAILABILITY FOR USAGE AVAILABLE	NUMBER OF VALUES	NUMBER OF VALUES DEFAULTED	MINIMUM VALUE	MAXIMUM VALUE	AVERAGE VALUE
01=DEPTH	YES	61	0	2480.00	2540.00	2510.00
02=SP	YES	61	0	50.50	62.00	56.33
03=GR	YES	61	0	14.71	35.13	22.52
04=DENSITY	YES	61	0	2.64	2.74	2.69
05=SONIC	YES	61	0	50.29	54.51	52.39
06=GNT/SNP %	NO					
07=CNL %	YES	61	0	0.74	5.19	1.97
08=NEUTRON COUNT	NO					
09=LLS	YES	61	0	265.46	1770.22	854.61
10=ILM	YES	61	0	246.60	1499.70	748.07
11=ILD	YES	61	0	275.42	1614.46	846.47
12=DEEP LATEROLOG	NO					
13=MICRORESISTIVITY	NO					
14=AZIMUTH	NO					
15=DIP	NO					
16=TEMPERATURE	NO					
17=INTEGRATED SONIC	NO					
18=CALIPER	NO					
19=	NO					
20=	NO					
21=PETRA SS	YES	61	0	0.00	0.59	0.36
22=PETRA LS	YES	61	0	0.00	0.98	0.36
23=PETRA DOL	YES	61	0	0.00	0.53	0.25
24=PETRA SH	YES	1	60	0.00	0.00	0.00
25=PETRA AN	NO					
26=PETRA HL	NO					
27=PETRA CL	NO					
28=PETRA POR	YES	61	0	0.00	0.03	0.01
29=PETRA 2POR	YES	1	60	0.00	0.00	0.00
30=PHIRA	NO					
31=SX0	NO					
32=SW	NO					
33=K	NO					
34=DI	YES	61	0	-342.12	234.13	-14.47
35=RT	YES	61	0	248.28	2038.60	768.81
36=RX0	YES	61	0	250.66	5372.04	845.59
37=RWA	YES	61	0	0.03	1.36	0.25
38=M	YES	1	60	0.78	0.78	0.78
39=N	YES	1	60	0.57	0.57	0.57
40=P	YES	1	60	0.72	0.72	0.72
41=ARCHIE M	NO					
42=SYNTH SEISM	NO					
43=MODEL SONIC	NO					
44=MODEL INT SONIC	NO					
45=	NO					
46=	NO					
47=	NO					
48=	NO					
49=	NO					
50=ALPHA	YES	61	0	0.03	0.90	0.67
51=BETA	YES	61	0	0.00	2.18	0.31
52=GAMMA	YES	61	0	0.00	0.33	0.00
53=DELTA	NO					
54=EPSILON	NO					
55=OMEGA	NO					

CONSTANTS	VALUE
01=MINIMUM DEPTH	2448.00
02=MAXIMUM DEPTH	2566.00
03=INCREMENT	1.00
04=ELEVATION	1278.00
05=LATITUDE	-9999.00
06=LONGITUDE	-9999.00
07=RM	-9999.00
08=TRM	-9999.00
09=RMF	2.14
10=TRMF	58.00
11=RMC	-9999.00
12=TRMC	-9999.00
13=BHT	92.00
14=MEAN-T	54.00
15=T-GRADIENT	-9999.00
16=TIME-C-GR	-9999.00
17=TIME-C-N	-9999.00
18=LOG SPEED GR	-9999.00
19=LOG SPEED N	-9999.00
20=TD	2757.00
21=	-9999.00
22=	-9999.00
23=	-9999.00
24=	-9999.00
25=	-9999.00
26=	-9999.00
27=	-9999.00
28=	-9999.00
29=	-9999.00
30=	-9999.00
31=	-9999.00
32=	-9999.00
33=	-9999.00
34=	-9999.00
35=	-9999.00
36=	-9999.00
37=	-9999.00
38=	-9999.00
39=	-9999.00
40=	-9999.00
41=	-9999.00
42=	-9999.00
43=	-9999.00
44=	-9999.00
45=	-9999.00
46=	-9999.00
47=	-9999.00
48=TOP VIOLA	-9999.00
49=TOP SIMPSON	-9999.00
50=TOP ARBUCKLE	-9999.00
51=	-9999.00
52=	-9999.00
53=	-9999.00
54=	-9999.00
55=	-9999.00
56=	-9999.00
57=	-9999.00
58=	-9999.00
59=	-9999.00
60=	-9999.00

37

```
DO YOU WANT ANOTHER DEPTH INTERVAL- YES OR NO
NO
DO YOU WANT A HISTOGRAM PRODUCED - YES OR NO
YES
01=DEPTH              02=SP                 03=GR                 04=DENSITY
05=SONIC              06=GNT/SNP %          07=CNL %              08=NEUTRON COUNT
09=LL8                10=ILM                11=ILD                12=DEEP LATEROLOG
13=MICRORESISTIVITY   14=AZIMUTH            15=DIP                16=TEMPERATURE
17=INTEGRATED SONIC   18=CALIPER            19=                   20=
21=PETRA SS           22=PETRA LS           23=PETRA DOL          24=PETRA SH
25=PETRA AN           26=PETRA HL           27=PETRA CL           28=PETRA POR
29=PETRA 2POR         30=PHIRA              31=SX0                32=SW
33=K                  34=DI                 35=RT                 36=RX0
37=RWA                38=M                  39=N                  40=P
41=ARCHIE M           42=SYNTH SEISM        43=MODEL SONIC        44=MODEL INT SONIC
45=                   46=                   47=                   48=
49=                   50=ALPHA              51=BETA               52=GAMMA
53=DELTA              54=EPSILON            55=OMEGA
ENTER LOG DESIRED - 02 TO 55
37
TOTAL INTERVAL AVAILABLE  2448.00 TO 2566.00
DO YOU WANT THE TOTAL INTERVAL - YES OR NO
NO
ENTER MINIMUM DEPTH DESIRED
2480.
ENTER MAXIMUM DEPTH DESIRED
2540.
ENTER MINIMUM VALUE OF HISTOGRAM
0.
ENTER MAXIMUM VALUE OF HISTOGRAM
0.5
ENTER INCREMENT VALUE OF HISTOGRAM
0.05
```

38

```
HISTOGRAM OF VALUES FOR 37-RWA
     WELL NAME:  CITIES SERVICE BECK A-1      SW-SE-SE 14-5S-12E
      LOCATION:  NEMAHA CO., KANSAS
          DATE:  JAN. 11, 1978
      INTERVAL:   2480.00 TO  2540.00

CLASS  MINIMUM       MAXIMUM  FREQUENCY
       VALUE         VALUE
    1     0.00 TO   0.05        1     X
    2     0.05 TO   0.10        8     XXXXXXXX
    3     0.10 TO   0.15       10     XXXXXXXXXX
    4     0.15 TO   0.20        7     XXXXXXX
    5     0.20 TO   0.25       11     XXXXXXXXXXX
    6     0.25 TO   0.30        8     XXXXXXXX
    7     0.30 TO   0.35        5     XXXXX
    8     0.35 TO   0.40        2     XX
    9     0.40 TO   0.45        3     XXX
   10     0.45 TO   0.50        2     XX

DO YOU WANT A HISTOGRAM PRODUCED - YES OR NO
NO
```

39

gopher menu

```
INPUT NAME OF DESIRED OPTION
KOBRA
```

40

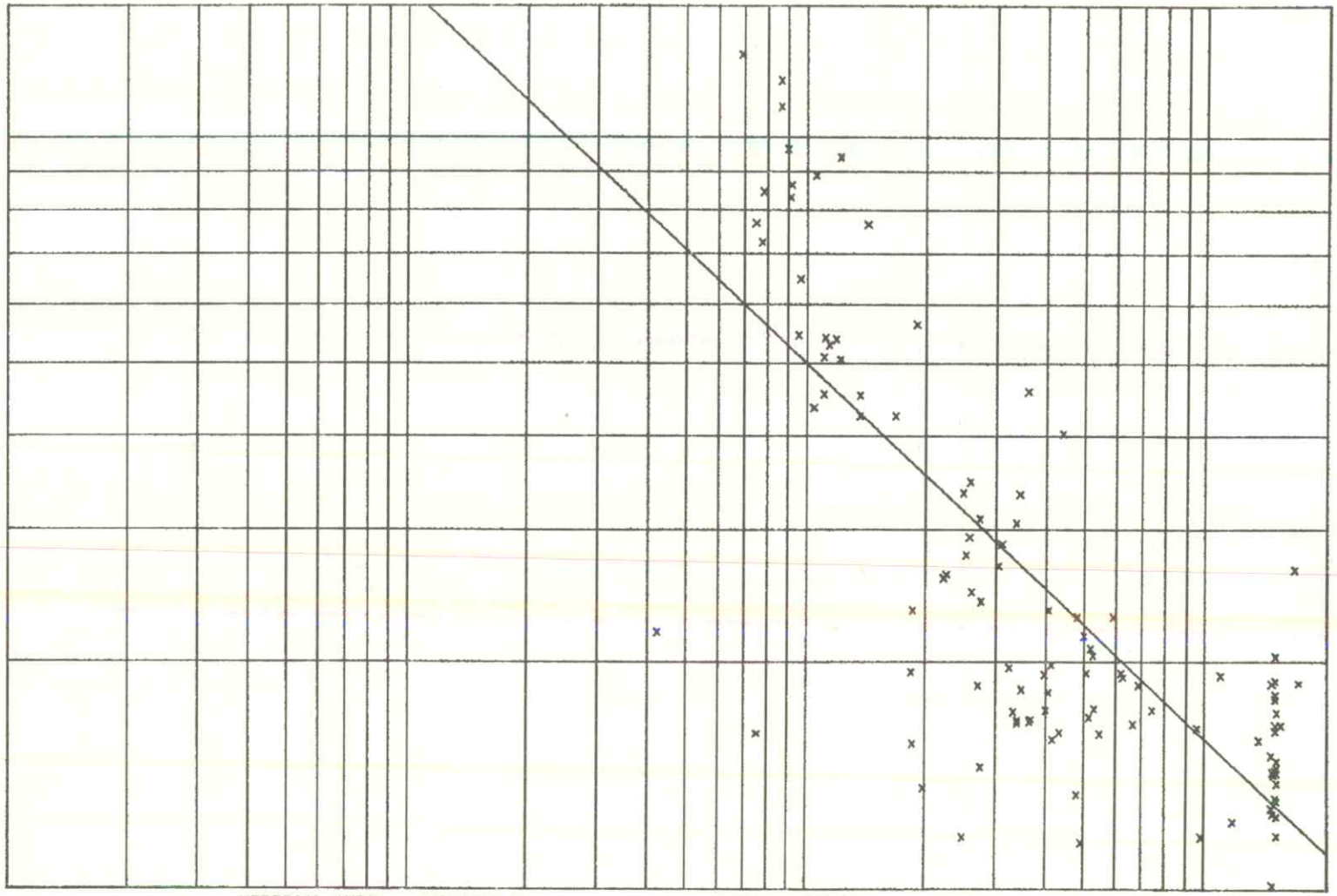
```
KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    RPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
RPPLOT
RPPLOT OPTION SELECTED
THE FOLLOWING RESISTIVITY LOGS ARE AVAILABLE
    09=LL8
    10=ILM
    11=ILD
    35=RT
    36=RX0
SELECT TRACK NUMBER OF RESISTIVITY TO BE USED
35
DO YOU HAVE A PRIORI WATER LINE - YES OR NO
YES
SPECIFY RW
.25
SPECIFY RW TEMPERATURE (DEG F)

SPECIFY ARCHIE EQUATION CONSTANTS - A,M
1.
2.
RESISTIVITY RANGE     42.40   2038.60
POROSITY RANGE         0.33     12.92
SPECIFY EXTREMES FOR PLOT
1.
2000.
1.
15.
```

RESISTIVITY-POROSITY CROSSPLOT
WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
DEPTH INTERVAL: 2448.00 2566.00
RESISTIVITY LOG: 35-RT
FORMATION TEMPERATURE: 91.6 DEG F
RW= 0.250 A= 1.00 M= 2.00



VERTICAL AXIS: POROSITY % 1.00 15.00
HORIZONTAL AXIS: RESISTIVITY OHM-M 1.00 2000.00

```
KOBRA RESERVOIR ANALYSIS MODULE

     DEPTH ----- SELECT DESIRED DEPTH INTERVAL
     TORNADO --- SMALL SLAM INVASION PARAMETERS
     RPPLOT ---- PICKETT PLOT
     SPRW ------ WATER RESISTIVITY FROM SP
     RWA ------- RECONNAISSANCE WATER RESISTIVITY
     PHIRA ----- WATER-FILLED POROSITY
     POREG ----- PORE GEOMETRY
     CLSAT ----- WATER SATURATION (SHALE-FREE)
     SHSAT ----- WATER SATURATION (SHALY MODELS)
     WASP ------ WAXMAN-SMITS MODEL
     PERM ------ PERMEABILITY INDEX
     CHERNOFF -- PHI.SW.SH.VSH.K FACES
     STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
DEPTH
TOTAL INTERVAL AVAILABLE  2448.00 TO  2566.00
SELECTED INTERVAL 2448.00 TO  2566.00
DO YOU WANT THE SELECTED INTERVAL - YES OR NO
NO
ENTER MINIMUM DEPTH DESIRED
2448.
ENTER MAXIMUM DEPTH DESIRED
2500.
KOBRA RESERVOIR ANALYSIS MODULE

     DEPTH ----- SELECT DESIRED DEPTH INTERVAL
     TORNADO --- SMALL SLAM INVASION PARAMETERS
     RPPLOT ---- PICKETT PLOT
     SPRW ------ WATER RESISTIVITY FROM SP
     RWA ------- RECONNAISSANCE WATER RESISTIVITY
     PHIRA ----- WATER-FILLED POROSITY
     POREG ----- PORE GEOMETRY
     CLSAT ----- WATER SATURATION (SHALE-FREE)
     SHSAT ----- WATER SATURATION (SHALY MODELS)
     WASP ------ WAXMAN-SMITS MODEL
     PERM ------ PERMEABILITY INDEX
     CHERNOFF -- PHI.SW.SH.VSH.K FACES
     STOP ------ KOBRA EXIT

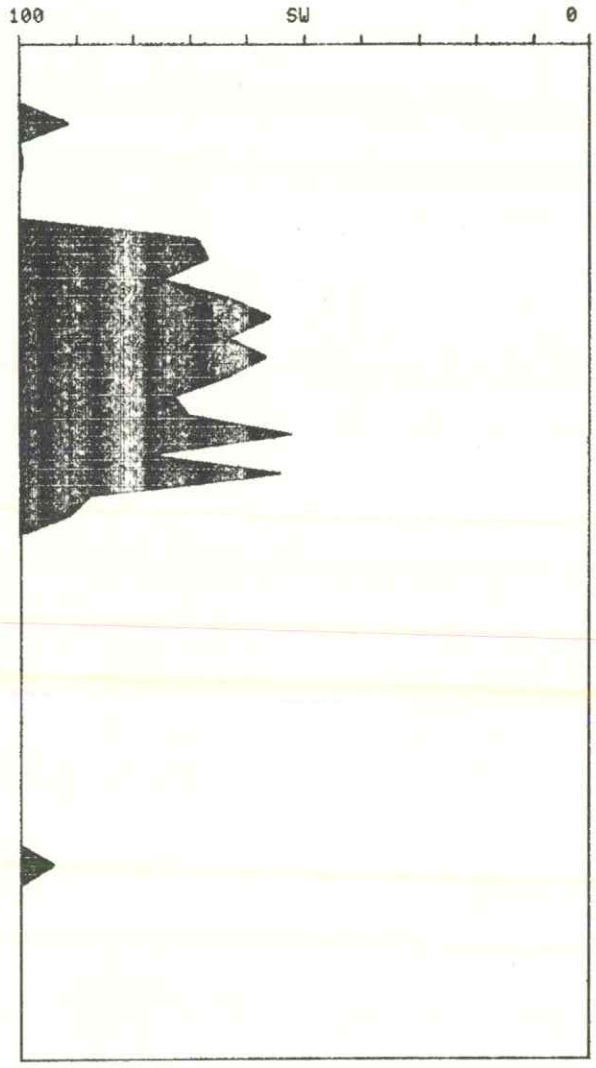
INPUT NAME OF DESIRED OPTION
CLSAT
CLSAT OPTION SELECTED
THE FOLLOWING RESISTIVITY LOGS ARE AVAILABLE
     09=LL8
     10=ILM
     11=ILD
     35=RT
     36=RX0
SELECT TRACK NUMBER OF RESISTIVITY TO BE USED
35
SPECIFY RW
0.34
SPECIFY RW TEMPERATURE (DEG F)

SPECIFY ARCHIE EQUATION CONSTANTS - A,M
1.
2.
SPECIFY SATURATION COEFFICIENT - N
2.
```

WATER SATURATION COMPUTATION (SHALE-FREE)
WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
DEPTH INTERVAL: 2448.00 2500.00
RESISTIVITY LOG: 35=RT
FORMATION TEMPERATURE: 91.1 DEG F
RW: 0.340
A= 1.00 M= 2.00 N= 2.00
SW = WATER SATURATION

DEPTH	VSH	PHI	R	C	SW
2448.0	0.069	0.021	42.4	0.089	4.082
2449.0	0.097	0.016	75.2	0.067	4.176
2450.0	0.000	0.052	114.4	0.054	1.031
2451.0	0.135	0.043	104.5	0.057	1.306
2452.0	0.073	0.064	96.6	0.059	0.915
2453.0	0.054	0.054	111.6	0.055	1.020
2454.0	0.041	0.053	119.1	0.053	0.993
2455.0	0.041	0.045	136.7	0.049	1.101
2456.0	0.034	0.023	185.3	0.042	1.822
2457.0	0.000	0.042	167.4	0.045	1.059
2458.0	0.000	0.040	440.4	0.027	0.689
2459.0	0.000	0.045	360.2	0.030	0.671
2460.0	0.000	0.056	189.4	0.042	0.751
2461.0	0.000	0.076	142.9	0.048	0.636
2462.0	0.000	0.094	121.7	0.052	0.561
2463.0	0.012	0.089	106.0	0.056	0.635
2464.0	0.016	0.109	86.2	0.062	0.571
2465.0	0.028	0.096	89.7	0.061	0.636
2466.0	0.050	0.083	91.2	0.061	0.731
2467.0	0.079	0.086	91.4	0.060	0.704
2468.0	0.067	0.119	86.2	0.062	0.526
2469.0	0.115	0.084	78.0	0.066	0.779
2470.0	0.062	0.129	68.5	0.070	0.545
2471.0	0.064	0.076	74.6	0.067	0.877
2472.0	0.053	0.072	77.4	0.066	0.911
2473.0	0.067	0.054	95.3	0.059	1.095
2474.0	0.081	0.050	110.5	0.055	1.090
2475.0	0.086	0.045	110.5	0.055	1.218
2476.0	0.061	0.050	121.4	0.052	1.045
2477.0	0.064	0.042	136.8	0.049	1.173
2478.0	0.110	0.019	184.9	0.042	2.205
2479.0	0.046	0.024	275.5	0.035	1.462
2480.0	0.004	0.016	434.0	0.027	1.736
2481.0	-1.000	0.008	649.6	-1.000	1.000
2482.0	-1.000	0.008	501.4	-1.000	1.000
2483.0	-1.000	0.011	491.8	0.026	2.285
2484.0	-1.000	0.016	366.9	0.030	1.813
2485.0	-1.000	0.018	346.5	0.031	1.702
2486.0	-1.000	0.016	339.5	0.031	1.905
2487.0	-1.000	0.017	331.1	0.032	1.867
2488.0	-1.000	0.026	305.0	0.033	1.241
2489.0	-1.000	0.016	340.3	0.031	1.882
2490.0	-1.000	0.033	343.5	0.031	0.941
2491.0	-1.000	0.028	310.3	0.033	1.150
2492.0	-1.000	0.030	272.9	0.035	1.138
2493.0	-1.000	0.034	257.5	0.036	1.048
2494.0	-1.000	0.033	248.2	0.037	1.100
2495.0	-1.000	0.029	257.1	0.036	1.237
2496.0	-1.000	0.018	270.9	0.035	1.904
2497.0	-1.000	0.014	273.9	0.035	2.428
2498.0	-1.000	0.027	251.4	0.036	1.324
2499.0	-1.000	0.030	337.1	0.031	1.039
2500.0	-1.000	0.019	324.1	0.032	1.643

DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES



(44)

```
KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    RPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
STOP
```

(45)

gopher menu

```
INPUT NAME OF DESIRED OPTION
ABACUS
```

(46)

```
ABACUS - AVAILABLE OPTIONS
    DEPTH ------- SELECT DESIRED DEPTH INTERVAL
    SCALE ------- MODIFY ONE WELL LOG
    MULTIPLEX --- MODIFY TWO WELL LOGS
    RANGE ------- ELIMINATE DATA OUTSIDE LIMITS
    SUM --------- COMPUTE STATISTICS
    STOP -------- FINISHED
SCALE
SCALE OPTION - AVAILABLE LOGS
 01=DEPTH              02=SP                 03=GR
 04=DENSITY            05=SONIC              06=GNT/SNP %
 07=CNL %              08=NEUTRON COUNT      09=LL8
 10=ILM                11=ILD                12=DEEP LATEROLOG
 13=MICRORESISTIVITY   14=AZIMUTH            15=DIP
 16=TEMPERATURE        17=INTEGRATED SONIC   18=CALIPER
 19=                   20=                   21=PETRA SS
 22=PETRA LS           23=PETRA DOL          24=PETRA SH
 25=PETRA AN           26=PETRA HL           27=PETRA CL
 28=PETRA POR          29=PETRA 2POR         30=PHIRA
 31=SX0                32=SW                 33=K
 34=DI                 35=RT                 36=RX0
 37=RWA                38=M                  39=N
 40=P                  41=ARCHIE M           42=SYNTH SEISM
 43=MODEL SONIC        44=MODEL INT SONIC    45=
 46=                   47=                   48=
 49=                   50=ALPHA              51=BETA
 52=GAMMA              53=DELTA              54=EPSILON
 55=OMEGA
AVAILABLE TRANSFORMATIONS
    1 --- NEW = A + B*OLD + C*(OLD**2)
    2 --- NEW = A + B*ALOG10(OLD) + C*LN(OLD)
    3 --- NEW = A + B*(10**OLD) + C*(E**OLD)
    4 --- NEW = A + 10**(B+C*OLD)
    5 --- NEW = A + B*(OLD**C)
INPUT DESIRED TRANSFORMATION
1
ENTER INPUT TRACK NUMBER - 01 TO 55
01
ENTER OUTPUT TRACK NUMBER - 02 TO 55
49
ENTER CONSTANTS A,B,C ON SEPARATE LINES
-25.07
0.01
0.
```

47

```
ABACUS - AVAILABLE OPTIONS
    DEPTH ------- SELECT DESIRED DEPTH INTERVAL
    SCALE ------- MODIFY ONE WELL LOG
    MULTIPLEX --- MODIFY TWO WELL LOGS
    RANGE ------- ELIMINATE DATA OUTSIDE LIMITS
    SUM --------- COMPUTE STATISTICS
    STOP -------- FINISHED
STOP
```

48

gopher menu

```
INPUT NAME OF DESIRED OPTION
MERLIN
```

49

```
MERLIN NUMERICAL PROCESSING MODULE
    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    FILTER ---- CONVOLVE WITH USER-DESIGNED FILTER
    REGRESS --- SIMPLE POLYNOMIAL OR MULTIPLE LINEAR
                REGRESSION
    PMA ------- REDUCED MAJOR AXIS
    PCA ------- PRINCIPAL COMPONENT ANALYSIS
    DISCRIM --- DISCRIMINANT FUNCTION ANALYSIS
    FOURIER --- SINGLE CHANNEL FOURIER ANALYSIS
    COSPECT --- MULTI-CHANNEL COSPECTRAL ANALYSIS
    STOP ------ EXIT FROM MERLIN
REGRESS
REGRESSION ANALYSIS - LOGS AVAILABLE
01=DEPTH              02=SP                 03=GR
04=DENSITY            05=SONIC              06=GNT/SNP %
07=CNL %              08=NEUTRON COUNT      09=LL8
10=ILM                11=ILD                12=DEEP LATEROLOG
13=MICRORESISTIVITY   14=AZIMUTH            15=DIP
16=TEMPERATURE        17=INTEGRATED SONIC   18=CALIPER
19=                   20=                   21=PETRA SS
22=PETRA LS           23=PETRA DOL          24=PETRA SH
25=PETRA AN           26=PETRA HL           27=PETRA CL
28=PETRA POR          29=PETRA 2POR         30=PHIRA
31=SX0                32=SW                 33=K
34=DI                 35=RT                 36=RX0
37=RWA                38=M                  39=N
40=P                  41=ARCHIE M           42=SYNTH SEISM
43=MODEL SONIC        44=MODEL INT SONIC    45=
46=                   47=                   48=
49=                   50=ALPHA              51=BETA
52=GAMMA              53=DELTA              54=EPSILON
55=OMEGA
ENTER DEPENDENT LOG - 01 TO 55
21
ENTER INDEPENDENT LOGS - 01 TO 55
SIMPLE REGRESSION UP TO ORDER 4 FOR SINGLE LOG
MULTIPLE REGRESSION FOR 2 TO 10 LOGS
ENTER 0 WHEN FINISHED
49
0
WILL COMPUTED REGRESSION VALUES BE
STORED - YES OR NO
YES
```

(50)

```
REGRESSION ANALYSIS
    WELL NAME : CITIES SERVICE BECK A-1      SW-SE-SE 14-5S-12E
    LOCATION  : NEMAHA CO., KANSAS
    DATE      : JAN. 11, 1978
    DEPTH INTERVAL: 2448.00 TO  2566.00
    DEPENDENT VARIABLE    : 21=PETRA SS
    INDEPENDENT VARIABLE  : 49=

SIMPLE REGRESSION

ORDER OF REGRESSION                    0        1        2        3        4
REGRESSION COEFFICIENT A     :     0.313    0.313    0.374    0.374    0.465
REGRESSION COEFFICIENT X     :              -0.121   -0.121   -0.407   -0.407
REGRESSION COEFFICIENT X**2  :                       -0.517   -0.517   -3.094
REGRESSION COEFFICIENT X**3  :                                 1.346    1.345
REGRESSION COEFFICIENT X**4  :                                          8.495

NUMBER OF SAMPLES                    119      119      119      119      119
SUM OF SQUARES TOTAL                 3.5      3.5      3.5      3.5      3.5
SUM OF SQUARES REGRESSION            0.0      0.2      0.5      0.7      1.5
SUM OF SQUARES DEVIATION             3.5      3.3      3.0      2.8      2.0
GOODNESS OF FIT                    0.000    0.058    0.157    0.218    0.436
CORRELATION COEFFICIENT            0.000    0.241    0.396    0.466    0.660
```

(51)

```
MERLIN NUMERICAL PROCESSING MODULE
    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    FILTER ---- CONVOLVE WITH USER-DESIGNED FILTER
    REGRESS --- SIMPLE POLYNOMIAL OR MULTIPLE LINEAR
                REGRESSION
    RMA ------- REDUCED MAJOR AXIS
    PCA ------- PRINCIPAL COMPONENT ANALYSIS
    DISCRIM --- DISCRIMINANT FUNCTION ANALYSIS
    FOURIER --- SINGLE CHANNEL FOURIER ANALYSIS
    COSPECT --- MULTI-CHANNEL COSPECTRAL ANALYSIS
    STOP ------ EXIT FROM MERLIN
DEPTH
TOTAL INTERVAL AVAILABLE  2448.00 TO  2566.00
SELECTED INTERVAL 2448.00 TO  2566.00
DO YOU WANT THE SELECTED INTERVAL - YES OR NO
NO
ENTER MINIMUM DEPTH DESIRED
2480.
ENTER MAXIMUM DEPTH DESIRED
2540.
MERLIN NUMERICAL PROCESSING MODULE
    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    FILTER ---- CONVOLVE WITH USER-DESIGNED FILTER
    REGRESS --- SIMPLE POLYNOMIAL OR MULTIPLE LINEAR
                REGRESSION
    RMA ------- REDUCED MAJOR AXIS
    PCA ------- PRINCIPAL COMPONENT ANALYSIS
    DISCRIM --- DISCRIMINANT FUNCTION ANALYSIS
    FOURIER --- SINGLE CHANNEL FOURIER ANALYSIS
    COSPECT --- MULTI-CHANNEL COSPECTRAL ANALYSIS
    STOP ------ EXIT FROM MERLIN
PCA
PRINCIPAL COMPONENT ANALYSIS
FOR EACH LOG DESIRED, INPUT ITS TWO DIGIT
TRACK NUMBER - A MAXIMUM OF 10 LOGS ARE ALLOWED
    ENTER 0 WHEN FINISHED
    01=DEPTH                02=SP                   03=GR
    04=DENSITY              05=SONIC                06=GNT/SNP %
    07=CNL %                08=NEUTRON COUNT        09=LL8
    10=ILM                  11=ILD                  12=DEEP LATEROLOG
    13=MICRORESISTIVITY     14=AZIMUTH              15=DIP
    16=TEMPERATURE          17=INTEGRATED SONIC     18=CALIPER
    19=                     20=                     21=PETRA SS
    22=PETRA LS             23=PETRA DOL            24=PETRA SH
    25=PETRA AN             26=PETRA HL             27=PETRA CL
    28=PETRA POR            29=PETRA 2POR           30=PHIRA
    31=SX0                  32=SW                   33=K
    34=DI                   35=RT                   36=RX0
    37=RWA                  38=M                    39=N
    40=P                    41=ARCHIE M             42=SYNTH SEISM
    43=MODEL SONIC          44=MODEL INT SONIC      45=
    46=                     47=                     48=
    49=                     50=ALPHA                51=BETA
    52=GAMMA                53=DELTA                54=EPSILON
    55=OMEGA
21
22
23
28
37
0
```

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
LOCATION : NEMAHA CO., KANSAS
DATE : JAN. 11, 1978
DEPTH : 2480.00 TO 2540.00
NUMBER OF OBSERVATIONS : 61
NUMBER OF DEFAULTS : 0

52

	21=PETRA	S22=PETRA	L23=PETRA	D28=PETRA	P37=RWA
AVERAGE	0.3678	0.3621	0.2509	0.0190	0.2528
VARIANCE	0.0314	0.1102	0.0276	0.0000	0.0376
DEVIATION	0.1774	0.3319	0.1663	0.0059	0.1941

VARIANCE-COVARIANCE MATRIX

	21=PETRA	S22=PETRA	L23=PETRA	D28=PETRA	P37=RWA
21=PETRA S	0.0314	-0.0567	0.0252	-0.0000	-0.0222
22=PETRA L	-0.0567	0.1102	-0.0531	-0.0002	0.0417
23=PETRA D	0.0252	-0.0531	0.0276	0.0002	-0.0197
28=PETRA P	-0.0000	-0.0002	0.0002	0.0000	0.0003
37=RWA	-0.0222	0.0417	-0.0197	0.0003	0.0376

	EIGENVALUE	PERCENT	EIGENVECTOR				
21=PETRA S	0.1831	88.4416	-0.3986	0.1010	-0.7167	-0.2765	0.4904
22=PETRA L	0.0196	9.4956	0.7702	-0.2789	-0.0177	-0.2980	0.4895
23=PETRA D	0.0042	2.0491	-0.3704	0.1562	0.6944	-0.3432	0.4880
28=PETRA P	0.0000	0.0126	-0.0009	0.0216	0.0400	0.8463	0.5306
37=RWA	0.0000	0.0008	0.3324	0.9418	-0.0445	-0.0210	-0.0007

CORRELATION MATRIX

	21=PETRA	S22=PETRA	L23=PETRA	D28=PETRA	P37=RWA
21=PETRA S	1.0000	-0.9631	0.8554	-0.0140	-0.6462
22=PETRA L	-0.9631	1.0000	-0.9629	-0.1328	0.6475
23=PETRA D	0.8554	-0.9629	1.0000	0.2446	-0.6128
28=PETRA P	-0.0140	-0.1328	0.2446	1.0000	0.2887
37=RWA	-0.6462	0.6475	-0.6128	0.2887	1.0000

	EIGENVALUE	PERCENT	EIGENVECTOR				
21=PETRA S	3.3692	67.3852	0.5186	-0.0272	0.4136	-0.6109	0.4311
22=PETRA L	1.2046	24.0937	-0.5368	-0.1020	-0.2233	-0.0333	0.8064
23=PETRA D	0.3284	6.5685	0.5166	0.2013	0.0177	0.7270	0.4043
28=PETRA P	0.0975	1.9516	0.0293	0.8842	-0.3837	-0.2642	0.0142
37=RWA	0.0000	0.0008	-0.4182	0.4079	0.7946	0.1647	0.0001

WILL PRINCIPAL COMPONENT SCORES BE
COMPUTED AND STORED - YES OR NO
YES
BASED ON COVARIANCE OR CORRELATION MATRIX
CORR
SCORES WILL BE STORED STARTING IN TRACK 50
NUMBER OF SCORES DESIRED - 1 TO 5
4

53

MERLIN NUMERICAL PROCESSING MODULE
DEPTH ----- SELECT DESIRED DEPTH INTERVAL
FILTER ---- CONVOLVE WITH USER-DESIGNED FILTER
REGRESS --- SIMPLE POLYNOMIAL OR MULTIPLE LINEAR
REGRESSION
RMA ------- REDUCED MAJOR AXIS
PCA ------- PRINCIPAL COMPONENT ANALYSIS
DISCRIM --- DISCRIMINANT FUNCTION ANALYSIS
FOURIER --- SINGLE CHANNEL FOURIER ANALYSIS
COSPECT --- MULTI-CHANNEL COSPECTRAL ANALYSIS
STOP ------ EXIT FROM MERLIN
STOP

54

gopher menu

INPUT NAME OF DESIRED OPTION
XYPETRA

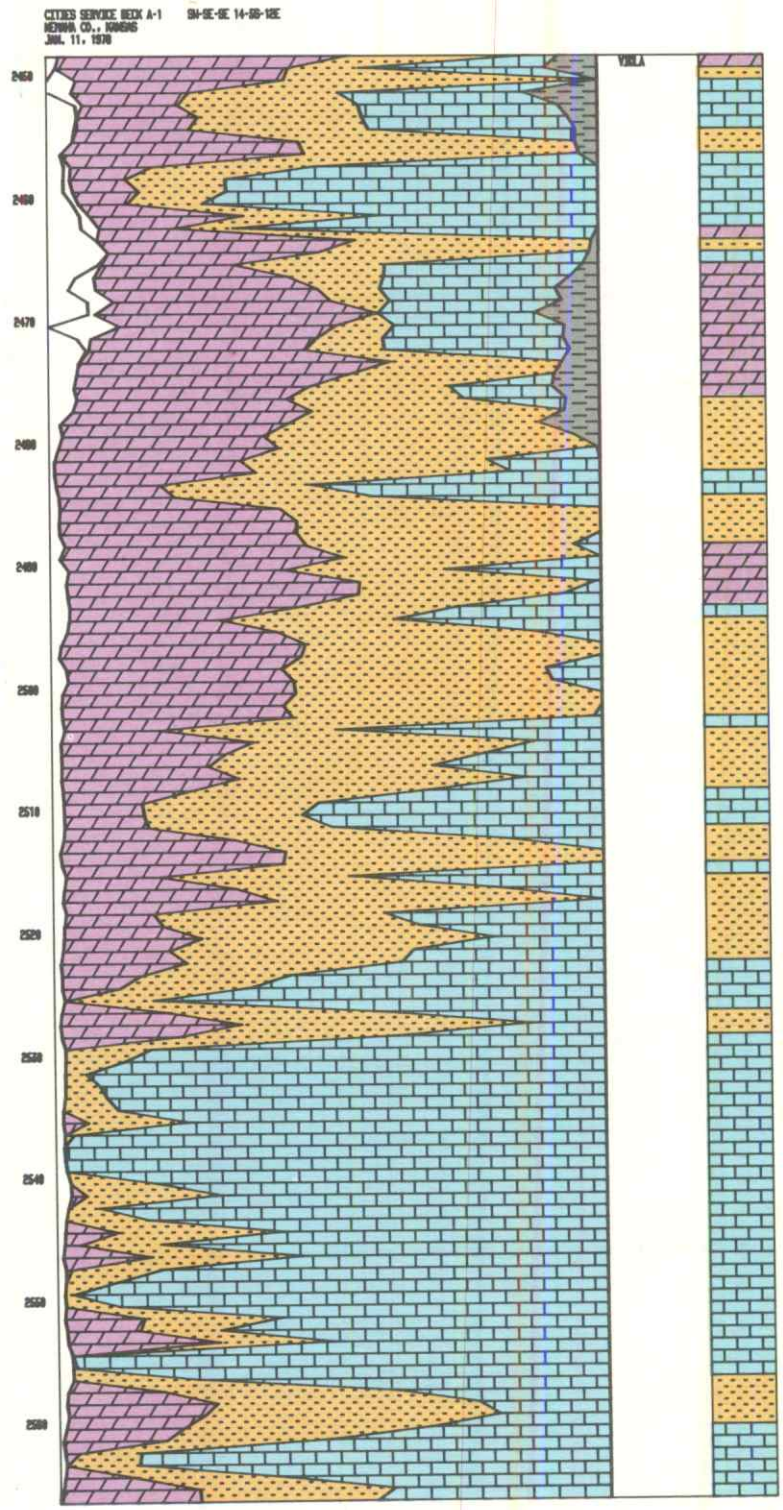
55

```
 PROGRAM PETRA: MINERALOGICAL/LITHOLOGICAL COMPONENT
    ESTIMATION FOR PETROPHYSICAL WELL LOGS
TOTAL INTERVAL AVAILABLE  2448.00 TO  2566.00
DO YOU WANT THE ENTIRE INTERVAL - YES OR NO
YES
SELECT PLOTTING OPTION
    1=POLYGON
    2=BLOCK
1
THE FOLLOWING COMPONENTS HAVE BEEN COMPUTED
    SS
    LS
    DOL
    SH
    POR
    2POR
NUMBER OF COMPONENTS - MAXIMUM OF 9
6
TYPE OF COMPONENTS DESIRED
    CAN USE SS,LS,DOL,SH,AN,HL,CL,POR,2POR
COMPONENT 1
POR
COMPONENT 2
2POR
COMPONENT 3
DOL
COMPONENT 4
SS
COMPONENT 5
LS
COMPONENT 6
SH
DO YOU WANT TO PLOT LITHOLOGIES - YES OR NO
YES
DO YOU WANT TO HAVE COLOR SHADING - YES OR NO
YES
SPECIFY DENSITY OF SHADING LINES
PER DEPTH UNIT
NORMAL DENSITY IS 08
ALLOWED DENSITY IS 01 TO 20
08
```

56

gopher menu

INPUT NAME OF DESIRED OPTION
BYE


CITIES SERVICE BEIX A-1
NEMAHA CO., KANSAS
JAN. 11, 1978
SW-SE-SE 14-5S-12E
YULA
2450
2460
2470
2480
2490
2500
2510
2520
2530
2540
2550
2560

CASE STUDY 3: "CLEAN" SANDSTONE

The St. Peter Sandstone is a Middle Ordovician sheet sand which can be traced from its outcrop in the Upper Mississippi Valley deep into the subsurface over large areas of the Midcontinent. The unit is markedly diachronous and is often known in Kansas as the "Simpson sand."

Quartz grains in the St. Peter are generally fine to medium in size, moderately well-sorted, sub-rounded to well-rounded, and are often frosted. The exceptional purity of the sandstone makes it suitable for glass manufacture in Arkansas, Missouri and Illinois (Giles, 1930). The sand is generally slightly cemented by carbonate or silica and is readily disaggregated.

The ultimate source of the detrital material was probably located in the Canadian Shield to the northeast (east in the Ordovician), which experienced severe tropical weathering in the early Middle Ordovician (Ross, 1976). Depositional environments have been variously ascribed to eolian, littoral and shallow marine models. However, recent studies on bed-form characteristics in the Wisconsin outcrop (Pryor and Amaral, 1971; Dott and Roshardt, 1972) and textural analysis (Amaral and Pryor, 1977) have favored a general interpretation of its origin as shallow marine sands. A shallow marine environment is also suggested for the Kansas subsurface equivalent, which commonly contains glauconite (Cole, 1975).

The Beck A-1 well (used for the preceding complex carbonate case study) penetrated a section of St. Peter Sandstone immediately above the Precambrian granite. Cuttings descriptions from the interval reported an excellent show of free oil in the uppermost part, but only minor staining in the main unit. A drill-stem test of the potential oil zone recovered 1000 feet of "sulphur water" with no indications of oil.

The case-study data are listed (Table 6) for an extended interval ranging from 2600-2700 feet depth, with the St. Peter Sandstone located between 2665-2700. Logs utilized are the spontaneous potential, gamma ray, density, sonic, CNL neutron, laterolog-8, medium and deep induction logs.

OUTPUT COMMENTARY

1 GOPHER menu. "COMMENT" prompt.

2 COMMENT option. The COMMENT track erased initially, and a caption for the St. Peter Sandstone entered at a position marking the top of the unit.

3 GOPHER menu. "PETRA" prompt.

4 PETRA option. Analysis restricted to the St. Peter Sandstone (2665-2700). Composition to be resolved in terms of porosity, quartz and shale, using density, sonic and neutron logs. The density and sonic default coefficients were found (coincidentally) to be acceptably representative values for shale in the section; however, the shale neutron coefficient was modified to 30 porosity units.

5 PETRA output. "Header" and graphic component key.

6 PETRA output. Summary of solution coefficients. The system is overdetermined and will be resolved by the least-squares algorithm. Information accepted as correct.

7 PETRA output. Graphic presentation of component proportions, comment track and values for all three diagnostics. A reasonably "clean sandstone" with minor shale content, punctuated by a 2-foot bed of shale (2673-74), which separates an "upper sandstone" from a "lower sandstone" unit. The error diagnostic values are generally acceptable as broadly consistent with data noise. However, the sum deviations show systematic effects which register "negative shale" proportions. The perturbations may be attributed to hydrocarbon effects, which are most pronounced in the upper unit (2665-72). The interpretation is fully consistent with the cuttings reports of oil-stainings.
Since the incorporation of oil as an additional component would only result in minor changes in porosity, quartz and shale estimates, a revised PETRA run is omitted in this case study. However, the reader is free to experiment with this option, in which case, oil should be entered as a secondary porosity

(2POR) component.

8 GOPHER menu. "STATISTICS" prompt.

9 STATISTICS option. Request for channel summaries for entire interval.

10 STATISTICS output. The data show a range of 46.25 millivolts, which is a provisional estimate of a static self-potential for the section.

11 STATISTICS option. Further STATISTICS summaries declined, but a histogram requested for SP values in the section.

12 STATISTICS output. SP histogram. The extreme modes suggest that -46 millivolts is a reasonable estimate for the SSP.
Further histograms declined.

13 GOPHER menu. "KOBRA" prompt.

14 KOBRA menu. "DEPTH" prompt. Depth range for reservoir analysis restricted to the St. Peter Sandstone (2665-2700). "SPRW" prompt. SSP and median depth entered.

15 SPRW output. The formation water resistivity is estimated by the option as 0.33 ohm-m at formation temperature. The computed salinity (total solids) is in reasonable agreement with analysis of the drill-stem test water sample which was reported to contain "chlorides 5000."

16 KOBRA menu. "POREG" prompt. Selection of the deep induction log, and specification of formation water resistivity as 0.33 ohm-m at formation temperature.

17 POREG output. Shale proportion, primary, secondary and total porosities, resistivity, apparent formation factor, cementation exponent, tortuosity and pore path ratio.
The upper unit (2665-72) is marked by cementation exponents consistently greater than two, which are contrasted with comparatively stable values of approximately 1.7 in the lower unit (2675-2700). The diagnosis of significant oil saturations in the upper unit, suggested by both cuttings and PETRA solution, is reinforced once again by this result.
A representative cementation exponent for the oil-free sandstone is therefore suggested as 1.7. This figure is generally equated with "slightly to moderately" cemented sandstones and matches cuttings descriptions of a "fine-grained, well sorted, friable" sandstone.

18 KOBRA menu. "RPPLOT" prompt. Pickett plot requested to crossplot resistivity and porosity values on a fully logarithmic graph. Deep induction log selected. Water line requested using SPRW estimate of formation water resisitvity and POREG estimate of cementation exponent. Selection of appropriate resistivity-porosity boundaries to plot.

19 RPPLOT output. "Pickett plot." The point distribution shows good concordance with the water line, and the upper sandstone zones are readily contrasted with those from the lower unit. Zones falling below the water line are generally associated with minor shale contents diagnosed by the PETRA solution.

20 KOBRA menu. "RWA" prompt. Selection of deep induction log.

21 RWA output. Listing of shale proportion, primary, secondary and total porosity, resistivity and reconnaissance water resistivity.
In yet another check, the R_{wa} estimates indicate that the estimate of formation water resistivity from the spontaneous potential log is a reasonable figure. Once again, the upper unit is strongly contrasted with the lower sandstone unit, while the "shaly" horizons are also discriminated to some degree.

22 KOBRA menu. "CLSAT" prompt. Selection of deep induction log. Specification of formation water resistivity, Archie equation constants, saturation exponent.

23 CLSAT output. Listing of shale proportion, total porosity, resistivity, porosity-water saturation product, water saturation. Graphic presentation of water/hydrocarbon saturation.

This analysis option ignores any conductivity contribution of shales, which are neglected as minor. The result indicates significant oil saturations in the upper unit and minor saturations in the base of the lower unit.

24 "PERM" prompt. Since the sandstone seems to be primarily water-wet, calculations were based on porosity alone. In the absence of porosity-permeability data from the St. Peter Sandstone, the default sandstone equation was employed.

25 PERM output. The permeability profile and its associated values should be viewed as a gross qualitative appreciation of permeability variation, which will deviate to the degree that the St. Peter Sandstone differs from a "typical" sandstone.

26 KOBRA menu. "STOP" prompt.

27 GOPHER menu. "BYE" prompt.

o-o-o

Table 6

CASE STUDY #3: "CLEAN" SANDSTONE DATA

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
LOCATION: NEMAHA CO., KANSAS
DATE: JAN. 11, 1978

CONSTANTS	VALUE
01=MINIMUM DEPTH	2600.00
02=MAXIMUM DEPTH	2700.00
03=INCREMENT	1.00
04=ELEVATION	1278.00
05=LATITUDE	-9999.00
06=LONGITUDE	-9999.00
07=RM	-9999.00
08=TRM	-9999.00
09=RMF	2.14
10=TRMF	58.00
11=RMC	-9999.00
12=TRMC	-9999.00
13=BHT	92.00
14=MEAN-T	54.00
15=T-GRADIENT	-9999.00
16=TIME-C-GR	-9999.00
17=TIME-C-N	-9999.00
18=LOG SPEED GR	-9999.00
19=LOG SPEED N	-9999.00
20=TD	2757.00

01=DEPTH	02=SP	03=GR	04=DENSITY	05=SONIC	07=CNL %	09=LL8	10=ILM	11=ILD
2600.000	46.750	15.944	2.632	54.912	2.3771737.920		570.158	285.755
2601.000	44.000	17.548	2.614	57.978	4.1641737.920		765.580	285.755
2602.000	43.000	15.537	2.637	61.157	5.6291770.220		575.440	158.488
2603.000	40.250	17.931	2.588	55.980	5.5701737.920		134.276	80.909
2604.000	37.750	19.760	2.516	58.142	8.305	89.536	52.480	60.255
2605.000	37.000	62.674	2.499	77.573	13.487	50.118	49.203	40.550
2606.000	36.250	63.142	2.601	76.121	18.670	164.435	28.575	27.542
2607.000	34.750	59.774	2.562	63.836	11.304	30.199	23.988	23.768
2608.000	35.000	102.778	2.563	66.786	10.857	33.728	19.769	20.323
2609.000	35.500	102.113	2.592	74.023	13.338	22.284	18.030	19.408
2610.000	34.750	90.845	2.607	76.858	13.085	35.974	21.877	19.952
2611.000	34.500	88.490	2.610	74.054	14.044	57.016	20.701	20.701
2612.000	34.500	94.368	2.566	66.965	9.908	21.478	22.490	22.490
2613.000	34.750	94.832	2.596	74.875	12.647	58.613	22.490	19.952
2614.000	33.750	83.797	2.573	71.283	11.299	29.648	17.538	19.952
2615.000	33.500	100.382	2.601	68.256	11.398	19.230	21.281	24.210
2616.000	34.750	44.042	2.681	80.446	15.445	89.536	32.210	27.797
2617.000	34.000	44.513	2.696	55.669	9.006	201.373	46.558	37.670
2618.000	34.000	40.477	2.668	56.139	4.880	136.772	67.920	55.975
2619.000	34.000	44.329	2.634	59.088	5.332	122.461	69.183	55.462
2620.000	34.000	56.516	2.626	59.219	6.539	71.779	49.659	43.651
2621.000	34.000	74.556	2.555	65.207	8.847	48.752	29.922	29.922
2622.000	33.500	75.023	2.449	65.676	15.043	50.118	27.797	19.054
2623.000	32.750	113.436	2.400	99.812	21.240	19.952	13.803	13.803
2624.000	32.750	113.899	2.479	100.276	27.437	12.705	10.280	10.764
2625.000	32.750	122.579	2.510	99.840	26.494	12.705	9.120	8.629
2626.000	32.750	125.741	2.523	94.339	26.225	13.427	7.655	7.726
2627.000	33.750	124.289	2.488	92.441	22.888	9.289	7.177	7.943
2628.000	34.250	143.429	2.507	100.670	23.365	9.908	8.241	8.871
2629.000	34.750	140.400	2.554	101.134	23.920	16.143	10.665	11.376
2630.000	36.500	113.073	2.591	84.950	17.874	27.039	18.030	17.538
2631.000	38.000	80.130	2.637	50.886	9.241	564.940	37.670	32.210
2632.000	39.750	25.716	2.661	51.357	1.1241116.810		73.113	58.613
2633.000	41.750	63.186	2.635	51.941	0.845	293.763	70.469	78.704
2634.000	41.750	63.656	2.606	58.146	1.499	66.680	81.657	87.096
2635.000	42.500	64.125	2.663	58.617	3.828	731.154	125.892	84.722
2636.000	42.750	18.848	2.686	50.995	2.2281737.920		218.775	111.686
2637.000	43.000	18.874	2.740	49.780	0.8691737.920		253.511	187.068
2638.000	44.000	15.867	2.695	50.477	0.7011770.220		544.514	251.186
2639.000	46.750	14.995	2.684	50.275	0.5451770.220		630.954	255.859
2640.000	50.000	16.034	2.692	51.308	0.3251737.920		597.051	291.070
2641.000	52.750	17.297	2.691	51.668	0.5101675.040		704.672	316.225
2642.000	54.250	19.233	2.690	52.814	0.6821599.480		642.673	313.332
2643.000	53.750	19.036	2.675	55.082	0.4361056.850		524.796	293.763
2644.000	50.500	17.603	2.659	56.339	0.309	666.800	461.318	263.026
2645.000	51.750	18.866	2.649	56.362	0.561	855.066	353.182	229.084
2646.000	52.250	23.608	2.677	55.935	1.033	353.182	244.343	210.863
2647.000	49.000	32.389	2.700	57.641	2.296	291.070	237.682	208.929
2648.000	48.500	44.310	2.681	57.581	3.624	390.838	285.755	224.906
2649.000	48.500	39.173	2.668	55.375	2.319	955.019	428.541	253.511
2650.000	47.750	32.692	2.672	53.196	1.2661541.780		478.629	270.394
2651.000	47.500	22.735	2.684	52.422	0.802	731.154	337.291	263.026
2652.000	47.750	25.230	2.709	53.041	1.293	293.763	316.225	246.603
2653.000	47.000	25.482	2.716	53.669	1.995	343.560	316.225	229.084
2654.000	48.000	22.819	2.752	52.934	2.151	630.954	405.515	224.906
2655.000	48.250	24.862	2.776	51.291	1.9211056.850		340.414	233.345
2656.000	47.750	23.695	2.788	50.575	2.909	452.898	380.185	218.775
2657.000	48.250	23.694	2.771	50.708	4.072	737.898	319.152	177.009
2658.000	49.000	25.184	2.761	50.118	4.556	390.838	188.800	130.616
2659.000	49.750	31.091	2.803	51.755	5.494	173.780	122.461	105.681
2660.000	50.500	33.068	2.793	54.164	6.832	130.616	109.647	93.755
2661.000	53.500	32.222	2.793	55.511	7.853	151.356	105.681	87.902
2662.000	54.250	32.442	2.767	53.665	7.442	152.755	115.877	89.536
2663.000	56.500	29.272	2.767	52.734	6.351	188.800	141.906	94.623
2664.000	61.500	24.003	2.724	51.938	4.621	229.084	175.389	90.365
2665.000	65.500	21.238	2.629	48.371	2.891	895.335	136.772	67.920
2666.000	66.750	13.422	2.514	54.025	2.512	195.882	48.752	46.558
2667.000	68.000	12.590	2.442	58.958	5.034	61.944	46.558	34.673
2668.000	66.750	13.738	2.406	63.951	7.556	56.493	29.107	27.797
2669.000	62.500	18.471	2.433	65.720	8.364	57.544	26.061	24.888
2670.000	55.000	36.713	2.384	68.806	9.194	34.355	25.822	24.210
2671.000	48.000	63.102	2.356	76.495	13.879	32.210	26.061	20.511
2672.000	43.500	88.165	2.351	85.684	18.893	37.670	18.365	15.417
2673.000	40.500	110.692	2.442	91.991	20.185	12.473	11.912	12.359
2674.000	49.000	133.219	2.474	93.183	23.908	9.908	10.375	10.000
2675.000	63.000	110.958	2.409	86.382	20.921	14.190	8.871	8.550
2676.000	69.000	63.064	2.353	83.059	18.926	13.877	8.472	8.317
2677.000	72.500	38.963	2.399	81.662	15.020	13.803	8.629	8.472
2678.000	75.000	30.972	2.441	78.614	13.094	15.848	8.953	8.629
2679.000	77.000	24.135	2.409	74.125	11.876	14.190	9.289	8.953
2680.000	78.500	20.796	2.449	72.635	11.806	17.060	10.000	8.953
2681.000	79.000	19.920	2.399	71.469	10.882	18.535	8.871	8.472
2682.000	78.750	19.833	2.383	70.046	10.349	13.931	8.790	7.943
2683.000	77.750	20.523	2.407	72.725	12.793	12.359	7.447	7.311
2684.000	77.750	21.412	2.341	74.466	13.826	11.271	7.046	6.792
2685.000	77.750	22.606	2.325	75.259	14.932	11.481	6.668	6.309
2686.000	78.750	22.233	2.343	74.501	14.223	10.568	6.194	5.861
2687.000	78.500	22.413	2.304	75.046	15.559	8.953	5.546	5.495
2688.000	77.750	26.062	2.292	78.247	17.874	8.241	5.345	5.152
2689.000	78.250	31.303	2.319	81.486	19.480	8.550	5.152	5.058
2690.000	77.750	33.369	2.282	82.941	19.875	8.165	5.152	5.058
2691.000	78.500	37.956	2.286	83.161	20.248	9.550	5.345	5.105
2692.000	78.000	37.493	2.274	82.030	18.381	10.185	5.345	5.296
2693.000	75.000	39.489	2.285	79.886	17.246	8.871	5.495	5.495
2694.000	72.500	47.361	2.328	80.297	17.570	8.317	5.915	5.861
2695.000	73.000	56.525	2.299	84.423	19.054	9.550	6.367	6.309
2696.000	74.000	63.621	2.311	84.744	19.109	9.817	7.177	6.792
2697.000	73.500	71.751	2.318	82.830	19.063	14.723	7.177	7.112
2698.000	69.000	87.872	2.280	79.715	17.314	11.481	7.177	7.726
2699.000	57.500	199.501	2.355	80.685	18.855	11.168	8.241	8.790
2700.000	44.500	199.956	2.434	84.295	18.820	13.304	10.185	10.000

(1)

gopher menu

```
INPUT NAME OF DESIRED OPTION
COMMENT
```

---

(2)

```
COMMENT - AVAILABLE OPTIONS
    BLANK ----- INITIALIZE ALL COMMENTS TO BLANKS
    LIST ------ LIST COMMENTS ON AN INTERVAL
    INSERT ---- ADD COMMENTS TO AN INTERVAL
    DELETE ---- DELETE COMMENTS FROM AN INTERVAL
    STOP ------ FINISHED
BLANK
COMMENT - AVAILABLE OPTIONS
    BLANK ----- INITIALIZE ALL COMMENTS TO BLANKS
    LIST ------ LIST COMMENTS ON AN INTERVAL
    INSERT ---- ADD COMMENTS TO AN INTERVAL
    DELETE ---- DELETE COMMENTS FROM AN INTERVAL
    STOP ------ FINISHED
INSERT
COMMENTS MAY BE A MAXIMUM OF 10 CHARACTERS
ENTER STARTING DEPTH - ENTER 0 IF FINISHED
2665.
DEPTH 2665.00 - ENTER RETURN IF FINISHED
----------
DEPTH 2666.00 - ENTER RETURN IF FINISHED
ST. PETER
DEPTH 2667.00 - ENTER RETURN IF FINISHED
 SANDSTONE
DEPTH 2668.00 - ENTER RETURN IF FINISHED

COMMENTS MAY BE A MAXIMUM OF 10 CHARACTERS
ENTER STARTING DEPTH - ENTER 0 IF FINISHED
0
COMMENT - AVAILABLE OPTIONS
    BLANK ----- INITIALIZE ALL COMMENTS TO BLANKS
    LIST ------ LIST COMMENTS ON AN INTERVAL
    INSERT ---- ADD COMMENTS TO AN INTERVAL
    DELETE ---- DELETE COMMENTS FROM AN INTERVAL
    STOP ------ FINISHED
STOP
```

gopher menu

(3)

```
INPUT NAME OF DESIRED OPTION
PETRA
```

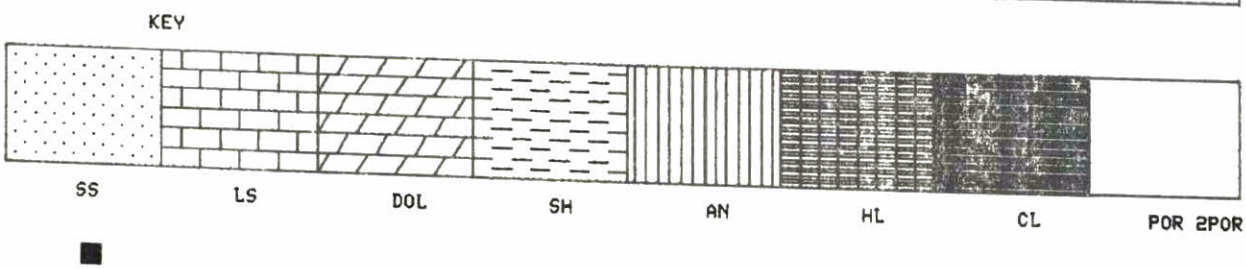
---

(4)

```
PROGRAM PETRA: MINERALOGICAL/LITHOLOGICAL COMPONENT
    ESTIMATION FOR PETROPHYSICAL WELL LOGS
TOTAL INTERVAL AVAILABLE  2600.00 TO  2700.00
DO YOU WANT THE ENTIRE INTERVAL - YES OR NO
NO
TOP OF INTERVAL (FEET)
2665.
BOTTOM OF INTERVAL (FEET)
2700.
SELECT DESIRED CALCULATION/PLOTTING
     1=PLOT EXISTING VALUES
     2=CALCULATE AND PLOT NEW VALUES
     3=CALCULATE NEW VALUES
     4=APPLY INVERSE SHARPENING FILTER
2
SELECT PLOTTING OPTION
     1=POLYGON
     2=BLOCK
1
THE FOLLOWING WELL LOGS ARE AVAILABLE
     SP
     GAMMA
     DENSITY
     SONIC
     NEUTRON
NUMBER OF LOGS - MAXIMUM OF 5
3
NUMBER OF COMPONENTS - MAXIMUM OF 9
3
TYPE OF LOGS LISTED BY INPUT ORDER
     CAN USE DENSITY,NEUTRON,SONIC,GAMMA,SP
LOG 1
DEN
LOG 2
SON
LOG 3
NEU
TYPE OF COMPONENTS DESIRED
     CAN USE SS,LS,DOL,SH,AN,HL,CL,POR,2POR
COMPONENT 1
POR
COMPONENT 2
SS
COMPONENT 3
SH
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
LIST
                POR      SS       SH
DENSITY        1.00    2.65     2.50
SONIC        189.00   55.50   100.00
NEUTRON      100.00   -5.00    40.00
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
NEU
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
SH
ENTER NEW COEFFICIENT VALUE
30.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
LIST
                POR      SS       SH
DENSITY        1.00    2.65     2.50
SONIC        189.00   55.50   100.00
NEUTRON      100.00   -5.00    30.00
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
DONE
INPUT ANY MODIFICATIONS TO COMPONENT KEY
```

5

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
LOCATION: NEMAHA CO., KANSAS JAN. 11, 1978
INTERVAL: 2665.00 TO 2700.00 BY 1.00
LOGS: DENSITY SONIC NEUTRON
COMPONENTS: POR SS SH



6

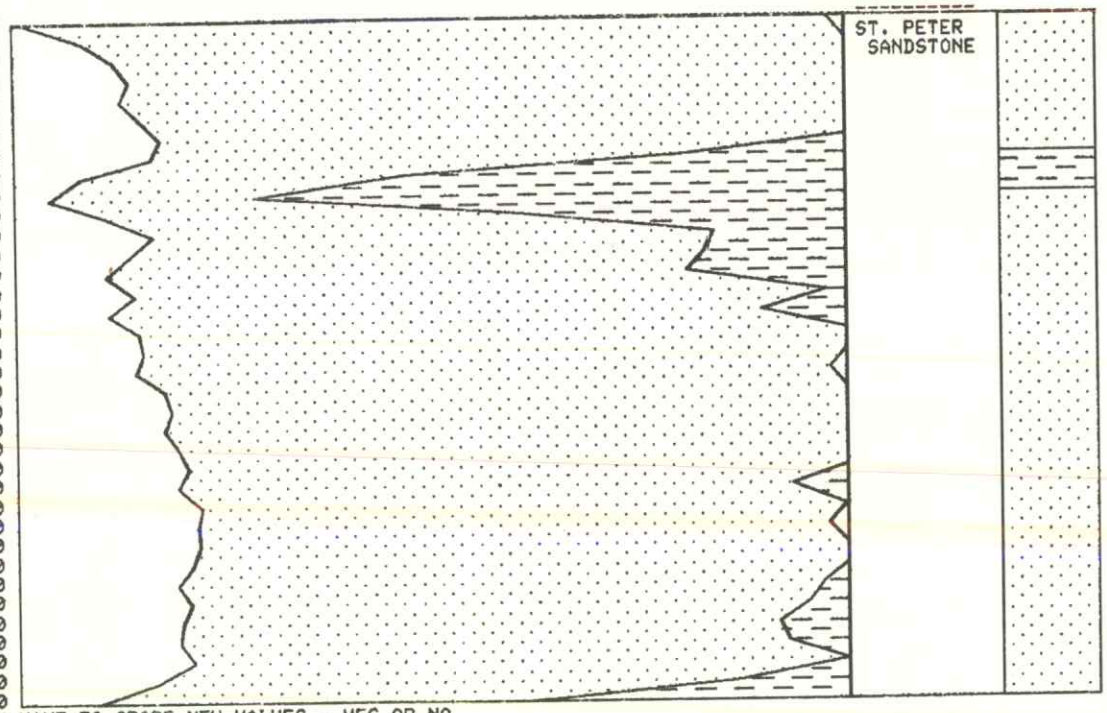
INPUT COEFFICIENTS:

	POR	SS	SH
DENSITY	1.00	2.65	2.50
SONIC	189.00	55.50	100.00
NEUTRON	100.00	-5.00	30.00

EQUATIONS EXCEED UNKNOWNS N+1>M

SOLUTION CALCULATED BY LEAST SQUARES
IS THE ABOVE INFORMATION CORRECT - YES OR NO
YES

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E



PROP VAR	SUM DEV	ERROR
0.09	0.00	4.24
0.22	8.98	2.73
0.31	9.07	2.30
0.35	7.30	1.86
0.33	4.80	1.67
0.38	5.16	1.17
0.43	1.76	0.74
0.78	0.00	0.05
0.83	0.00	1.10
0.64	0.00	0.23
0.87	0.00	0.51
0.73	0.00	0.71
0.70	0.00	0.17
0.69	0.00	0.02
0.42	0.00	0.70
0.53	0.00	1.05
0.37	2.72	1.04
0.38	4.32	1.23
0.42	0.00	1.33
0.43	3.51	1.23
0.45	3.78	1.38
0.43	3.49	1.34
0.46	4.72	1.63
0.49	3.74	1.57
0.61	0.00	1.27
0.52	0.00	1.03
0.56	0.00	1.10
0.51	2.13	0.79
0.49	2.80	0.96
0.53	0.00	0.96
0.59	0.00	0.41
0.65	0.00	0.35
0.62	0.00	0.81
0.50	3.08	1.03
0.69	0.00	1.27
0.85	0.00	0.37

DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES
ARE YOU FINISHED WITH PETRA - YES OR NO
YES

gopher menu

INPUT NAME OF DESIRED OPTION
STATISTICS

8

9

```
SUMMARY STATISTICS AND HISTOGRAMS
TOTAL INTERVAL AVAILABLE  2600.00 TO 2700.00
DO YOU WANT THE TOTAL INTERVAL - YES OR NO
YES
```

10

```
     WELL NAME:  CITIES SERVICE BECK A-1      SW-SE-SE 14-5S-12E
      LOCATION:  NEMAHA CO., KANSAS
          DATE:  JAN. 11, 1978
      INTERVAL:   2600.00 TO  2700.00
```

LOG NUMBER	AVAILABILITY FOR USAGE AVAILABLE	NUMBER OF VALUES	NUMBER OF VALUES DEFAULTED	MINIMUM VALUE	MAXIMUM VALUE	AVERAGE VALUE
01=DEPTH	YES	101	0	2600.00	2700.00	2650.00
02=SP	YES	101	0	32.75	79.00	51.79
03=GR	YES	101	0	12.59	199.95	52.56
04=DENSITY	YES	101	0	2.27	2.80	2.54
05=SONIC	YES	101	0	48.37	101.13	7.97
06=GNT/SNP %	NO					
07=CNL %	YES	101	0	0.30	27.43	0.42
08=NEUTRON COUNT	NO					
09=LL8	YES	101	0	8.16	1770.22	363.53
10=ILM	YES	101	0	5.15	765.58	135.74
11=ILD	YES	101	0	5.05	316.22	81.79
12=DEEP LATEROLOG	NO					
13=MICRORESISTIVITY	NO					
14=AZIMUTH	NO					
15=DIP	NO					
16=TEMPERATURE	NO					
17=INTEGRATED SONIC	NO					
18=CALIPER	NO					
19=	NO					
20=	NO					
21=PETRA SS	YES	36	65	0.24	0.96	0.75
22=PETRA LS	NO					
23=PETRA DOL	NO					
24=PETRA SH	YES	36	65	0.00	0.71	0.09
25=PETRA AN	NO					
26=PETRA HL	NO					
27=PETRA CL	NO					
28=PETRA POR	YES	36	65	0.01	0.22	0.15
29=PETRA 2POR	NO					
30=PHIRA	NO					
31=SX0	NO					
32=SW	NO					
33=K	NO					
34=DI	NO					
35=RT	NO					
36=RX0	NO					
37=RWA	NO					
38=M	NO					
39=N	NO					
40=P	NO					
41=ARCHIE M	NO					
42=SYNTH SEISM	NO					
43=MODEL SONIC	NO					
44=MODEL INT SONIC	NO					
45=	NO					
46=	NO					
47=	NO					
48=	NO					
49=	NO					
50=ALPHA	YES	36	65	0.09	0.87	0.52
51=BETA	YES	36	65	0.00	9.07	1.98
52=GAMMA	YES	36	65	0.02	4.24	1.12
53=DELTA	NO					
54=EPSILON	NO					
55=OMEGA	NO					

■

(11)

```
DO YOU WANT ANOTHER DEPTH INTERVAL- YES OR NO
NO
DO YOU WANT A HISTOGRAM PRODUCED - YES OR NO
YES
01=DEPTH              02=SP                 03=GR                 04=DENSITY
05=SONIC              06=GNT/SNP %          07=CNL %              08=NEUTRON COUNT
09=LL8                10=ILM                11=ILD                12=DEEP LATEROLOG
13=MICRORESISTIVITY   14=AZIMUTH            15=DIP                16=TEMPERATURE
17=INTEGRATED SONIC   18=CALIPER            19=                   20=
21=PETRA SS           22=PETRA LS           23=PETRA DOL          24=PETRA SH
25=PETRA AN           26=PETRA HL           27=PETRA CL           28=PETRA POR
29=PETRA 2POR         30=PHIRA              31=SX0                32=SW
33=K                  34=DI                 35=RT                 36=RX0
37=RWA                38=M                  39=N                  40=P
41=ARCHIE M           42=SYNTH SEISM        43=MODEL SONIC        44=MODEL INT SONIC
45=                   46=                   47=                   48=
49=                   50=ALPHA              51=BETA               52=GAMMA
53=DELTA              54=EPSILON            55=OMEGA
ENTER LOG DESIRED - 02 TO 55
02
TOTAL INTERVAL AVAILABLE  2600.00 TO 2700.00
DO YOU WANT THE TOTAL INTERVAL - YES OR NO
YES
ENTER MINIMUM VALUE OF HISTOGRAM
30.
ENTER MAXIMUM VALUE OF HISTOGRAM
80.
ENTER INCREMENT VALUE OF HISTOGRAM
5.
```

(12)

```
HISTOGRAM OF VALUES FOR 02=SP
     WELL NAME:  CITIES SERVICE BECK A-1      SW-SE-SE 14-59-12E
      LOCATION:  NEMAHA CO., KANSAS
          DATE:  JAN. 11, 1978
      INTERVAL:   2600.00 TO  2700.00

CLASS  MINIMUM       MAXIMUM  FREQUENCY
       VALUE         VALUE
    1    30.00 TO  35.00       21     XXXXXXXXXXXXXXXXXXXX
    2    35.00 TO  40.00        8     XXXXXXXX
    3    40.00 TO  45.00       12     XXXXXXXXXXXX
    4    45.00 TO  50.00       17     XXXXXXXXXXXXXXXXX
    5    50.00 TO  55.00       10     XXXXXXXXXX
    6    55.00 TO  60.00        3     XXX
    7    60.00 TO  65.00        3     XXX
    8    65.00 TO  70.00        6     XXXXXX
    9    70.00 TO  75.00        5     XXXXX
   10    75.00 TO  80.00       16     XXXXXXXXXXXXXXXX

DO YOU WANT A HISTOGRAM PRODUCED - YES OR NO
NO
```

(13)

gopher menu

```
INPUT NAME OF DESIRED OPTION
KOBRA
```

```
KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    RPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
DEPTH
TOTAL INTERVAL AVAILABLE  2600.00 TO  2700.00
SELECTED INTERVAL 2600.00 TO  2700.00
DO YOU WANT THE SELECTED INTERVAL - YES OR NO
NO
ENTER MINIMUM DEPTH DESIRED
2665.
ENTER MAXIMUM DEPTH DESIRED
2700.
KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    RPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
SPRW
SPRW OPTION SELECTED
SPECIFY DEPTH OF ZONE
2685.
SPECIFY STATIC SELF POTENTIAL
-46.
```

14

15

```
SPRW
    RMF=     2.140     AT      58.0
    SURFACE TEMPERATURE        54.0
    BHT       92.0
    TD    2757.00
    ZONE DEPTH         2685.00
    ZONE TEMPERATURE     91.0
    SSP       -46.0
    RW AT FORMATION TEMPERATURE     0.3304
    FORMATION WATER SALINITY (PPM)  14678.
```

■

16

```
KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    RPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
POREG
POREG OPTION SELECTED
THE FOLLOWING RESISTIVITY LOGS ARE AVAILABLE
    09=LL8
    10=ILM
    11=ILD
SELECT TRACK NUMBER OF RESISTIVITY TO BE USED
11
SPECIFY RW
0.33
SPECIFY RW TEMPERATURE (DEG F)
```

17

```
POREG COMPUTATION
GEOMETRICAL CHARACTERISTICS OF WATER-FILLED POROSITY
    WELL NAME: CITIES SERVICE BECK A-1      SW-SE-SE 14-5S-12E
          DEPTH INTERVAL:    2665.00   2700.00
       RESISTIVITY LOG: 11=ILD
   FORMATION TEMPERATURE:  90.9 DEG F
                 RW:    0.330
```

DEPTH	VSH	POR	2POR	PHI	R	F	M	T	L
2665.0	0.021	0.010	-1.000	0.010	67.92	205.81	1.17	2.18	1.47
2666.0	0.000	0.083	-1.000	0.083	46.55	141.08	1.99	11.74	3.42
2667.0	0.000	0.118	-1.000	0.118	34.67	105.07	2.18	12.44	3.52
2668.0	0.000	0.137	-1.000	0.137	27.79	84.23	2.23	11.57	3.40
2669.0	0.000	0.127	-1.000	0.127	24.88	75.41	2.09	9.60	3.09
2670.0	0.000	0.150	-1.000	0.150	24.21	73.36	2.26	11.04	3.32
2671.0	0.000	0.174	-1.000	0.174	20.51	62.15	2.36	10.87	3.29
2672.0	0.191	0.163	-1.000	0.163	15.41	46.71	2.11	7.62	2.76
2673.0	0.532	0.077	-1.000	0.077	12.35	37.45	1.41	2.90	1.70
2674.0	0.710	0.041	-1.000	0.041	10.00	30.30	1.07	1.26	1.12
2675.0	0.390	0.109	-1.000	0.109	8.55	25.91	1.47	2.84	1.68
2676.0	0.159	0.165	-1.000	0.165	8.31	25.20	1.79	4.16	2.04
2677.0	0.170	0.136	-1.000	0.136	8.47	25.67	1.62	3.49	1.87
2678.0	0.191	0.108	-1.000	0.108	8.62	26.15	1.47	2.84	1.68
2679.0	0.024	0.143	-1.000	0.143	8.95	27.13	1.69	3.88	1.97
2680.0	0.101	0.112	-1.000	0.112	8.95	27.13	1.50	3.04	1.74
2681.0	0.000	0.148	-1.000	0.148	8.47	25.67	1.69	3.80	1.94
2682.0	0.000	0.153	-1.000	0.153	7.94	24.07	1.69	3.69	1.92
2683.0	0.019	0.144	-1.000	0.144	7.31	22.15	1.60	3.21	1.79
2684.0	0.000	0.178	-1.000	0.178	6.79	20.58	1.75	3.66	1.91
2685.0	0.000	0.186	-1.000	0.186	6.30	19.11	1.75	3.56	1.88
2686.0	0.000	0.178	-1.000	0.178	5.86	17.76	1.66	3.16	1.77
2687.0	0.000	0.194	-1.000	0.194	5.49	16.65	1.71	3.23	1.79
2688.0	0.000	0.206	-1.000	0.206	5.15	15.61	1.74	3.23	1.79
2689.0	0.066	0.194	-1.000	0.194	5.05	15.32	1.66	2.97	1.72
2690.0	0.001	0.222	-1.000	0.222	5.05	15.32	1.81	3.40	1.84
2691.0	0.023	0.217	-1.000	0.217	5.10	15.46	1.79	3.37	1.83
2692.0	0.000	0.219	-1.000	0.219	5.29	16.05	1.82	3.52	1.87
2693.0	0.000	0.210	-1.000	0.210	5.49	16.65	1.80	3.49	1.87
2694.0	0.029	0.192	-1.000	0.192	5.86	17.76	1.74	3.41	1.84
2695.0	0.046	0.208	-1.000	0.208	6.30	19.11	1.88	3.98	1.99
2696.0	0.082	0.197	-1.000	0.197	6.79	20.58	1.86	4.06	2.01
2697.0	0.071	0.194	-1.000	0.194	7.11	21.55	1.87	4.19	2.04
2698.0	0.000	0.211	-1.000	0.211	7.72	23.41	2.02	4.94	2.22
2699.0	0.130	0.166	-1.000	0.166	8.79	26.63	1.83	4.44	2.10
2700.0	0.378	0.095	-1.000	0.095	10.00	30.30	1.45	2.90	1.70

```
DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES
```

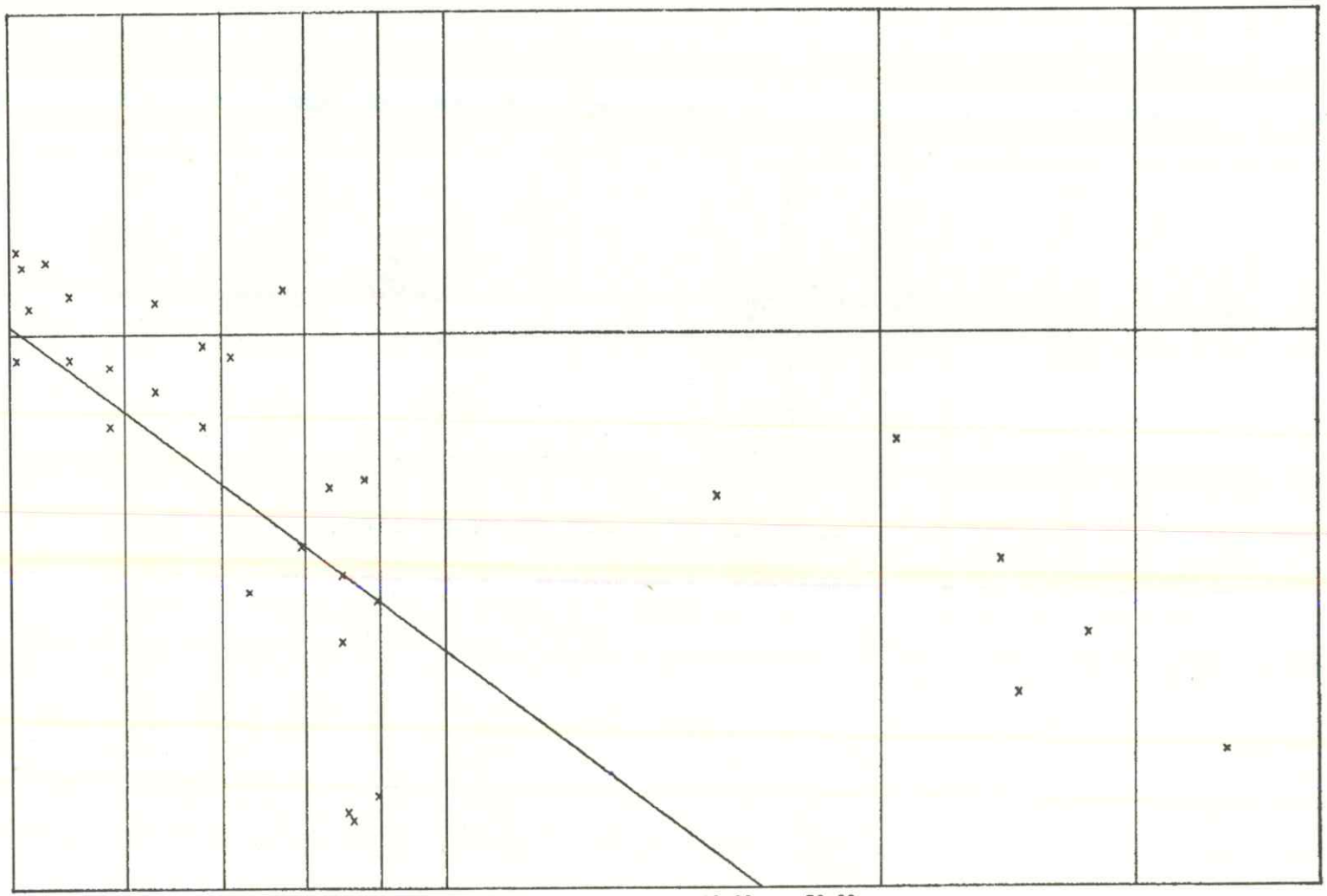
```
KOBRA RESERVOIR ANALYSIS MODULE

     DEPTH ----- SELECT DESIRED DEPTH INTERVAL
     TORNADO --- SMALL SLAM INVASION PARAMETERS
     PPPLOT ---- PICKETT PLOT
     SPRW ------ WATER RESISTIVITY FROM SP
     RWA ------- RECONNAISSANCE WATER RESISTIVITY
     PHIRA ----- WATER-FILLED POROSITY
     POREG ----- PORE GEOMETRY
     CLSAT ----- WATER SATURATION (SHALE-FREE)
     SHSAT ----- WATER SATURATION (SHALY MODELS)
     WASP ------ WAXMAN-SMITS MODEL
     PERM ------ PERMEABILITY INDEX
     CHERNOFF -- PHI.SW.SH.VSH.K FACES
     STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
RPPLOT
RPPLOT OPTION SELECTED
THE FOLLOWING RESISTIVITY LOGS ARE AVAILABLE
     09=LL8
     10=ILM
     11=ILD
SELECT TRACK NUMBER OF RESISTIVITY TO BE USED
11
DO YOU HAVE A PRIORI WATER LINE - YES OR NO
YES
SPECIFY RW
0.33
SPECIFY RW TEMPERATURE (DEG F)

SPECIFY ARCHIE EQUATION CONSTANTS - A,M
1.
1.7
RESISTIVITY RANGE      5.05     67.92
POROSITY RANGE         1.06     22.24
SPECIFY EXTREMES FOR PLOT
5.
40.
10.
30.
```

RESISTIVITY-POROSITY CROSSPLOT
WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
DEPTH INTERVAL: 2665.00 2700.00
RESISTIVITY LOG: 11=ILD
FORMATION TEMPERATURE: 90.9 DEG F
RW= 0.330 A= 1.00 M= 1.70



VERTICAL AXIS: POROSITY % 10.00 30.00
HORIZONTAL AXIS: RESISTIVITY OHM-M 5.00 40.00

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KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    RPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
RWA
RWA OPTION SELECTED
THE FOLLOWING RESISTIVITY LOGS ARE AVAILABLE
    09=LL8
    10=ILM
    11=ILD
SELECT TRACK NUMBER OF RESISTIVITY TO BE USED
11
SPECIFY ARCHIE EQUATION CONSTANTS - A,M
1.
1.7
```
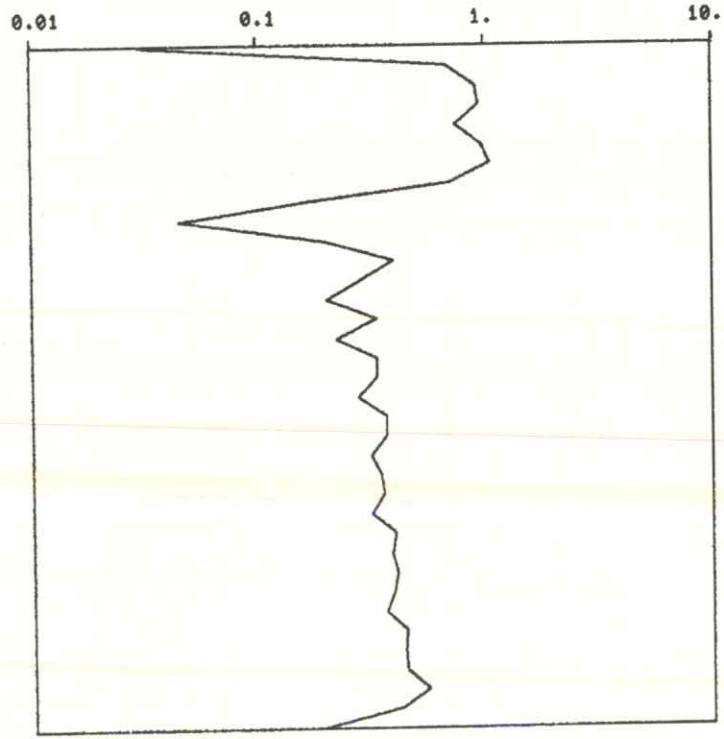

RWA COMPUTATION
WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
DEPTH INTERVAL: 2665.00 2700.00
RESISTIVITY LOG: 11=ILD
A= 1.00 M= 1.70

DEPTH	VSH	POR	2POR	PHI	R	RWA
2665.0	0.021	0.010	-1.000	0.010	67.92	0.030
2666.0	0.000	0.083	-1.000	0.083	46.55	0.680
2667.0	0.000	0.118	-1.000	0.118	34.67	0.922
2668.0	0.000	0.137	-1.000	0.137	27.79	0.951
2669.0	0.000	0.127	-1.000	0.127	24.88	0.748
2670.0	0.000	0.150	-1.000	0.150	24.21	0.969
2671.0	0.000	0.174	-1.000	0.174	20.51	1.058
2672.0	0.191	0.163	-1.000	0.163	15.41	0.706
2673.0	0.532	0.077	-1.000	0.077	12.35	0.159
2674.0	0.710	0.041	-1.000	0.041	10.00	0.044
2675.0	0.390	0.109	-1.000	0.109	8.55	0.200
2676.0	0.159	0.165	-1.000	0.165	8.31	0.389
2677.0	0.170	0.136	-1.000	0.136	8.47	0.285
2678.0	0.191	0.108	-1.000	0.108	8.62	0.199
2679.0	0.024	0.143	-1.000	0.143	8.95	0.329
2680.0	0.101	0.112	-1.000	0.112	8.95	0.217
2681.0	0.000	0.148	-1.000	0.148	8.47	0.329
2682.0	0.000	0.153	-1.000	0.153	7.94	0.327
2683.0	0.019	0.144	-1.000	0.144	7.31	0.274
2684.0	0.000	0.178	-1.000	0.178	6.79	0.361
2685.0	0.000	0.186	-1.000	0.186	6.30	0.363
2686.0	0.000	0.178	-1.000	0.178	5.86	0.312
2687.0	0.000	0.194	-1.000	0.194	5.49	0.338
2688.0	0.000	0.206	-1.000	0.206	5.15	0.353
2689.0	0.066	0.194	-1.000	0.194	5.05	0.311
2690.0	0.001	0.222	-1.000	0.222	5.05	0.392
2691.0	0.023	0.217	-1.000	0.217	5.10	0.383
2692.0	0.000	0.219	-1.000	0.219	5.29	0.401
2693.0	0.000	0.210	-1.000	0.210	5.49	0.387
2694.0	0.029	0.192	-1.000	0.192	5.86	0.354
2695.0	0.046	0.208	-1.000	0.208	6.30	0.438
2696.0	0.082	0.197	-1.000	0.197	6.79	0.430
2697.0	0.071	0.194	-1.000	0.194	7.11	0.439
2698.0	0.000	0.211	-1.000	0.211	7.72	0.550
2699.0	0.130	0.166	-1.000	0.166	8.79	0.418
2700.0	0.378	0.095	-1.000	0.095	10.00	0.185



DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES

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KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    RPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

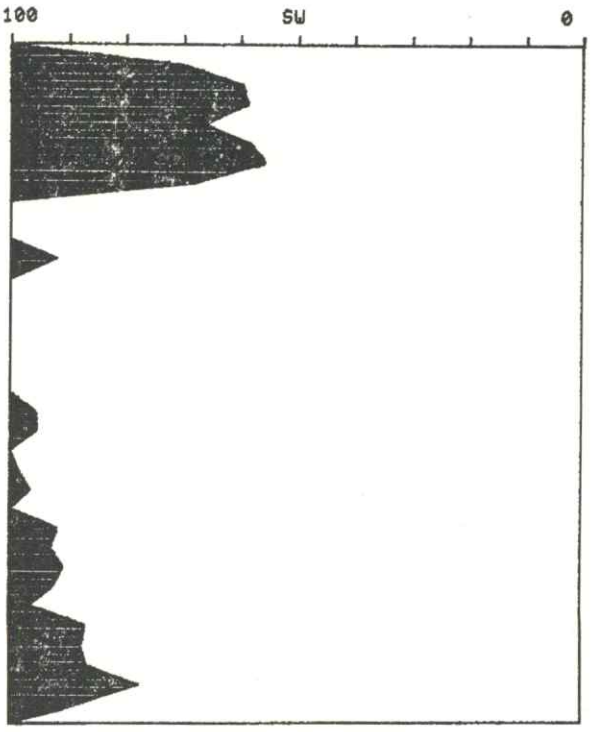
INPUT NAME OF DESIRED OPTION
CLSAT
CLSAT OPTION SELECTED
THE FOLLOWING RESISTIVITY LOGS ARE AVAILABLE
    09=LL8
    10=ILM
    11=ILD
SELECT TRACK NUMBER OF RESISTIVITY TO BE USED
11
SPECIFY RW
0.33
SPECIFY RW TEMPERATURE (DEG F)

SPECIFY ARCHIE EQUATION CONSTANTS - A,M
1.
1.7
SPECIFY SATURATION COEFFICIENT - N
2.
```

22

```
WATER SATURATION COMPUTATION (SHALE-FREE)
   WELL NAME: CITIES SERVICE BECK A-1      SW-SE-SE 14-5S--12E
         DEPTH INTERVAL:     2665.00    2700.00
       RESISTIVITY LOG: 11=ILD
   FORMATION TEMPERATURE:  90.9 DEG F
                     RW:     0.330
          A=      1.00      M=      1.70      N=      2.00
          SW = WATER SATURATION
  DEPTH     VSH     PHI       R        C       SW
 2665.0   0.021   0.010    67.9    0.035    3.315
 2666.0   0.000   0.083    46.5    0.057    0.696
 2667.0   0.000   0.118    34.6    0.070    0.598
 2668.0   0.000   0.137    27.7    0.080    0.588
 2669.0   0.000   0.127    24.8    0.084    0.663
 2670.0   0.000   0.150    24.2    0.087    0.583
 2671.0   0.000   0.174    20.5    0.097    0.558
 2672.0   0.191   0.163    15.4    0.111    0.683
 2673.0   0.532   0.077    12.3    0.111    1.437
 2674.0   0.710   0.041    10.0    0.112    2.708
 2675.0   0.390   0.109     8.5    0.141    1.283
 2676.0   0.159   0.165     8.3    0.152    0.920
 2677.0   0.170   0.136     8.4    0.146    1.074
 2678.0   0.191   0.108     8.6    0.140    1.287
 2679.0   0.024   0.143     8.9    0.143    1.001
 2680.0   0.101   0.112     8.9    0.138    1.231
 2681.0   0.000   0.148     8.4    0.148    1.000
 2682.0   0.000   0.153     7.9    0.153    1.003
 2683.0   0.019   0.144     7.3    0.159    1.097
 2684.0   0.000   0.178     6.7    0.170    0.954
 2685.0   0.000   0.186     6.3    0.177    0.952
 2686.0   0.000   0.178     5.8    0.183    1.028
 2687.0   0.000   0.194     5.4    0.191    0.987
 2688.0   0.000   0.206     5.1    0.199    0.965
 2689.0   0.066   0.194     5.0    0.199    1.029
 2690.0   0.001   0.222     5.0    0.203    0.916
 2691.0   0.023   0.217     5.1    0.202    0.928
 2692.0   0.000   0.219     5.2    0.198    0.906
 2693.0   0.000   0.210     5.4    0.193    0.922
 2694.0   0.029   0.192     5.8    0.185    0.964
 2695.0   0.046   0.208     6.3    0.180    0.867
 2696.0   0.082   0.197     6.7    0.172    0.875
 2697.0   0.071   0.194     7.1    0.168    0.866
 2698.0   0.000   0.211     7.7    0.163    0.774
 2699.0   0.130   0.166     8.7    0.148    0.888
 2700.0   0.378   0.095    10.0    0.127    1.334
DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES
```

23



(24)

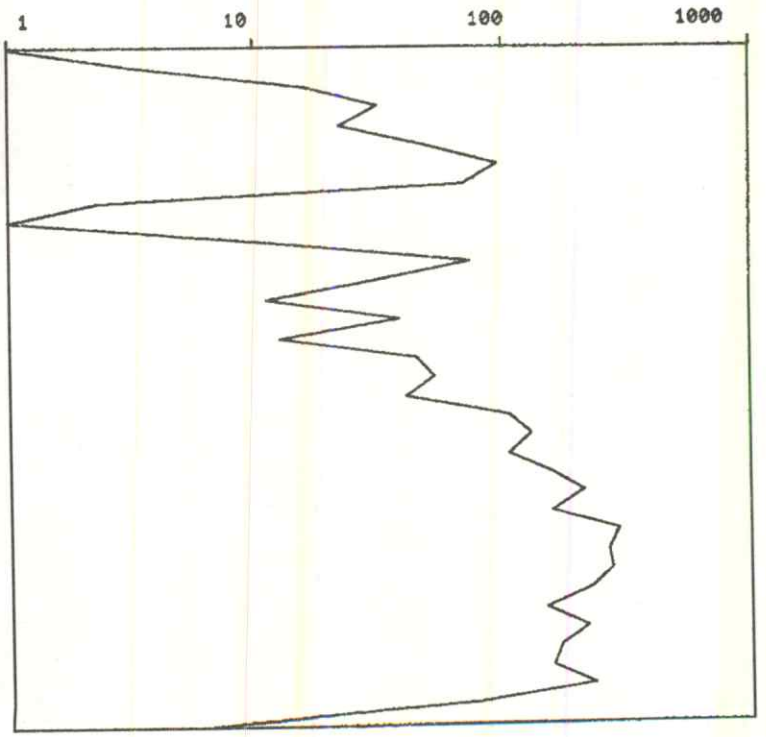
```
KOBRA RESERVOIR ANALYSIS MODULE

     DEPTH ----- SELECT DESIRED DEPTH INTERVAL
     TORNADO --- SMALL SLAM INVASION PARAMETERS
     RPPLOT ---- PICKETT PLOT
     SPRW ------ WATER RESISTIVITY FROM SP
     RWA ------- RECONNAISSANCE WATER RESISTIVITY
     PHIRA ----- WATER-FILLED POROSITY
     POREG ----- PORE GEOMETRY
     CLSAT ----- WATER SATURATION (SHALE-FREE)
     SHSAT ----- WATER SATURATION (SHALY MODELS)
     WASP ------ WAXMAN-SMITS MODEL
     PERM ------ PERMEABILITY INDEX
     CHERNOFF -- PHI.SW.SH.VSH.K FACES
     STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
PERM
PERM OPTION SELECTED
DO YOU WANT TO USE SWI IN PREDICTION - YES OR NO
NO
PERMEABILITY INDEX COMPUTED FROM EQUATION
OF THE FORM: K = A * (PHI**B)
PHI IS IN PERCENTAGE
DO YOU HAVE VALUES FOR A,B - YES OR NO
NO
SANDSTONE OR CARBONATE - SS,LS
SS
```

(25)

```
PERM COMPUTATION
    WELL NAME: CITIES SERVICE BECK A-1     SW-SE-SE 14-5S-12E
          DEPTH INTERVAL:    2665.00   2700.00
          BASED ON POROSITY
          A=    0.0001     B=    4.5900
   DEPTH      VSH      PHI      SW        K
  2665.0    0.021    0.010  -1.000     0.00
  2666.0    0.000    0.083  -1.000     3.18
  2667.0    0.000    0.118  -1.000    16.07
  2668.0    0.000    0.137  -1.000    31.76
  2669.0    0.000    0.127  -1.000    22.40
  2670.0    0.000    0.150  -1.000    48.42
  2671.0    0.000    0.174  -1.000    96.19
  2672.0    0.191    0.163  -1.000    69.83
  2673.0    0.532    0.077  -1.000     2.28
  2674.0    0.710    0.041  -1.000     0.13
  2675.0    0.390    0.109  -1.000    11.39
  2676.0    0.159    0.165  -1.000    73.99
  2677.0    0.170    0.136  -1.000    30.54
  2678.0    0.191    0.108  -1.000    10.94
  2679.0    0.024    0.143  -1.000    38.44
  2680.0    0.101    0.112  -1.000    12.56
  2681.0    0.000    0.148  -1.000    44.81
  2682.0    0.000    0.153  -1.000    52.54
  2683.0    0.019    0.144  -1.000    40.54
  2684.0    0.000    0.178  -1.000   104.82
  2685.0    0.000    0.186  -1.000   129.33
  2686.0    0.000    0.178  -1.000   104.77
  2687.0    0.000    0.194  -1.000   154.94
  2688.0    0.000    0.206  -1.000   208.24
  2689.0    0.066    0.194  -1.000   154.97
  2690.0    0.001    0.222  -1.000   289.96
  2691.0    0.023    0.217  -1.000   264.21
  2692.0    0.000    0.219  -1.000   271.81
  2693.0    0.000    0.210  -1.000   223.40
  2694.0    0.029    0.192  -1.000   147.89
  2695.0    0.046    0.208  -1.000   214.28
  2696.0    0.082    0.197  -1.000   167.50
  2697.0    0.071    0.194  -1.000   156.42
  2698.0    0.000    0.211  -1.000   229.57
  2699.0    0.130    0.166  -1.000    77.13
  2700.0    0.378    0.095  -1.000     6.05
DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES
```



26

```
KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    PPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
STOP
```

27

gopher menu

```
INPUT NAME OF DESIRED OPTION
BYE
```

CASE STUDY 4: "SHALY" SANDSTONE

Elongate sandstone bodies of the Cherokee Group (Middle Pennsylvanian) in southeast Kansas have been prolific producers of oil for many years. Depositional origins of individual sands have been variously ascribed to nearshore bars, barrier islands, tidal channels, and alluvial valley-fill (Ebanks and James, 1974), as specific elements of a generalized paralic environment.

The shallower oil-fields are characterized by relatively heavy oil, with gravities in the neighborhood of 25° API. As a result, many fields have already experienced primary and secondary operations, and some are now possible candidates for tertiary recovery.

Monroe 1-T (SE 9-21S-22E) was drilled through a productive section of the Skinner sandstone in the Selma field. The field had been water-flooded for a number of years, and the purpose of the well was to gain detailed information for a tertiary oil recovery project. The reservoir unit was cored for engineering and geological data, and the numerical results are shown in Table 7. Lithology and bedding-structure description were based on whole core; engineering measurements on averages of 2 inch plugs; petrographic data drawn from gray-level image analysis of thin-sections, using a VP-8 video unit. A graphic summary of the information in Table 7 is drafted as Figure 20, and photographs of typical core and thin-section are shown in Figure 21.

The case-study log set (Table 8) records gamma ray, density, CNL neutron, and deep induction log readings for a 100-foot interval (650-750) containing the Skinner Sandstone (714-741).

TABLE 7: Core measurements of porosity, permeability, oil saturation, water saturation, accessory rock fragments, and bedding structures (RP=ripples; TX=trough cross-beds; PX=planar cross-beds; CG=conglomerate; WV=wavy bedding; DS=disturbed bedding; SL=siltstone) in the Skinner sandstone of the Monroe 1-T well.

D (ft.)	0%	k (md)	So%	Sw%	R%	B
715	15	1.1	22	49	35	SL
716	16	1.7	29	42	33	RP
717	16	31	40	28	19	RP
718	20	45	37	33	18	RP
719	21	52	37	34	18	TX
723	18	17	36	36	30	RP
724	19	24	37	31	29	PX
725	21	64	42	26	20	PX
726	22	82	41	27	20	RP
727	19	29	36	30	31	RP
728	20	37	38	30	31	RP
729	22	107	40	29	23	TX
730	21	68	36	27	23	TX
731	19	21	35	27	30	TX
732	20	36	38	30	32	TX
733	21	64	37	32	30	TX
734	20	57	36	33	34	TX
735	18	22	35	38	38	SL
736	18	40	42	38	28	CG
737	20	121	46	38	21	CG
738	19	67	45	38	24	DS
739	20	106	53	31	23	WV
740	20	94	56	27	26	TX
741	19	32	57	26	28	TX

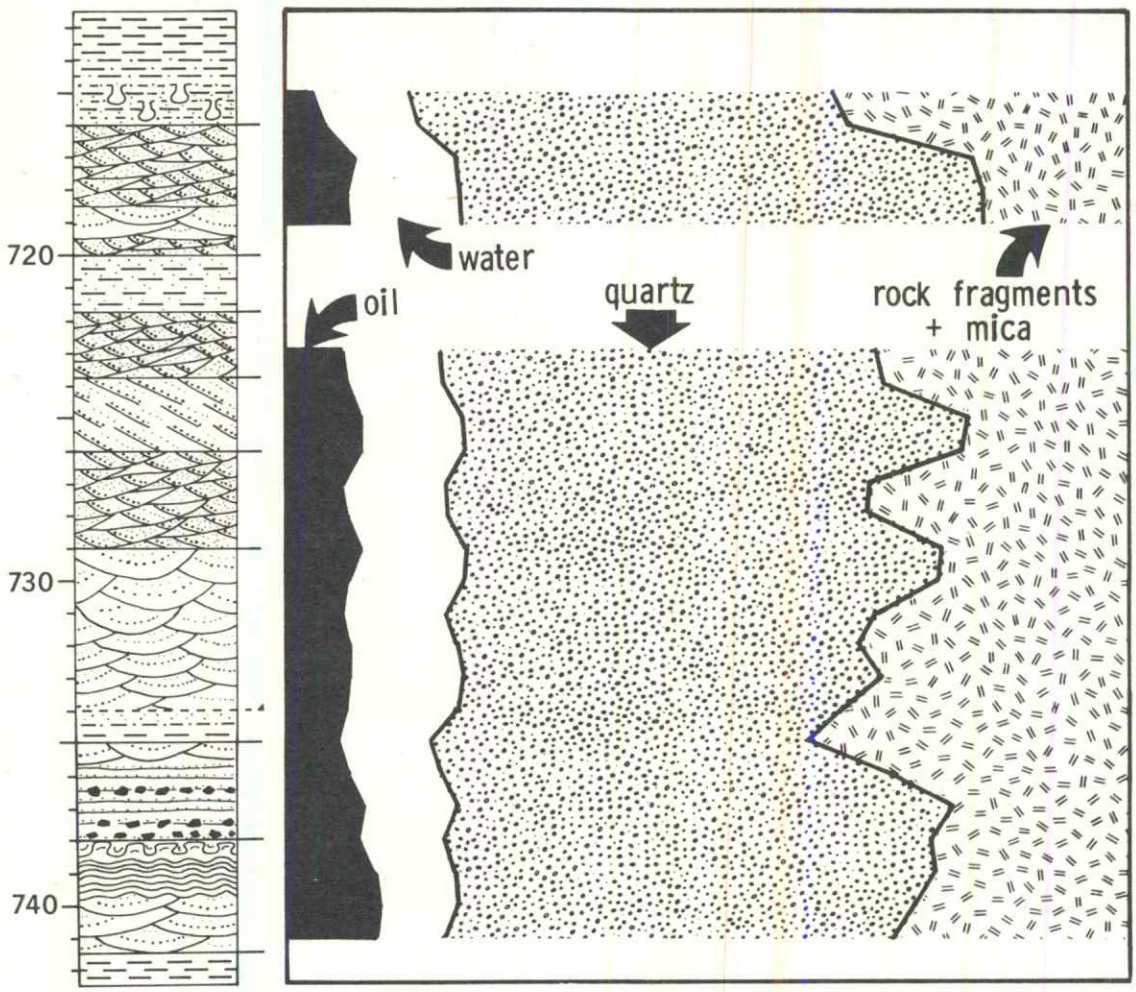
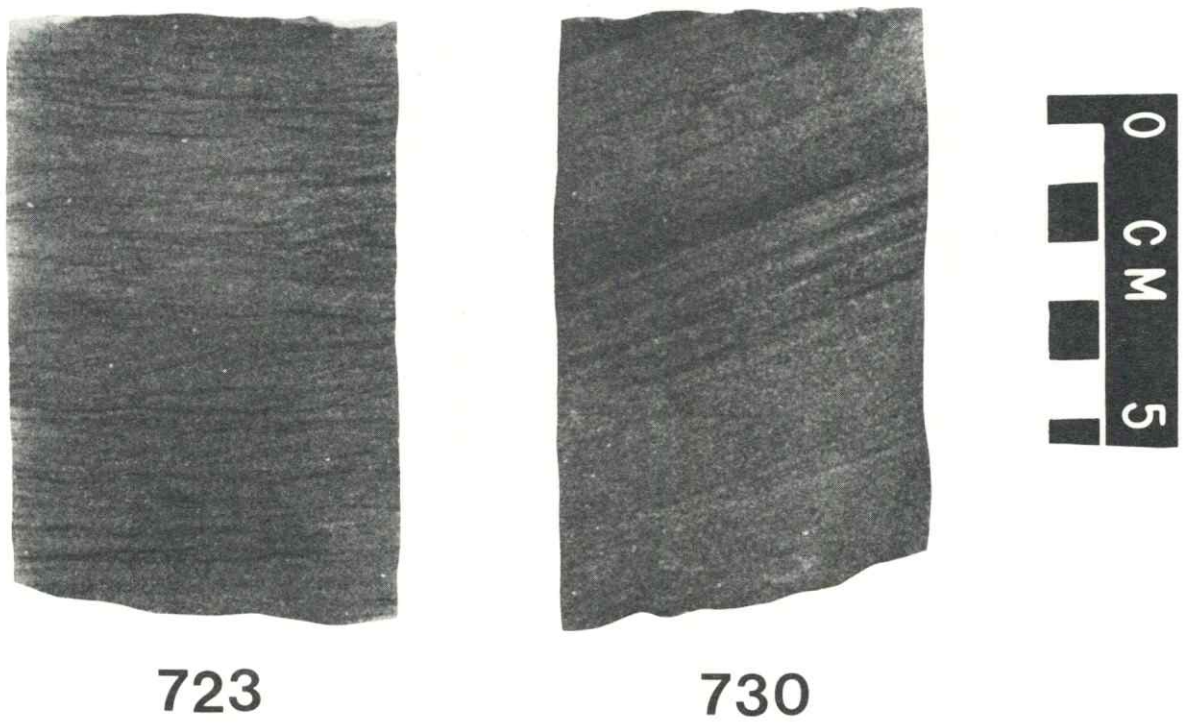


FIGURE 20: Graphic profile of Skinner sandstone in the Monroe I-T well, based on core analysis data of Table 7.



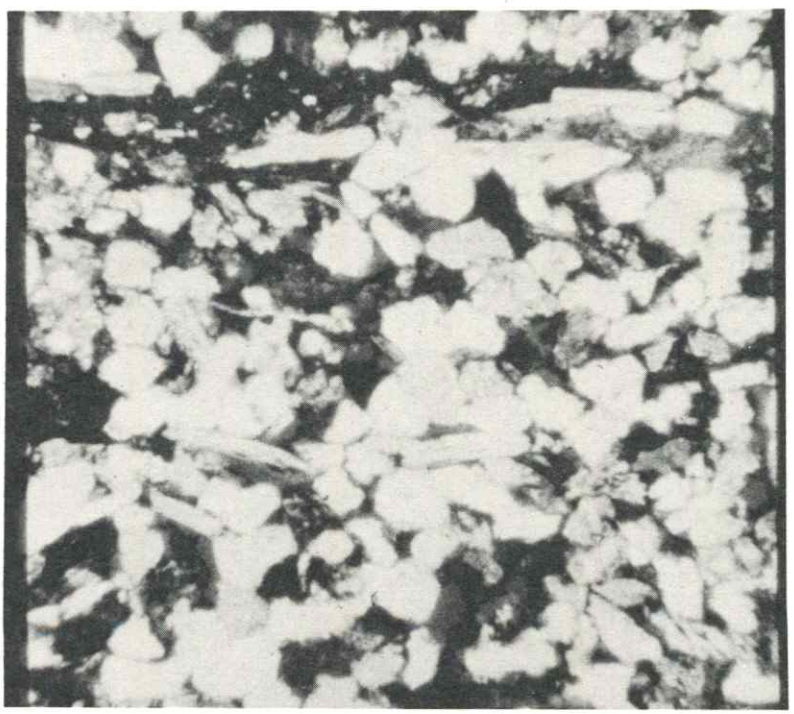


FIGURE 21: Representative cores and thin-section from Monroe 1-T.

OUTPUT COMMENTARY

1 GOPHER menu. "COMMENT" prompt.

2 COMMENT option. COMMENT track initialized by "BLANK" instruction. Entry of alphanumeric information triggered by "INSERT." Core measurements of porosity, permeability and bedding structure input at appropriate depths. (Note that these values have been averaged between plugs to give an approximate compatibility in vertical resolution with measurements from geophysical logs.)
Completion of COMMENT option by "STOP."

3 GOPHER menu. "DATABASE" prompt.

4 DATABASE option. Request for update of file with modification of a well log. The empty channel 19 is selected for insertion of averaged oil saturations from core analysis. These values are likely to be reasonable approximations of the reservoir parameters, since the field has been extensively water-flooded and the saturations are probably close to residual, while the low gravity of the oil should inhibit flushing loss during core recovery. Note that while information entered in the COMMENT track is "passive," data encoded in a regular KOALA channel may be used as input for many KOALA options.

5 GOPHER menu. "LEXICON" prompt.

6 LEXICON option. Since core oil saturations have been entered in channel 19, the channel is renamed "CORE SO%."

7 GOPHER menu. "AUTOPLOT" prompt.

8 AUTOPLOT option. The automatic production of frequency crossplots for all available combinations of gamma ray, density, sonic and neutron logs on fixed "chart-book scales." Crossplots for the entire interval are requested.

9 AUTOPLOT output. Neutron-density frequency crossplot. (Sandstone-shale triangle added manually.)

10 AUTOPLOT output. Neutron-gamma ray frequency crossplot.

11 AUTOPLOT output. Density-gamma ray frequency crossplot. Further AUTOPLOT usage declined.

12 GOPHER menu. "MNP" prompt.

13 MNP option. Total interval requested, with stipulation of fresh mud-filtrate for computation of M, N and P values.
MNP output. Only values for N can be calculated, since no sonic log is available. (M and P values are defaulted.) Automatic storage of N values in designated N channel (39). Further MNP usage declined.

14 GOPHER menu. "CROSSPLOT" prompt.

15 CROSSPLOT option. Frequency crossplot requested for entire interval, using gamma ray and N values.

16 CROSSPLOT output. Gamma ray - N frequency plot. Manual addition of heuristic quartz-shale-mica triangle.
The purpose of the computation of N and its crossplot against the gamma ray log is to suppress the component of porosity variation and isolate gamma ray-neutron-density characteristics of quartz, shale and mica components. This approach parallels similar studies of Middle Jurassic micaceous sandstones in the North Sea.

17 GOPHER menu. "PETRA" prompt.

18 PETRA option. Stipulation of parameters for initial PETRA run, using gamma ray, density and neutron logs to resolve porosity, sandstone (quartz), anhydrite (as surrogate for mica), and shale.

Modification of default coefficients to values deduced from CROSSPLOT output. Modification of component key to identify "anhydrite" as muscovite.

19 PETRA output. Solution "header" and key.

20 PETRA output. Summary of coefficients to be used for solution. Since equations match unknowns, resolution of components will be made by a simple matrix inversion algorithm. The information is accepted as correct.

21 PETRA output. Graphic presentation of component proportions with COMMENT notations and associated diagnostics. (The error diagnostic is defaulted.) In terms of diagnostics and "geological characterization," the solution is generally acceptable as a reasonable solution. However, the sum deviation values indicate two highly anomalous intervals, located between 667-671 and 742-750. Although the upper anomaly has been rationalized as a shaly sandstone, it marks the position of a coal bed, characterized by high neutron/low density values. The lower anomaly corresponds to a black shale (probably with minor enrichment in uranium content) whose gamma ray values are significantly higher than the "typical shales" higher in the section.
The component proportions of this initial run are stored on demand and further PETRA option usage requested.

22 PETRA option. A revised solution is devised for the "coal horizon" (667-671) using the density and neutron logs to resolve coal and shale components. The coal coefficients are modified to conform with estimates of these values drawn from an ECHO dump of values from this interval.

23 PETRA option. Coefficient summary. Stipulation made by PETRA that a least-squares solution will be made of the overdetermined system. Acceptance of the information signaled by the user.

24 PETRA output. Graphic solution of PETRA revision with associated diagnostics. Storage of component proportions requested by user, which will be overwritten on previous solution. Further use of PETRA declined.

25 GOPHER menu. "STATISTICS" prompt.

26 STATISTICS option. Summaries of channel contents requested for restricted interval 650-665, which corresponds to a "typical shale" zone.

27 STATISTICS output. The STATISTICS option has been requested to obtain an estimate of shale resistivity to be used in subsequent shaly sand reservoir analysis options. A value of approximately 9 ohm-m is indicated to be a representative figure.

28 STATISTICS option. Further STATISTICS and histogram production is declined.

29 GOPHER menu. "KOBRA" prompt.

30 KOBRA menu. "DEPTH" prompt. Interval for reservoir analysis set between 714 and 741 feet depth. KOBRA menu. "SHSAT" prompt.

31 SHSAT option. KOALA indicates that the only resistivity log available is the deep induction, which is selected by the user. A formation water resistivity of 0.5 ohm-m is specified, which has already been corrected to reservoir temperature. Archie equation coefficients of 1 and 2.1 are entered (derived from formation factor measurements of core plugs). A shale resistivity of 9 ohm-m is used (corresponding to the estimate for the STATISTICS output).

32 SHSAT output. Summary of input data. Output of depth, shale proportion and porosity (both from PETRA channels), resistivity, and water saturations for laminated, dispersed and total shale models. Since no sonic log is available, the dispersed shale model is defaulted. Graphic presentation of water saturations computed by the total shale model. Request for total shale model water saturations to be stored in the water saturation channel 32. (Note that the three model water saturations are automatically stored in the Greek channels 50-52, which

allows immediate comparison between the different estimates.)

33 KOBRA menu. "PERM" prompt. A prediction of permeability index is requested, based on KOBRA estimates of porosity and irreducible water saturation. Since no coefficients specific to this reservoir are available, the default sandstone relationship is selected (corresponding to the Timur Equation).

34 PERM output. Summary of equation coefficients. Output of depth, shale proportion, porosity, water saturation and permeability. Graphic presentation of permeability index variation. Note that although this procedure is appropriate for a virgin reservoir, extensive waterflooding of this section has raised water saturations above their irreducible level. As a result, the computed permeability indices should be consistent underestimates of their true values. The user elects to store the permeability indices in channel 33.

35 KOBRA menu. "CHERNOFF" prompt.

36 CHERNOFF output. Cartoon faces coded with porosity (area of eyes), oil saturation/water saturation (pupil/sclera), shale proportion (area of nose), and permeability index (curvature of mouth). The data which defines the facial structure are drawn from appropriate KOALA channels and represent current contents generated by PETRA and KOBRA activities.

37 KOBRA menu. "STOP" prompt.

38 GOPHER menu. "LOGPLOT" prompt.

39 LOGPLOT option. Specifications for graphic log presentation of core oil saturation (channel 19) and SHSAT water saturation (channel 32), overlaid in one track on compatible scales for the Skinner sandstone.

40 LOGPLOT output. The presentation effectively shows the relationship between oil saturations estimated from core measurements and log analyses. Further LOGPLOT usage declined.

41 GOPHER menu. "BYE" prompt.

REMARKS

Although this case study is advertised as a "shaly sandstone" example, petrographic studies indicate that mica is a major component, which must be differentiated from the clay mineral content in order for reasonable oil saturations to be computed. The final LOGPLOT comparison of water saturations calculated from the Simandoux equation ("Total Shale Model") shows a remarkably good complementary match with the core oil saturation measurements. In the view of the authors, this result should be regarded as fortuitous, rather than an endorsement of the Simandoux equation.

o-o-o

Table 8
CASE STUDY #4
SHALY SANDSTONE
DATA

WELL NAME: MONROE 1-T
LOCATION: SE 9 21S 22E KANSAS
DATE: DEC 18, 1976

01-DEPTH	03-GR	04-DENSITY	07-CNL %	11-ILD
650.000	119.000	2.560	28.100	7.900
651.000	114.000	2.570	27.700	8.100
652.000	117.000	2.560	26.900	8.700
653.000	126.000	2.550	28.000	9.300
654.000	131.000	2.580	29.500	10.200
655.000	133.000	2.520	29.500	10.700
656.000	132.000	2.560	30.400	10.700
657.000	128.000	2.570	31.300	10.500
658.000	125.000	2.590	29.000	10.300
659.000	121.000	2.640	28.700	9.900
660.000	119.000	2.640	29.000	9.400
661.000	129.000	2.570	28.400	7.800
662.000	137.000	2.510	30.700	6.500
663.000	127.000	2.460	30.700	6.900
664.000	122.000	2.520	29.800	7.800
665.000	130.000	2.550	28.900	8.000
666.000	133.000	2.510	31.100	7.800
667.000	135.000	2.380	32.300	7.300
668.000	143.000	2.040	36.900	6.300
669.000	105.000	1.970	46.600	6.100
670.000	90.000	1.770	48.000	6.500
671.000	114.000	2.040	37.900	7.000
672.000	121.000	2.550	29.300	7.500
673.000	127.000	2.620	30.200	7.900
674.000	134.000	2.580	31.900	7.300
675.000	140.000	2.560	33.600	6.600
676.000	134.000	2.500	35.200	6.200
677.000	132.000	2.480	34.100	6.000
678.000	126.000	2.520	32.200	6.100
679.000	122.000	2.570	30.600	6.800
680.000	119.000	2.600	24.100	8.000
681.000	115.000	2.570	22.800	9.700
682.000	111.000	2.570	23.800	11.700
683.000	111.000	2.580	23.400	12.700
684.000	111.000	2.620	23.800	13.900
685.000	110.000	2.570	24.700	13.500
686.000	110.000	2.540	24.400	13.400
687.000	109.000	2.550	24.000	13.400
688.000	108.000	2.550	23.600	13.600
689.000	111.000	2.550	24.000	13.900
690.000	111.000	2.580	24.300	14.200
691.000	112.000	2.550	23.600	14.100
692.000	113.000	2.540	24.200	14.000
693.000	113.000	2.530	23.700	13.900
694.000	114.000	2.530	23.700	13.700
695.000	114.000	2.520	24.900	13.500
696.000	114.000	2.540	23.200	13.600
697.000	109.000	2.490	22.500	13.700
698.000	111.000	2.510	24.000	13.900
699.000	114.000	2.520	25.100	14.300
700.000	114.000	2.510	25.300	14.600
701.000	113.000	2.520	24.100	15.000
702.000	113.000	2.510	22.900	15.400
703.000	113.000	2.500	23.400	15.700
704.000	112.000	2.530	23.800	15.400
705.000	112.000	2.550	24.100	15.100
706.000	111.000	2.510	24.500	14.600
707.000	112.000	2.500	25.700	13.900
708.000	115.000	2.500	27.300	13.400
709.000	116.000	2.530	28.700	13.500
710.000	117.000	2.500	29.300	13.500
711.000	120.000	2.550	27.600	13.300
712.000	118.000	2.530	27.600	13.600
713.000	110.000	2.500	26.100	14.000
714.000	104.000	2.470	24.500	15.100
715.000	96.000	2.450	23.300	16.600
716.000	88.000	2.420	23.000	18.700
717.000	75.000	2.370	23.600	22.100
718.000	65.000	2.330	22.600	25.000
719.000	62.000	2.320	22.300	25.900
720.000	97.000	2.400	24.400	25.100
721.000	106.000	2.480	26.800	24.400
722.000	83.000	2.410	26.300	24.400
723.000	70.000	2.360	25.100	25.900
724.000	64.000	2.350	23.400	29.500
725.000	58.000	2.350	22.400	32.600
726.000	55.000	2.310	22.400	32.900
727.000	53.000	2.280	23.100	32.700
728.000	51.000	2.300	22.700	32.900
729.000	48.000	2.280	22.500	33.100
730.000	51.000	2.290	21.600	32.800
731.000	56.000	2.340	22.400	32.300
732.000	59.000	2.310	23.300	31.700
733.000	61.000	2.330	24.900	31.300
734.000	68.000	2.320	25.800	31.000
735.000	73.000	2.340	24.700	31.100
736.000	62.000	2.320	23.500	31.900
737.000	56.000	2.310	22.900	34.000
738.000	58.000	2.310	23.100	37.300
739.000	63.000	2.310	22.400	40.900
740.000	66.000	2.350	24.000	44.300
741.000	95.000	2.460	26.100	23.000
742.000	130.000	2.600	33.000	15.600
743.000	135.000	2.620	33.200	12.000
744.000	162.000	2.450	32.500	8.800
745.000	168.000	2.460	31.900	7.500
746.000	165.000	2.500	32.100	6.900
747.000	160.000	2.510	32.900	6.500
748.000	158.000	2.530	33.600	6.100
749.000	157.000	2.500	34.000	5.700
750.000	159.000	2.500	33.700	5.500

gopher menu

INPUT NAME OF DESIRED OPTION
COMMENT

```
COMMENT - AVAILABLE OPTIONS
    BLANK ----- INITIALIZE ALL COMMENTS TO BLANKS
    LIST ------ LIST COMMENTS ON AN INTERVAL
    INSERT ---- ADD COMMENTS TO AN INTERVAL
    DELETE ---- DELETE COMMENTS FROM AN INTERVAL
    STOP ------ FINISHED
BLANK
COMMENT - AVAILABLE OPTIONS
    BLANK ----- INITIALIZE ALL COMMENTS TO BLANKS
    LIST ------ LIST COMMENTS ON AN INTERVAL
    INSERT ---- ADD COMMENTS TO AN INTERVAL
    DELETE ---- DELETE COMMENTS FROM AN INTERVAL
    STOP ------ FINISHED
INSERT
COMMENTS MAY BE A MAXIMUM OF 10 CHARACTERS
ENTER STARTING DEPTH - ENTER 0 IF FINISHED
712.
DEPTH  712.00 - ENTER RETURN IF FINISHED
 SKINNER
DEPTH  713.00 - ENTER RETURN IF FINISHED
 SANDSTONE
DEPTH  714.00 - ENTER RETURN IF FINISHED
----------
DEPTH  715.00 - ENTER RETURN IF FINISHED
 15 1.1 SL
DEPTH  716.00 - ENTER RETURN IF FINISHED
 16 1.7 RP
DEPTH  717.00 - ENTER RETURN IF FINISHED
 20  31 RP
DEPTH  718.00 - ENTER RETURN IF FINISHED
220  45 RP
DEPTH  719.00 - ENTER RETURN IF FINISHED
 21  52 TX
DEPTH  720.00 - ENTER RETURN IF FINISHED
   SHALE
DEPTH  721.00 - ENTER RETURN IF FINISHED
   SHALE
DEPTH  722.00 - ENTER RETURN IF FINISHED
        RP
DEPTH  723.00 - ENTER RETURN IF FINISHED
 18  17 RP
DEPTH  724.00 - ENTER RETURN IF FINISHED
 19  24 PX
DEPTH  725.00 - ENTER RETURN IF FINISHED
 21  64 PX
DEPTH  726.00 - ENTER RETURN IF FINISHED
 22  82 RP
DEPTH  727.00 - ENTER RETURN IF FINISHED
 19  29 RP
DEPTH  728.00 - ENTER RETURN IF FINISHED
 20  37 RP
DEPTH  729.00 - ENTER RETURN IF FINISHED
 22 107 TX
DEPTH  730.00 - ENTER RETURN IF FINISHED
 21  68 TX
DEPTH  731.00 - ENTER RETURN IF FINISHED
 19  21 TX
DEPTH  732.00 - ENTER RETURN IF FINISHED
 20  36 TX
DEPTH  733.00 - ENTER RETURN IF FINISHED
 21  64 TX
DEPTH  734.00 - ENTER RETURN IF FINISHED
 20  57 TX
DEPTH  735.00 - ENTER RETURN IF FINISHED
 18  22 TX
DEPTH  736.00 - ENTER RETURN IF FINISHED
 18  40 CG
DEPTH  737.00 - ENTER RETURN IF FINISHED
 20 121 CG
DEPTH  738.00 - ENTER RETURN IF FINISHED
 19  67 DS
DEPTH  739.00 - ENTER RETURN IF FINISHED
 20 106 WV
DEPTH  740.00 - ENTER RETURN IF FINISHED
 20  94 TX
DEPTH  741.00 - ENTER RETURN IF FINISHED
 19  32 TX
DEPTH  742.00 - ENTER RETURN IF FINISHED
----------
DEPTH  743.00 - ENTER RETURN IF FINISHED
POR  K  BD
DEPTH  744.00 - ENTER RETURN IF FINISHED
0
DEPTH  745.00 - ENTER RETURN IF FINISHED

COMMENTS MAY BE A MAXIMUM OF 10 CHARACTERS
ENTER STARTING DEPTH - ENTER 0 IF FINISHED
0
COMMENT - AVAILABLE OPTIONS
    BLANK ----- INITIALIZE ALL COMMENTS TO BLANKS
    LIST ------ LIST COMMENTS ON AN INTERVAL
    INSERT ---- ADD COMMENTS TO AN INTERVAL
    DELETE ---- DELETE COMMENTS FROM AN INTERVAL
    STOP ------ FINISHED
STOP
```

gopher menu

(3)

```
INPUT NAME OF DESIRED OPTION
DATABASE
```

(4)

```
DO YOU WANT TO CREATE A NEW FILE OR UPDATE AN EXISTING FILE
UPDATE
DO YOU WANT TO MODIFY WELL LABEL - YES OR NO
NO
DO YOU WANT TO MODIFY CONSTANTS - YES OR NO
NO
DO YOU WANT TO DELETE A WELL LOG - YES OR NO
NO
DO YOU WANT TO MODIFY A WELL LOG - YES OR NO
YES
WHICH TRACK OF INFORMATION WILL BE REPLACED
 01=DEPTH              02=SP                 03=GR
 04=DENSITY            05=SONIC              06=GNT/SNP %
 07=CNL %              08=NEUTRON COUNT      09=LL8
 10=ILM                11=ILD                12=DEEP LATEROLOG
 13=MICRORESISTIVITY   14=AZIMUTH            15=DIP
 16=TEMPERATURE        17=INTEGRATED SONIC   18=CALIPER
 19=                   20=                   21=PETRA SS
 22=PETRA LS           23=PETRA DOL          24=PETRA SH
 25=PETRA AN           26=PETRA HL           27=PETRA CL
 28=PETRA POR          29=PETRA 2POR         30=PHIRA
 31=SX0                32=SW                 33=K
 34=DI                 35=RT                 36=RX0
 37=RWA                38=M                  39=N
 40=P                  41=ARCHIE M           42=SYNTH SEISM
 43=MODEL SONIC        44=MODEL INT SONIC    45=
 46=                   47=                   48=
 49=                   50=ALPHA              51=BETA
 52=GAMMA              53=DELTA              54=EPSILON
 55=OMEGA
ENTER WELL LOG NUMBER TO BE MODIFIED (02-55)
19
ENTER DEPTH TO BE MODIFIED
714.
ENTER NEW LOG VALUE
0.
ENTER DEPTH TO BE MODIFIED
715.
ENTER NEW LOG VALUE
22.
ENTER DEPTH TO BE MODIFIED
716.
ENTER NEW LOG VALUE
29.
ENTER DEPTH TO BE MODIFIED
717.
ENTER NEW LOG VALUE
40.
ENTER DEPTH TO BE MODIFIED
718.
ENTER NEW LOG VALUE
37.
ENTER DEPTH TO BE MODIFIED
719.
ENTER NEW LOG VALUE
37.
ENTER DEPTH TO BE MODIFIED
720.
ENTER NEW LOG VALUE
0.
ENTER DEPTH TO BE MODIFIED
721.
ENTER NEW LOG VALUE
0.
ENTER DEPTH TO BE MODIFIED
722.
ENTER NEW LOG VALUE
0.
ENTER DEPTH TO BE MODIFIED
723.
ENTER NEW LOG VALUE
36.
ENTER DEPTH TO BE MODIFIED
724.
ENTER NEW LOG VALUE
37.
ENTER DEPTH TO BE MODIFIED
725.
ENTER NEW LOG VALUE
42.
ENTER DEPTH TO BE MODIFIED
726.
ENTER NEW LOG VALUE
41.
ENTER DEPTH TO BE MODIFIED
727.
ENTER NEW LOG VALUE
36.
ENTER DEPTH TO BE MODIFIED
728.
ENTER NEW LOG VALUE
38.
ENTER DEPTH TO BE MODIFIED
729.
ENTER NEW LOG VALUE
40.
ENTER DEPTH TO BE MODIFIED
730.
ENTER NEW LOG VALUE
36.
ENTER DEPTH TO BE MODIFIED
731.
ENTER NEW LOG VALUE
35.
ENTER DEPTH TO BE MODIFIED
732.
ENTER NEW LOG VALUE
38.
ENTER DEPTH TO BE MODIFIED
733.
ENTER NEW LOG VALUE
37.
ENTER DEPTH TO BE MODIFIED
734.
ENTER NEW LOG VALUE
36.
ENTER DEPTH TO BE MODIFIED
735.
ENTER NEW LOG VALUE
35.
ENTER DEPTH TO BE MODIFIED
736.
ENTER NEW LOG VALUE
42.
ENTER DEPTH TO BE MODIFIED
737.
ENTER NEW LOG VALUE
46.
ENTER DEPTH TO BE MODIFIED
738.
ENTER NEW LOG VALUE
45.
ENTER DEPTH TO BE MODIFIED
739.
ENTER NEW LOG VALUE
53.
ENTER DEPTH TO BE MODIFIED
740.
ENTER NEW LOG VALUE
56.
ENTER DEPTH TO BE MODIFIED
741.
ENTER NEW LOG VALUE
57.
ENTER DEPTH TO BE MODIFIED
0
DO YOU WANT TO MODIFY A WELL LOG - YES OR NO
NO
```

5

gopher menu

INPUT NAME OF DESIRED OPTION
LEXICON

6

```
LEXICON - AVAILABLE OPTIONS
          LIST ------ LIST CURRENT NAMES OF BOTH
                      WELL LOGS AND CONSTANTS
          LOG ------- MODIFY WELL LOG NAME
          CONSTANT -- MODIFY CONSTANT NAME
          STOP ------ FINISHED
LOG
ENTER NUMBER TO BE CHANGED - 01 TO 60
19
ENTER NEW NAME - MAXIMUM 20 CHARACTERS
CORE 50%
LEXICON - AVAILABLE OPTIONS
          LIST ------ LIST CURRENT NAMES OF BOTH
                      WELL LOGS AND CONSTANTS
          LOG ------- MODIFY WELL LOG NAME
          CONSTANT -- MODIFY CONSTANT NAME
          STOP ------ FINISHED
STOP
```

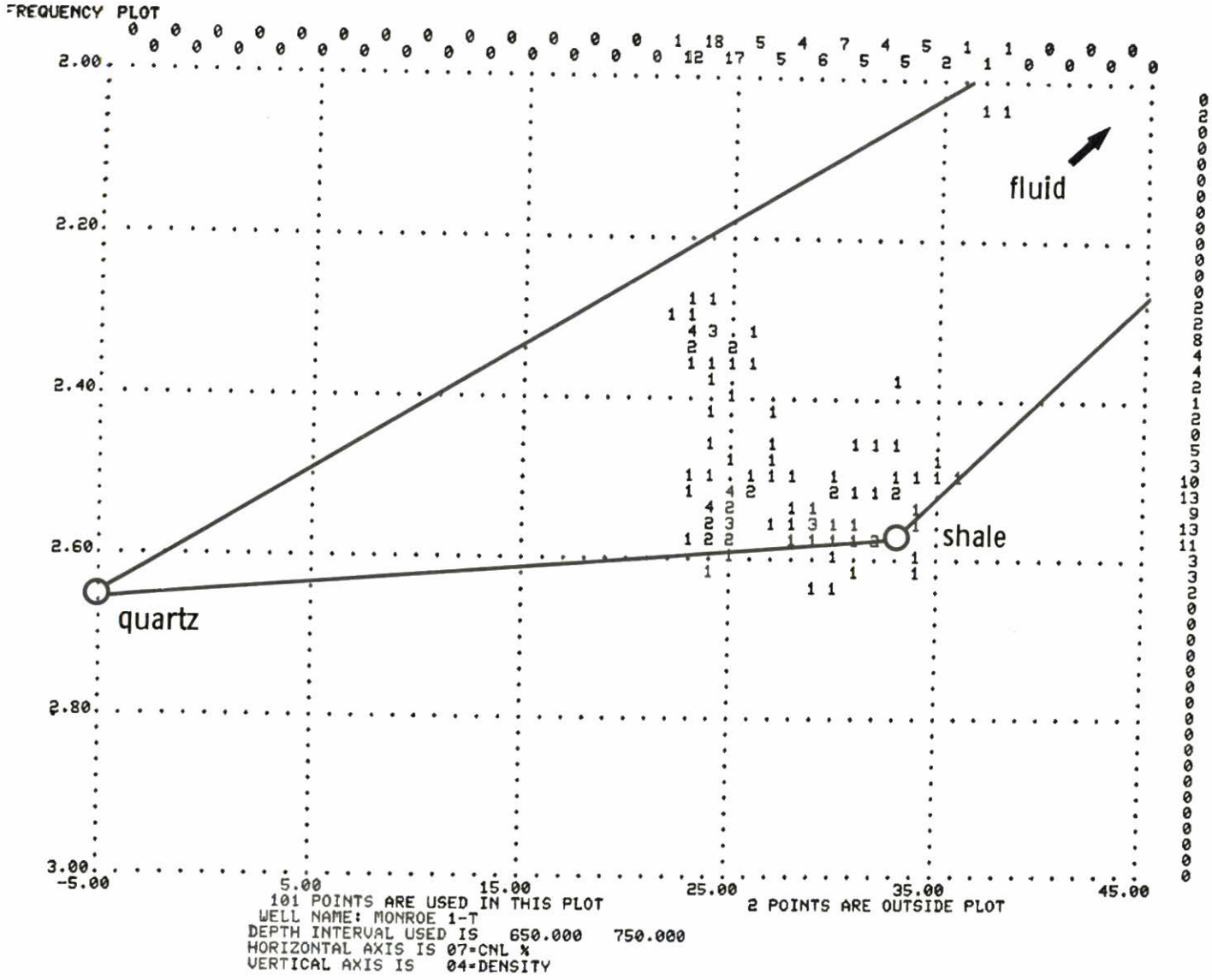
7

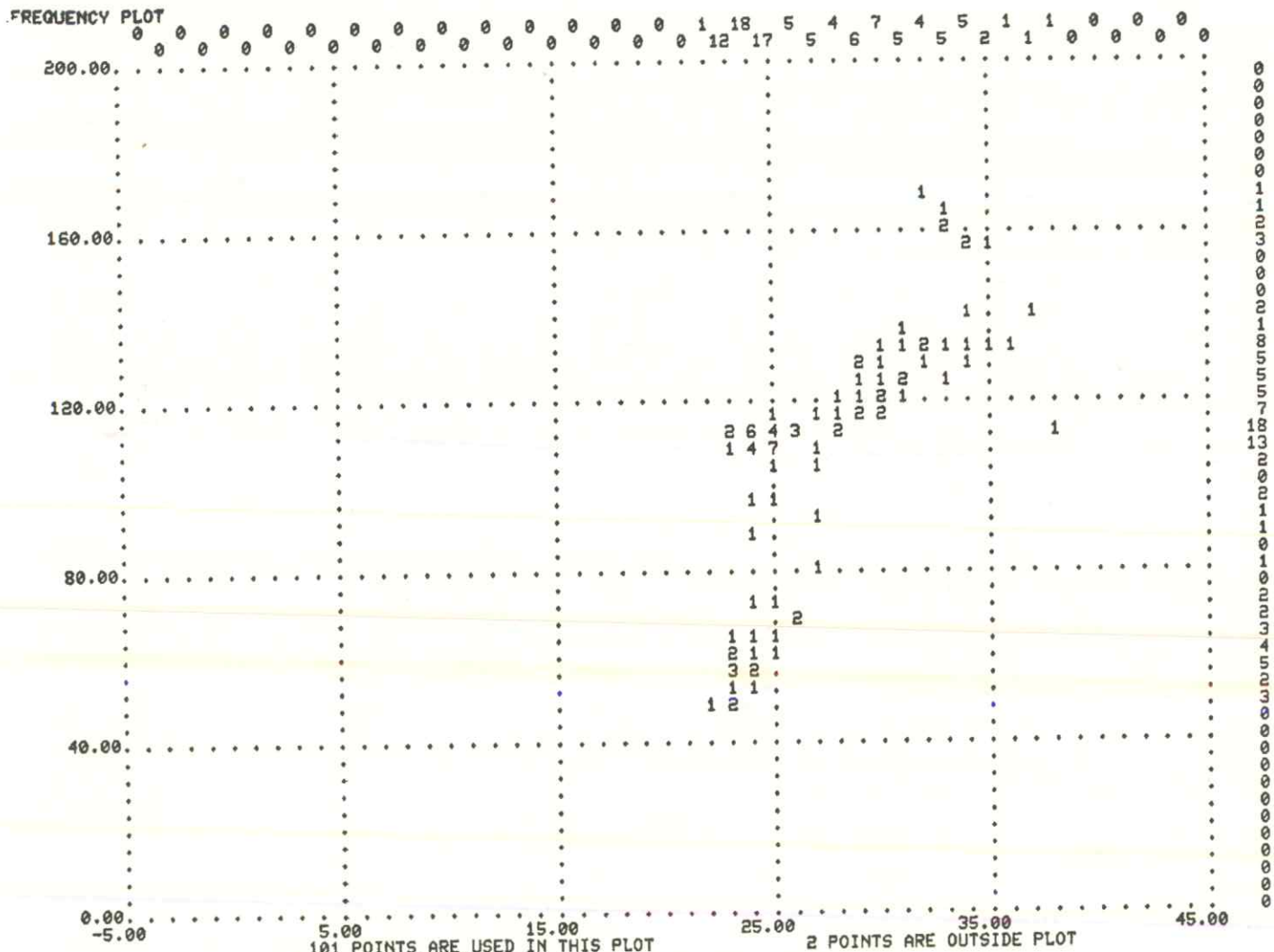
gopher menu

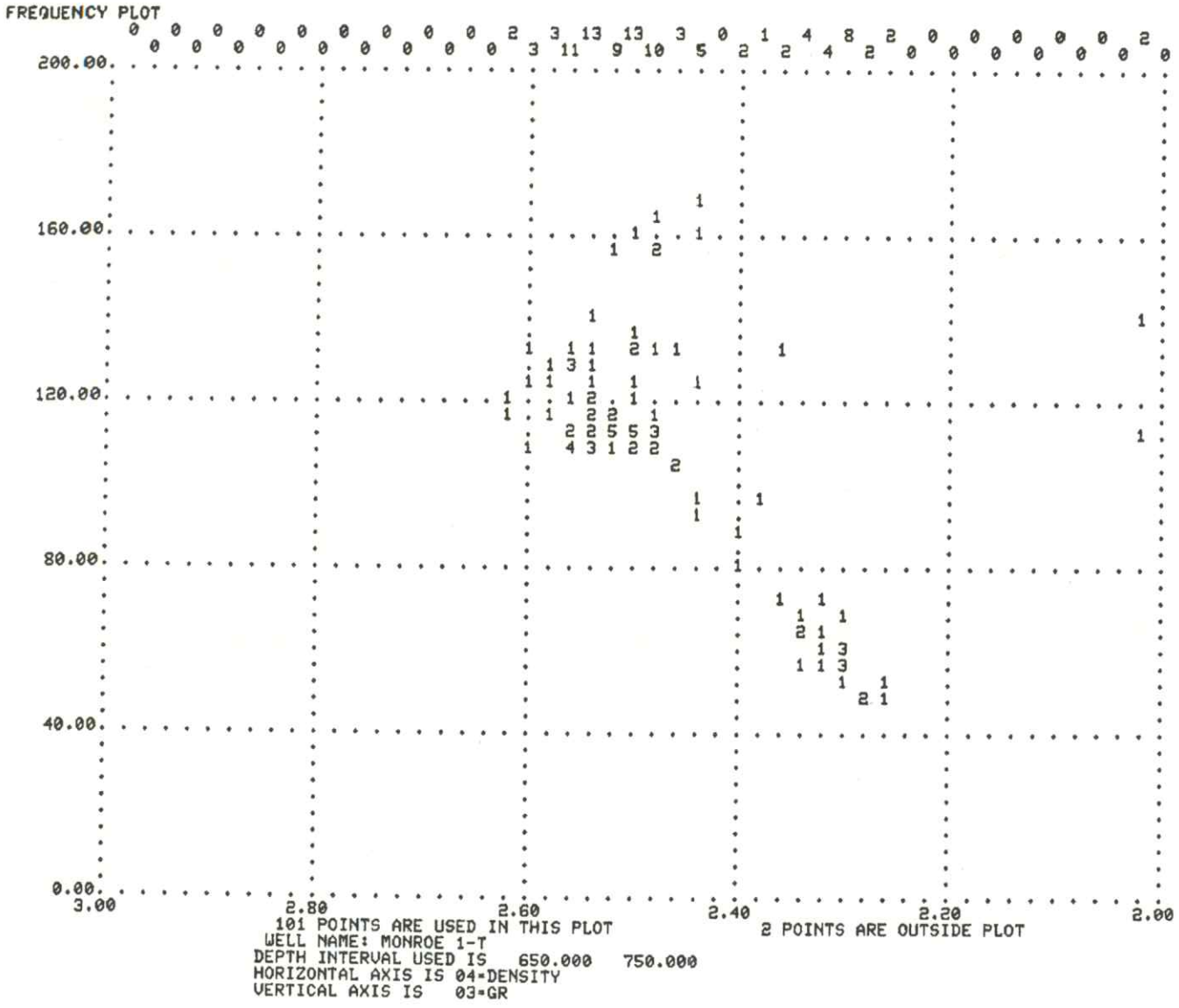
INPUT NAME OF DESIRED OPTION
AUTO

8

```
AUTOMATIC CROSSPLOT PROGRAM
TOTAL INTERVAL AVAILABLE   650.00 TO   750.00
DO YOU WANT THE TOTAL INTERVAL - YES OR NO
YES
```


FREQUENCY PLOT
2.00
2.20
2.40
2.60
2.80
3.00
-5.00
5.00
15.00
25.00
35.00
45.00
fluid
shale
quartz
101 POINTS ARE USED IN THIS PLOT
2 POINTS ARE OUTSIDE PLOT
WELL NAME: MONROE 1-T
DEPTH INTERVAL USED IS 650.000 750.000
HORIZONTAL AXIS IS 07=CNL %
VERTICAL AXIS IS 04=DENSITY


FREQUENCY PLOT
200.00
160.00
120.00
80.00
40.00
0.00
-5.00
5.00
15.00
25.00
35.00
45.00
101 POINTS ARE USED IN THIS PLOT
2 POINTS ARE OUTSIDE PLOT
WELL NAME: MONROE 1-T
DEPTH INTERVAL USED IS 650.000 750.000
HORIZONTAL AXIS IS 07=CNL %
VERTICAL AXIS IS 03=GR



DO YOU WANT TO CHANGE THE DEPTH INTERVAL - YES OR NO
NO

(12)

gopher menu

```
INPUT NAME OF DESIRED OPTION
MNP
```

---

(13)

```
M-N-P PROGRAM
TOTAL INTERVAL AVAILABLE   650.00 TO   750.00
DO YOU WANT THE TOTAL INTERVAL - YES OR NO
YES
DO YOU WANT FRESH MUD OR SALT MUD - F OR S
F
```

```
M-N-P PROGRAM
TOTAL INTERVAL AVAILABLE   650.00 TO   750.00
DO YOU WANT THE TOTAL INTERVAL - YES OR NO
YES
DO YOU WANT FRESH MUD OR SALT MUD - F OR S
F

    DEPTH       M        N       P
    650.0*999.000    0.460*999.000
    651.0*999.000    0.460*999.000
    652.0*999.000    0.468*999.000
    653.0*999.000    0.464*999.000
    654.0*999.000    0.446*999.000
    655.0*999.000    0.463*999.000
    656.0*999.000    0.446*999.000
    657.0*999.000    0.437*999.000
    658.0*999.000    0.446*999.000
    659.0*999.000    0.434*999.000
    660.0*999.000    0.432*999.000
    661.0*999.000    0.456*999.000
    662.0*999.000    0.458*999.000
    663.0*999.000    0.474*999.000
    664.0*999.000    0.461*999.000
    665.0*999.000    0.458*999.000
    666.0*999.000    0.456*999.000
    667.0*999.000    0.490*999.000
    668.0*999.000    0.606*999.000
    669.0*999.000    0.550*999.000
    670.0*999.000    0.675*999.000
    671.0*999.000    0.597*999.000
    672.0*999.000    0.456*999.000
    673.0*999.000    0.430*999.000
    674.0*999.000    0.431*999.000
    675.0*999.000    0.425*999.000
    676.0*999.000    0.431*999.000
    677.0*999.000    0.445*999.000
    678.0*999.000    0.446*999.000
    679.0*999.000    0.442*999.000
    680.0*999.000    0.474*999.000
    681.0*999.000    0.491*999.000
    682.0*999.000    0.485*999.000
    683.0*999.000    0.484*999.000
    684.0*999.000    0.470*999.000
    685.0*999.000    0.479*999.000
    686.0*999.000    0.490*999.000
    687.0*999.000    0.490*999.000
    688.0*999.000    0.492*999.000
    689.0*999.000    0.490*999.000
    690.0*999.000    0.479*999.000
    691.0*999.000    0.492*999.000
    692.0*999.000    0.492*999.000
    693.0*999.000    0.498*999.000
    694.0*999.000    0.498*999.000
    695.0*999.000    0.494*999.000
    696.0*999.000    0.498*999.000
    697.0*999.000    0.520*999.000
    698.0*999.000    0.503*999.000
    699.0*999.000    0.492*999.000
    700.0*999.000    0.494*999.000
    701.0*999.000    0.499*999.000
    702.0*999.000    0.510*999.000
    703.0*999.000    0.510*999.000
    704.0*999.000    0.498*999.000
    705.0*999.000    0.489*999.000
    706.0*999.000    0.500*999.000
    707.0*999.000    0.495*999.000
    708.0*999.000    0.484*999.000
    709.0*999.000    0.466*999.000
    710.0*999.000    0.471*999.000
    711.0*999.000    0.467*999.000
    712.0*999.000    0.473*999.000
    713.0*999.000    0.492*999.000
    714.0*999.000    0.513*999.000
    715.0*999.000    0.528*999.000
    716.0*999.000    0.542*999.000
    717.0*999.000    0.557*999.000
    718.0*999.000    0.581*999.000
    719.0*999.000    0.588*999.000
    720.0*999.000    0.540*999.000
    721.0*999.000    0.494*999.000
    722.0*999.000    0.522*999.000
    723.0*999.000    0.550*999.000
    724.0*999.000    0.567*999.000
    725.0*999.000    0.574*999.000
    726.0*999.000    0.592*999.000
    727.0*999.000    0.600*999.000
    728.0*999.000    0.594*999.000
    729.0*999.000    0.605*999.000
    730.0*999.000    0.607*999.000
    731.0*999.000    0.579*999.000
    732.0*999.000    0.585*999.000
    733.0*999.000    0.564*999.000
    734.0*999.000    0.562*999.000
    735.0*999.000    0.561*999.000
    736.0*999.000    0.579*999.000
    737.0*999.000    0.588*999.000
    738.0*999.000    0.587*999.000
    739.0*999.000    0.592*999.000
    740.0*999.000    0.562*999.000
    741.0*999.000    0.506*999.000
    742.0*999.000    0.418*999.000
    743.0*999.000    0.412*999.000
    744.0*999.000    0.465*999.000
    745.0*999.000    0.466*999.000
    746.0*999.000    0.452*999.000
    747.0*999.000    0.444*999.000
    748.0*999.000    0.433*999.000
    749.0*999.000    0.439*999.000
    750.0*999.000    0.441*999.000
DO YOU WANT A DIFFERENT DEPTH - YES OR NO
NO
```

(14)

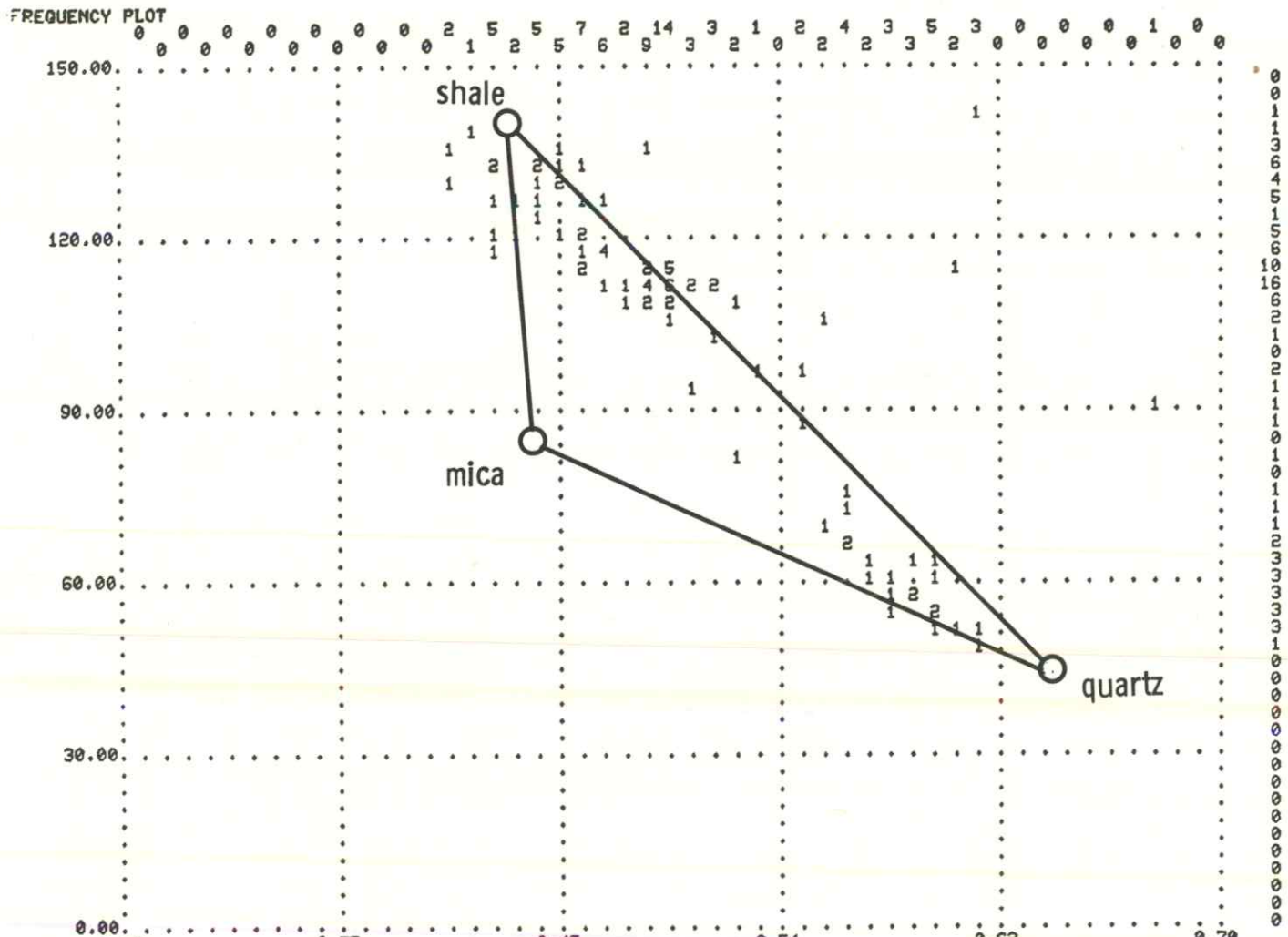
gopher menu

```
INPUT NAME OF DESIRED OPTION
CROSSPLOT
```

---

(15)

```
CROSSPLOT PROGRAM
01=DEPTH                02=SP                   03=GR
04=DENSITY              05=SONIC                06=GNT/SNP %
07=CNL %                08=NEUTRON COUNT        09=LL8
10=ILM                  11=ILD                  12=DEEP LATEROLOG
13=MICRORESISTIVITY     14=AZIMUTH              15=DIP
16=TEMPERATURE          17=INTEGRATED SONIC     18=CALIPER
CORE SO%                20=                     21=PETRA SS
22=PETRA LS             23=PETRA DOL            24=PETRA SH
25=PETRA AN             26=PETRA HL             27=PETRA CL
28=PETRA POR            29=PETRA 2POR           30=PHIRA
31=SX0                  32=SW                   33=K
34=DI                   35=RT                   36=RX0
37=RWA                  38=M                    39=N
40=P                    41=ARCHIE M             42=SYNTH SEISM
43=MODEL SONIC          44=MODEL INT SONIC      45=
46=                     47=                     48=
49=                     50=ALPHA                51=BETA
52=GAMMA                53=DELTA                54=EPSILON
55=OMEGA
CROSSPLOT PROGRAM
    PARAMETERS FOR HORIZONTAL AXIS
         LOG NUMBER (01-55)
39
         LEFTMOST VALUE
0.3
         RIGHTMOST VALUE
0.7
    PARAMETERS FOR VERTICAL AXIS
         LOG NUMBER (01-55)
03
         BOTTOMMOST VALUE
0.
         TOPMOST VALUE
150.
    PARAMETERS FOR Z AXIS
         CROSSPLOT -- LOG NUMBER 0
         ZPLOT ------ LOG NUMBER 01-55
0
   ENTER MINIMUM DEPTH DESIRED
650.
   ENTER MAXIMUM DEPTH DESIRED
750.
```



101 POINTS ARE USED IN THIS PLOT
7 POINTS ARE OUTSIDE PLOT
WELL NAME: MONROE 1-T
DEPTH INTERVAL USED IS 650.000 750.000
HORIZONTAL AXIS IS 39=N
VERTICAL AXIS IS 03=GR

gopher menu

(17)

```
INPUT NAME OF DESIRED OPTION
PETRA
```

(18)

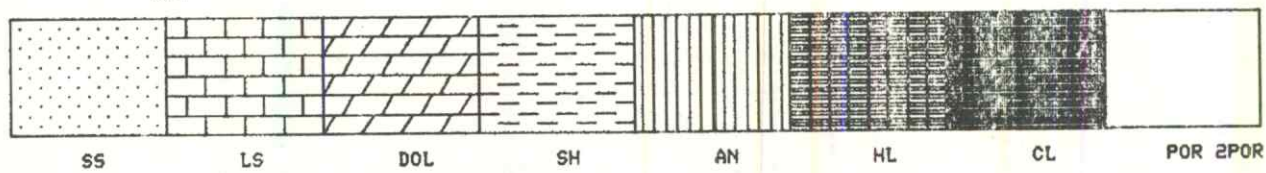
```
PROGRAM PETRA: MINERALOGICAL/LITHOLOGICAL COMPONENT
    ESTIMATION FOR PETROPHYSICAL WELL LOGS
TOTAL INTERVAL AVAILABLE   650.00 TO   750.00
DO YOU WANT THE ENTIRE INTERVAL - YES OR NO
YES
SELECT DESIRED CALCULATION/PLOTTING
    1=PLOT EXISTING VALUES
    2=CALCULATE AND PLOT NEW VALUES
    3=CALCULATE NEW VALUES
    4=APPLY INVERSE SHARPENING FILTER
2
SELECT PLOTTING OPTION
    1=POLYGON
    2=BLOCK
1
THE FOLLOWING WELL LOGS ARE AVAILABLE
    GAMMA
    DENSITY
    NEUTRON
NUMBER OF LOGS - MAXIMUM OF 5
3
NUMBER OF COMPONENTS - MAXIMUM OF 9
4
TYPE OF LOGS LISTED BY INPUT ORDER
    CAN USE DENSITY,NEUTRON,SONIC,GAMMA,SP
LOG 1
GAMMA
LOG 2
DEN
LOG 3
NEU
TYPE OF COMPONENTS DESIRED
    CAN USE SS,LS,DOL,SH,AN,HL,CL,POR,2POR
COMPONENT 1
POR
COMPONENT 2
SS
COMPONENT 3
AN
CONPONENT 4
SH
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
LIST
              POR      SS       AN       SH
GAMMA       10.00   30.00    10.00   100.00
DENSITY      1.00    2.65     2.98     2.50
NEUTRON    100.00   -5.00    -0.20    40.00
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
GAMMA
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
POR
ENTER NEW COEFFICIENT VALUE
45.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
GAMMA
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
SS
ENTER NEW COEFFICIENT VALUE
45.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
GAMMA
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
AN
ENTER NEW COEFFICIENT VALUE
85.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
GAMMA
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
SH
ENTER NEW COEFFICIENT VALUE
140.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
DENS
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
AN
ENTER NEW COEFFICIENT VALUE
2.82
```

```
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
DENS
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
SH
ENTER NEW COEFFICIENT VALUE
2.55
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
NEU
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
AN
ENTER NEW COEFFICIENT VALUE
20.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DO
NE
NEU
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
SH
ENTER NEW COEFFICIENT VALUE
33.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
LIST
                POR      SS      AN      SH
GAMMA         45.00   45.00   85.00  140.00
DENSITY        1.00    2.65    2.82    2.55
NEUTRON      100.00   -5.00   20.00   33.00
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
DONE
INPUT ANY MODIFICATIONS TO COMPONENT KEY
AN = MUSCOVITE
```

```
WELL NAME: MONROE 1-T
 LOCATION: SE 9 21S 22E  KANSAS  DEC 18, 1976
 INTERVAL:   650.00 TO   750.00 BY 1.00
     LOGS: GAMMA     DENSITY   NEUTRON
COMPONENTS: POR   SS    AN    SH
```

19

KEY



MODIFICATIONS: AN = MUSCOVITE

20

INPUT COEFFICIENTS:

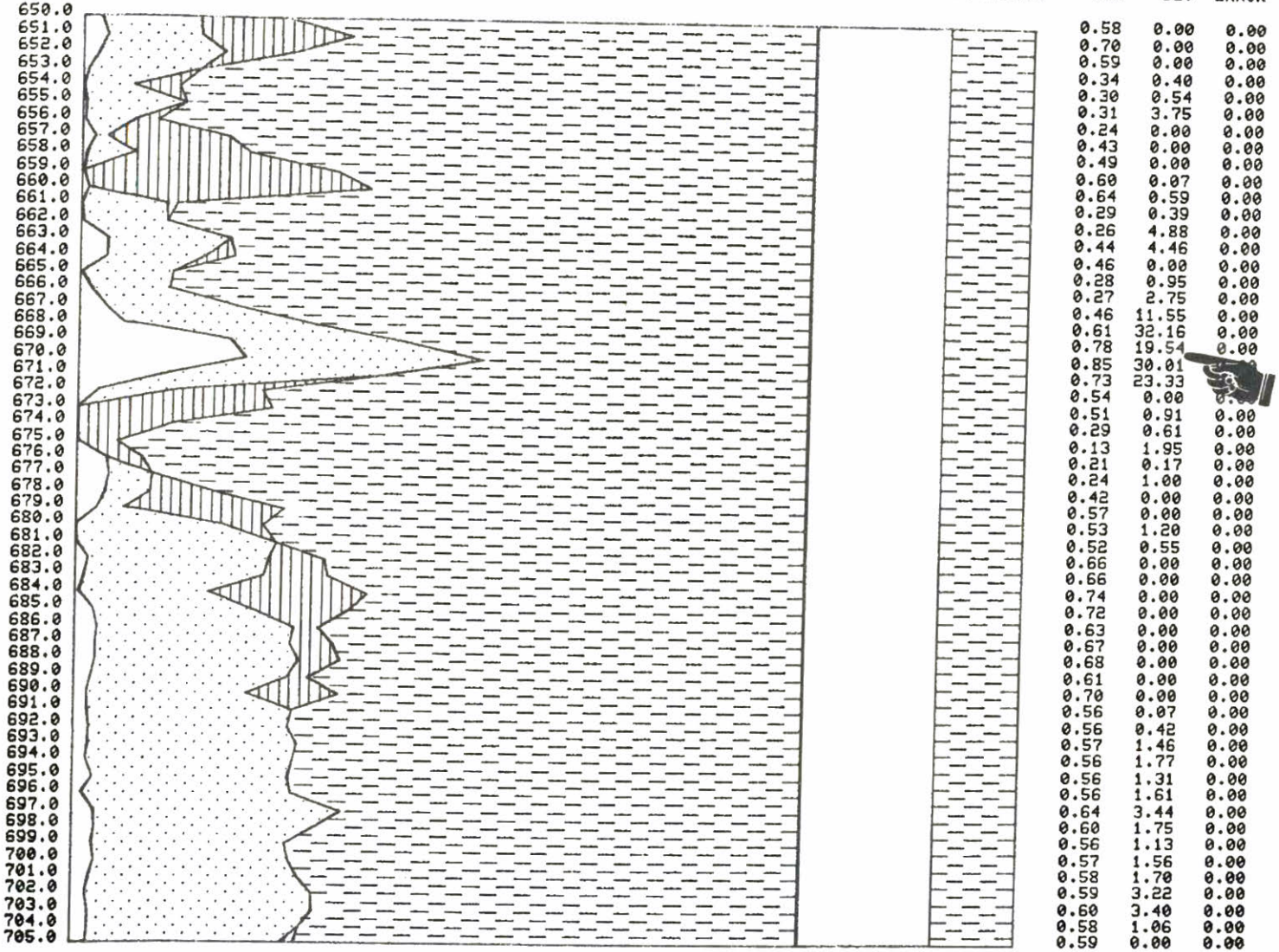
	POR	SS	AN	SH
GAMMA	45.00	45.00	85.00	140.00
DENSITY	1.00	2.65	2.82	2.55
NEUTRON	100.00	-5.00	20.00	33.00

EQUATIONS EQUAL UNKNOWNS N+1=M

SOLUTION CALCULATED BY MATRIX INVERSION

```
IS THE ABOVE INFORMATION CORRECT - YES OR NO
YES
```

WELL NAME: MONROE 1-T



PROP VAR	SUM DEV	ERROR
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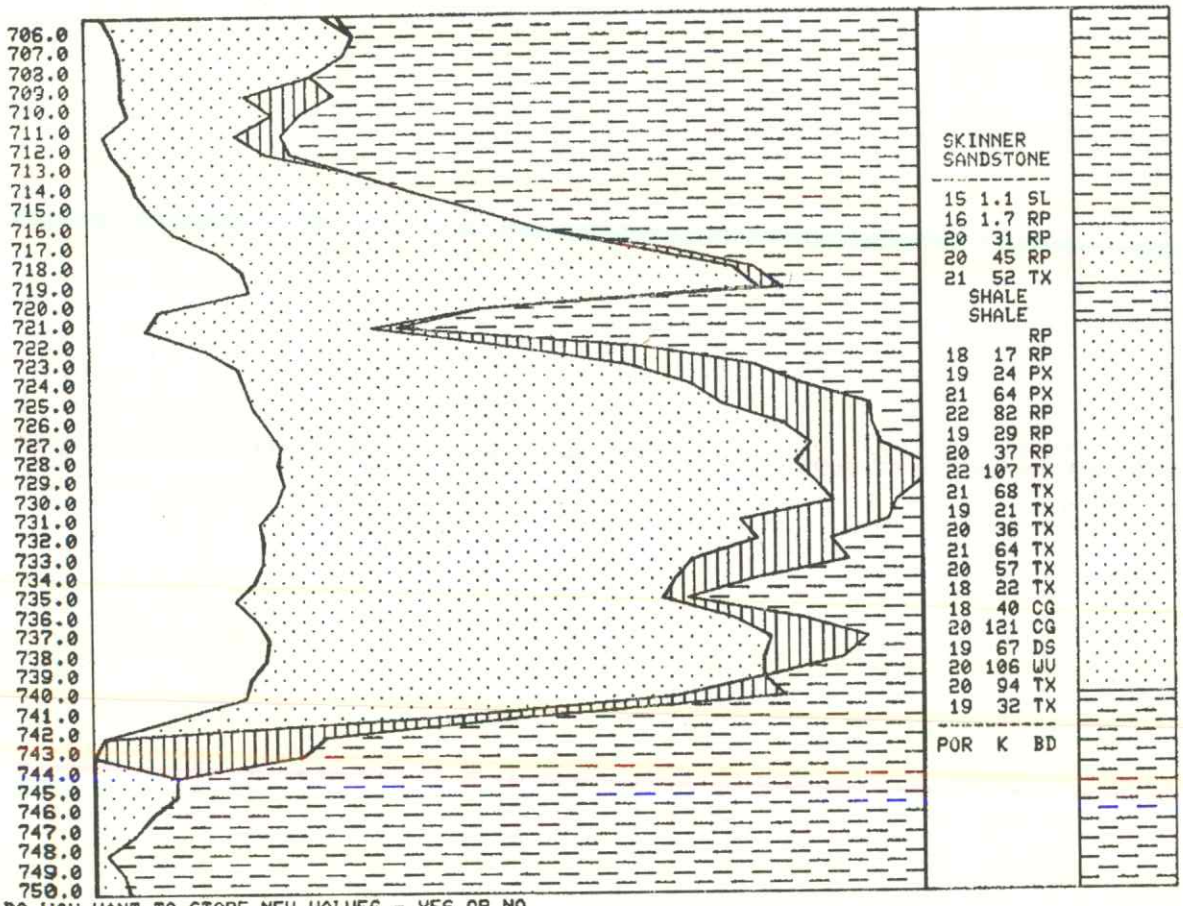
0.70	0.00	0.00
0.59	0.00	0.00
0.34	0.40	0.00
0.30	0.54	0.00
0.31	3.75	0.00
0.24	0.00	0.00
0.43	0.00	0.00
0.49	0.00	0.00
0.60	0.07	0.00
0.64	0.59	0.00
0.29	0.39	0.00
0.26	4.88	0.00
0.44	4.46	0.00
0.46	0.00	0.00
0.28	0.95	0.00
0.27	2.75	0.00
0.46	11.55	0.00
0.61	32.16	0.00
0.78	19.54	0.00
0.85	30.01	0.00
0.73	23.33	0.00
0.54	0.00	0.00
0.51	0.91	0.00
0.29	0.61	0.00
0.13	1.95	0.00
0.21	0.17	0.00
0.24	1.00	0.00
0.42	0.00	0.00
0.57	0.00	0.00
0.53	1.20	0.00
0.52	0.55	0.00
0.66	0.00	0.00
0.66	0.00	0.00
0.74	0.00	0.00
0.72	0.00	0.00
0.63	0.00	0.00
0.67	0.00	0.00
0.68	0.00	0.00
0.61	0.00	0.00
0.70	0.00	0.00
0.56	0.07	0.00
0.56	0.42	0.00
0.57	1.46	0.00
0.56	1.77	0.00
0.56	1.31	0.00
0.56	1.61	0.00
0.64	3.44	0.00
0.60	1.75	0.00
0.56	1.13	0.00
0.57	1.56	0.00
0.58	1.70	0.00
0.59	3.22	0.00
0.60	3.40	0.00
0.58	1.06	0.00
0.59	0.00	0.00



0.60	1.32	0.00
0.59	1.16	0.00
0.55	0.60	0.00
0.62	0.00	0.00
0.55	0.00	0.00
0.51	0.00	0.00
0.52	0.00	0.00
0.61	0.09	0.00
0.68	1.53	0.00
0.74	1.33	0.00
0.78	0.96	0.00
0.83	0.00	0.00
0.76	0.00	0.00
0.74	0.00	0.00
0.74	3.73	0.00
0.69	0.00	0.00
0.94	0.00	0.00
0.90	0.00	0.00
0.85	0.00	0.00
0.81	0.00	0.00
0.74	0.00	0.00
0.70	0.00	0.00
0.72	0.04	0.00
0.69	1.15	0.00
0.66	0.00	0.00
0.78	0.00	0.00
0.78	0.00	0.00
0.86	0.00	0.00
0.87	0.00	0.00
0.83	0.00	0.00
0.80	0.00	0.00
0.76	0.00	0.00
0.77	0.00	0.00
0.72	0.32	0.00
0.86	0.00	0.00
0.86	0.00	0.00
0.54	4.01	0.00
0.50	5.66	0.00
0.24	17.38	0.00
0.23	19.80	0.00
0.17	16.27	0.00
0.12	12.70	0.00
0.03	9.84	0.00
0.09	10.89	0.00
0.10	12.10	0.00

DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES
ARE YOU FINISHED WITH PETRA - YES OR NO
NO

22

```
PROGRAM PETRA: MINERALOGICAL/LITHOLOGICAL COMPONENT
    ESTIMATION FOR PETROPHYSICAL WELL LOGS
TOTAL INTERVAL AVAILABLE   650.00 TO   750.00
DO YOU WANT THE ENTIRE INTERVAL - YES OR NO
NO
TOP OF INTERVAL (FEET)
667.
BOTTOM OF INTERVAL (FEET)
671.
SELECT DESIRED CALCULATION/PLOTTING
    1=PLOT EXISTING VALUES
    2=CALCULATE AND PLOT NEW VALUES
    3=CALCULATE NEW VALUES
    4=APPLY INVERSE SHARPENING FILTER
2
SELECT PLOTTING OPTION
    1=POLYGON
    2=BLOCK
1
THE FOLLOWING WELL LOGS ARE AVAILABLE
    GAMMA
    DENSITY
    NEUTRON
NUMBER OF LOGS - MAXIMUM OF 5
2
NUMBER OF COMPONENTS - MAXIMUM OF 9
2
TYPE OF LOGS LISTED BY INPUT ORDER
    CAN USE DENSITY,NEUTRON,SONIC,GAMMA,SP
LOG 1
DENS
LOG 2
NEU
TYPE OF COMPONENTS DESIRED
    CAN USE SS,LS,DOL,SH,AN,HL,CL,POR,2POR
COMPONENT 1
CL
COMPONENT 2
SH
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
LIST
              CL       SH
DENSITY      1.60     2.55
NEUTRON     50.00    33.00
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
DENS
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
CL
ENTER NEW COEFFICIENT VALUE
1.77
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
NEU
ENTER COMPONENT DESIRED - SS,LS,DOL,SH,AN,HL,CL,POR,2POR
CL
ENTER NEW COEFFICIENT VALUE
48.
ENTER MODIFICATION DESIRED - GAMMA,DENSITY,SONIC,NEUTRON,SP,LIST,DONE
DONE
INPUT ANY MODIFICATIONS TO COMPONENT KEY
```

23

INPUT COEFFICIENTS:

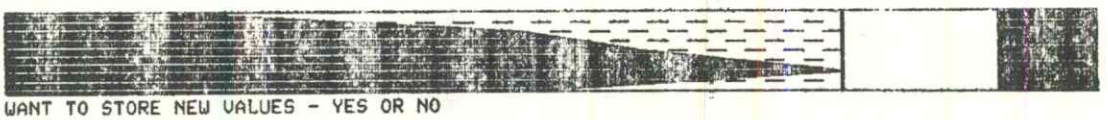
	CL	SH
DENSITY	1.77	2.55
NEUTRON	48.00	33.00

```
EQUATIONS EXCEED UNKNOWNS      N+1>M
SOLUTION CALCULATED BY LEAST SQUARES
IS THE ABOVE INFORMATION CORRECT - YES OR NO
YES
```

WELL NAME: MONROE 1-T

24

DEPTH COMPONENTS COMMENTS LITHOLOGY



667.0
668.0
669.0
670.0
671.0

DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES
ARE YOU FINISHED WITH PETRA - YES OR NO
YES

PROP VAR	SUM DEV	ERROR
0.62	0.00	2.38
0.94	0.00	3.54
0.73	0.00	1.45
0.00	0.00	0.00
0.94	0.00	2.94

25

gopher menu

INPUT NAME OF DESIRED OPTION
STAT

26

SUMMARY STATISTICS AND HISTOGRAMS
TOTAL INTERVAL AVAILABLE 650.00 TO 750.00
DO YOU WANT THE TOTAL INTERVAL - YES OR NO
NO
ENTER MINIMUM DEPTH DESIRED
650.
ENTER MAXIMUM DEPTH DESIRED
665.

WELL NAME: MONROE 1-T
LOCATION: SE 9 21S 22E KANSAS
DATE: DEC 18, 1976
INTERVAL: 650.00 TO 665.00

LOG NUMBER	AVAILABILITY FOR USAGE AVAILABLE	NUMBER OF VALUES	NUMBER OF VALUES DEFAULTED	MINIMUM VALUE	MAXIMUM VALUE	AVERAGE VALUE
01=DEPTH	YES	16	0	650.00	665.00	657.50
02=SP	NO					
03=GR	YES	16	0	114.00	137.00	125.62
04=DENSITY	YES	16	0	2.46	2.64	2.55
05=SONIC	NO					
06=GNT/SNP %	NO					
07=CNL %	YES	16	0	26.90	31.30	29.16
08=NEUTRON COUNT	NO					
09=LL8	NO					
10=ILM	NO					
11=ILD	YES	16	0	6.50	10.70	8.91
12=DEEP LATEROLOG	NO					
13=MICRORESISTIVITY	NO					
14=AZIMUTH	NO					
15=DIP	NO					
16=TEMPERATURE	NO					
17=INTEGRATED SONIC	NO					
18=CALIPER	NO					
CORE SO%	YES	0	16			
20=	YES	16	0	0.00	4.88	1.00
21=PETRA SS	YES	16	0	0.00	0.16	0.09
22=PETRA LS	NO					
23=PETRA DOL	NO					
24=PETRA SH	YES	16	0	0.60	0.90	0.79
25=PETRA AN	YES	16	0	0.00	0.38	0.10
26=PETRA HL	NO					
27=PETRA CL	YES	0	16			
28=PETRA POR	YES	16	0	0.00	0.03	0.01
29=PETRA 2POR	NO					
30=PHIRA	NO					
31=SX0	NO					
32=SW	YES	16	0	1.00	178.45	50.30
33=K	YES	16	0	0.00	1.00	0.12
34=DI	NO					
35=RT	NO					
36=RX0	NO					
37=RWA	NO					
38=M	YES	0	16			
39=N	YES	16	0	0.43	0.47	0.45
40=P	YES	0	16			
41=ARCHIE M	YES	13	3	2.51	2.64	2.57
42=SYNTH SEISM	NO					
43=MODEL SONIC	NO					
44=MODEL INT SONIC	NO					
45=	YES	15	1	107.50	147.69	124.44
46=	YES	6	10	4.55	5.18	4.99
47=	NO					
48=	NO					
49=	NO					
50=ALPHA	YES	16	0	0.24	0.70	0.43
51=BETA	YES	16	0	0.00	4.88	1.00
52=GAMMA	YES	16	0	0.00	0.00	0.00
53=DELTA	YES	0	16			
54=EPSILON	YES	0	16			
55=OMEGA	YES	0	16			

CONSTANTS	VALUE
01=MINIMUM DEPTH	650.00
02=MAXIMUM DEPTH	750.00
03=INCREMENT	1.00
04=ELEVATION	-9999.00
05=LATITUDE	-9999.00
06=LONGITUDE	-9999.00
07=RM	-9999.00
08=TRM	-9999.00
09=RMF	0.15
10=TRMF	72.00
11=RMC	-9999.00
12=TRMC	-9999.00
13=BHT	79.00
14=MEAN-T	57.00
15=T-GRADIENT	-9999.00
16=TIME-C-GR	-9999.00
17=TIME-C-N	-9999.00
18=LOG SPEED GR	-9999.00
19=LOG SPEED N	-9999.00
20=TD	779.00
21=	-9999.00
22=	-9999.00
23=	-9999.00
24=	-9999.00
25=	-9999.00
26=	-9999.00
27=	-9999.00
28=	-9999.00
29=	-9999.00
30=	-9999.00
31=	-9999.00
32=	-9999.00
33=	-9999.00
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37=	-9999.00
38=	-9999.00
39=	-9999.00
40=	-9999.00
41=	-9999.00
42=	-9999.00
43=	-9999.00
44=	-9999.00
45=	-9999.00
46=	-9999.00
47=	-9999.00
48=TOP VIOLA	-9999.00
49=TOP SIMPSON	-9999.00
50=TOP ARBUCKLE	-9999.00
51=	-9999.00
52=	-9999.00
53=	-9999.00
54=	-9999.00
55=	-9999.00
56=	-9999.00
57=	-9999.00
58=	-9999.00
59=	-9999.00
60=	-9999.00

(28)

```
DO YOU WANT ANOTHER DEPTH INTERVAL- YES OR NO
NO
DO YOU WANT A HISTOGRAM PRODUCED - YES OR NO
NO
```

---

(29)

gopher menu

```
INPUT NAME OF DESIRED OPTION
KOBRA
```

---

(30) (31)

```
KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    RPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
DEPTH
TOTAL INTERVAL AVAILABLE   650.00 TO   750.00
SELECTED INTERVAL  650.00 TO   750.00
DO YOU WANT THE SELECTED INTERVAL - YES OR NO
NO
ENTER MINIMUM DEPTH DESIRED
714.
ENTER MAXIMUM DEPTH DESIRED
741.
KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    RPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
SHSAT

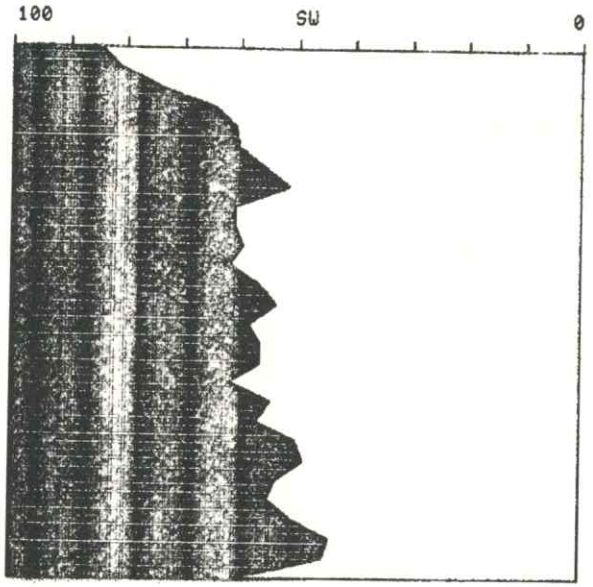
SHSAT OPTION SELECTED
THE FOLLOWING RESISTIVITY LOGS ARE AVAILABLE
    11-ILD
SELECT TRACK NUMBER OF RESISTIVITY TO BE USED
11
SPECIFY RW
0.5
SPECIFY RW TEMPERATURE (DEG F)

SPECIFY ARCHIE EQUATION CONSTANTS - A,M
1.
2.1
SPECIFY RSH
9.
```

WATER SATURATION COMPUTATION (SHALY-SAND)
WELL NAME: MONROE 1-T
DEPTH INTERVAL: 714.00 741.00
RESISTIVITY LOG: 11=ILD
FORMATION TEMPERATURE: 67.9 DEG F
RW: 0.500
A= 1.00 M= 2.10 N= 2.00 RSH= 9.00
SW = WATER SATURATION
SWLS=LAMINATED SHALE SWDS=DISPERSED SHALE SWT=TOTAL SHALE

DEPTH	VSH	PHI	R	SWLS	SWDS	SWTS
714.0	0.607	0.058	15.10	1.00	1.00	0.84
715.0	0.530	0.075	16.60	0.26	1.00	0.81
716.0	0.451	0.102	18.70	0.33	1.00	0.73
717.0	0.300	0.155	22.10	0.45	1.00	0.64
718.0	0.199	0.184	25.00	0.49	1.00	0.60
719.0	0.166	0.192	25.90	0.51	1.00	0.60
720.0	0.529	0.082	25.10	1.00	1.00	0.55
721.0	0.629	0.067	24.40	1.00	1.00	0.51
722.0	0.336	0.140	24.40	0.26	1.00	0.60
723.0	0.201	0.178	25.90	0.49	1.00	0.60
724.0	0.144	0.186	29.50	0.50	1.00	0.59
725.0	0.062	0.196	32.60	0.58	1.00	0.61
726.0	0.059	0.213	32.90	0.53	1.00	0.56
727.0	0.048	0.229	32.70	0.51	1.00	0.53
728.0	0.000	0.227	32.90	0.58	1.00	0.58
729.0	0.000	0.233	33.10	0.56	1.00	0.56
730.0	0.031	0.224	32.80	0.54	1.00	0.56
731.0	0.040	0.203	32.30	0.59	1.00	0.61
732.0	0.109	0.208	31.70	0.48	1.00	0.54
733.0	0.089	0.207	31.30	0.52	1.00	0.56
734.0	0.202	0.197	31.00	0.34	1.00	0.50
735.0	0.282	0.173	31.10	0.10	1.00	0.48
736.0	0.144	0.199	31.90	0.43	1.00	0.53
737.0	0.067	0.213	34.00	0.51	1.00	0.54
738.0	0.096	0.209	37.30	0.43	1.00	0.50
739.0	0.191	0.191	40.90	0.20	1.00	0.44
740.0	0.166	0.185	44.30	0.24	1.00	0.45
741.0	0.482	0.096	23.00	1.00	1.00	0.61

DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES
WHICH TYPE IS STORED AS SW OR SX0 -- SWLS,SWDS,SWT
SWT



(33)

```
KOBRA RESERVOIR ANALYSIS MODULE

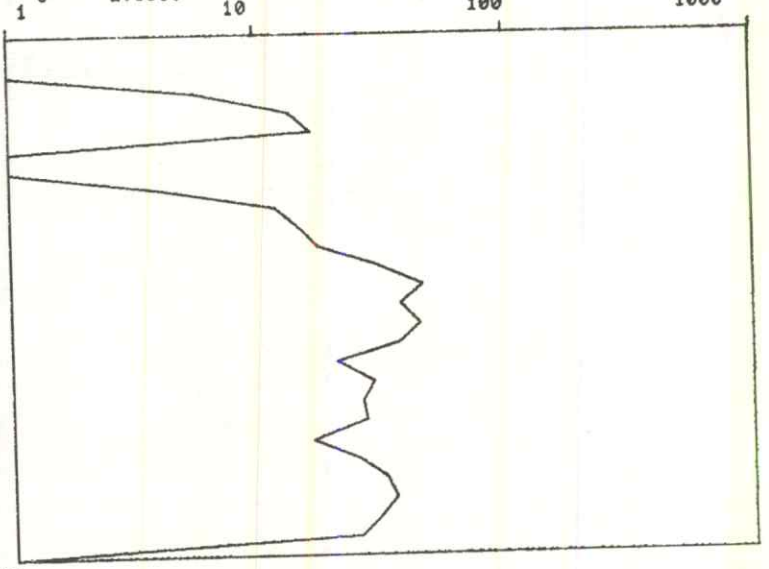
    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    RPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
PERM
PERM OPTION SELECTED
DO YOU WANT TO USE SWI IN PREDICTION - YES OR NO
YES
PERMEABILITY INDEX COMPUTED FROM EQUATION
OF THE FORM: K = A * (PHI**B) / (SWI**C)
PHI AND SWI ARE IN PERCENTAGE
DO YOU HAVE VALUES FOR A,B,C - YES OR NO
NO
SANDSTONE OR CARBONATE - SS,LS
SS
```

(34)

```
PERM COMPUTATION
    WELL NAME: MONROE 1-T
          DEPTH INTERVAL:      714.00    741.00
          BASED ON POROSITY AND WATER SATURATION
          A=    0.1360     B=    4.4000     C=    2.0000
```

DEPTH	VSH	PHI	SW	K
714.0	0.607	0.058	0.843	0.04
715.0	0.530	0.075	0.811	0.15
716.0	0.451	0.102	0.737	0.68
717.0	0.300	0.155	0.644	5.67
718.0	0.199	0.184	0.607	13.68
719.0	0.166	0.192	0.602	16.93
720.0	0.529	0.082	0.558	0.46
721.0	0.629	0.067	0.513	0.23
722.0	0.336	0.140	0.609	4.10
723.0	0.201	0.178	0.609	11.86
724.0	0.144	0.186	0.594	15.07
725.0	0.062	0.196	0.615	17.54
726.0	0.059	0.213	0.566	30.06
727.0	0.048	0.229	0.536	46.21
728.0	0.000	0.227	0.583	37.50
729.0	0.000	0.233	0.565	44.70
730.0	0.031	0.224	0.565	37.18
731.0	0.040	0.203	0.617	20.52
732.0	0.109	0.208	0.545	29.12
733.0	0.089	0.207	0.569	26.31
734.0	0.202	0.197	0.502	27.08
735.0	0.282	0.173	0.488	16.28
736.0	0.144	0.199	0.535	24.96
737.0	0.067	0.213	0.548	32.18
738.0	0.096	0.209	0.505	34.91
739.0	0.191	0.191	0.442	30.30
740.0	0.166	0.185	0.452	25.06
741.0	0.482	0.096	0.611	0.78




```
DO YOU WANT TO STORE NEW VALUES - YES OR NO
YES
```

35

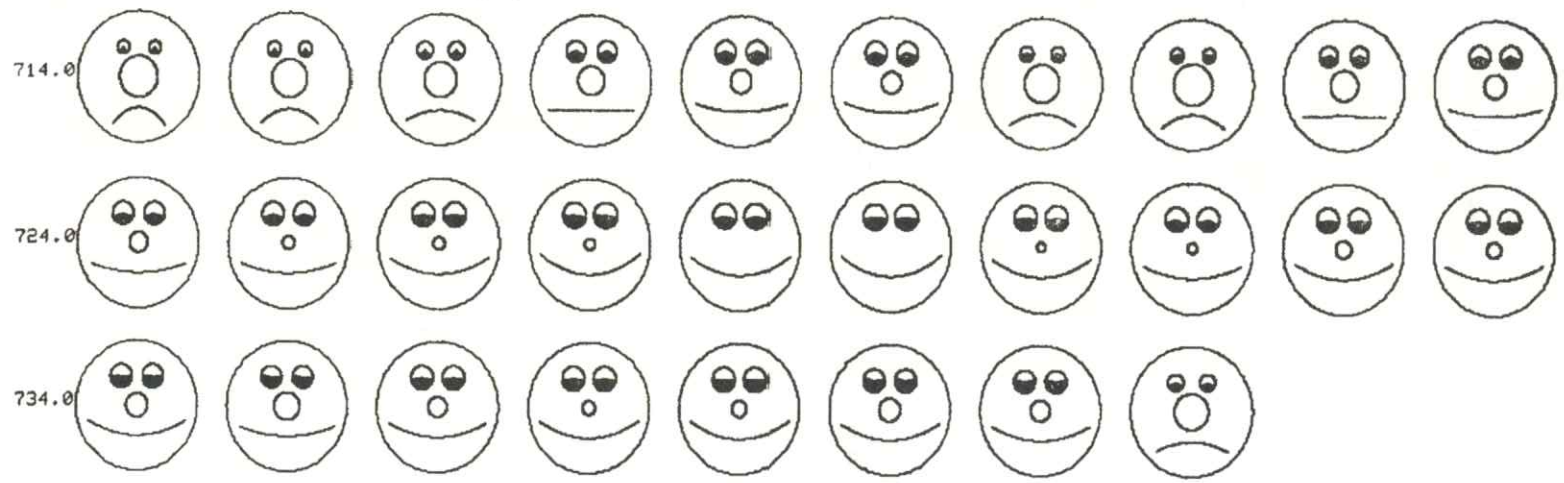
```
KOBRA RESERVOIR ANALYSIS MODULE

     DEPTH ----- SELECT DESIRED DEPTH INTERVAL
     TORNADO --- SMALL SLAM INVASION PARAMETERS
     RPPLOT ---- PICKETT PLOT
     SPRW ------ WATER RESISTIVITY FROM SP
     PWA ------- RECONNAISSANCE WATER RESISTIVITY
     PHIRA ----- WATER-FILLED POROSITY
     POREG ----- PORE GEOMETRY
     CLSAT ----- WATER SATURATION (SHALE-FREE)
     SHSAT ----- WATER SATURATION (SHALY MODELS)
     WASP ------ WAXMAN-SMITS MODEL
     PERM ------ PERMEABILITY INDEX
     CHERNOFF -- PHI.SW.SH.VSH.K FACES
     STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
CHERNOFF
```

36

CHERNOFF FACES
WELL NAME: MONROE 1-T
DEPTH INTERVAL: 714.00 TO 741.00



37

```
KOBRA RESERVOIR ANALYSIS MODULE

    DEPTH ----- SELECT DESIRED DEPTH INTERVAL
    TORNADO --- SMALL SLAM INVASION PARAMETERS
    PPPLOT ---- PICKETT PLOT
    SPRW ------ WATER RESISTIVITY FROM SP
    RWA ------- RECONNAISSANCE WATER RESISTIVITY
    PHIRA ----- WATER-FILLED POROSITY
    POREG ----- PORE GEOMETRY
    CLSAT ----- WATER SATURATION (SHALE-FREE)
    SHSAT ----- WATER SATURATION (SHALY MODELS)
    WASP ------ WAXMAN-SMITS MODEL
    PERM ------ PERMEABILITY INDEX
    CHERNOFF -- PHI.SW.SH.VSH.K FACES
    STOP ------ KOBRA EXIT

INPUT NAME OF DESIRED OPTION
STOP
```

38

gopher menu

```
INPUT NAME OF DESIRED OPTION
LOGPLOT
```

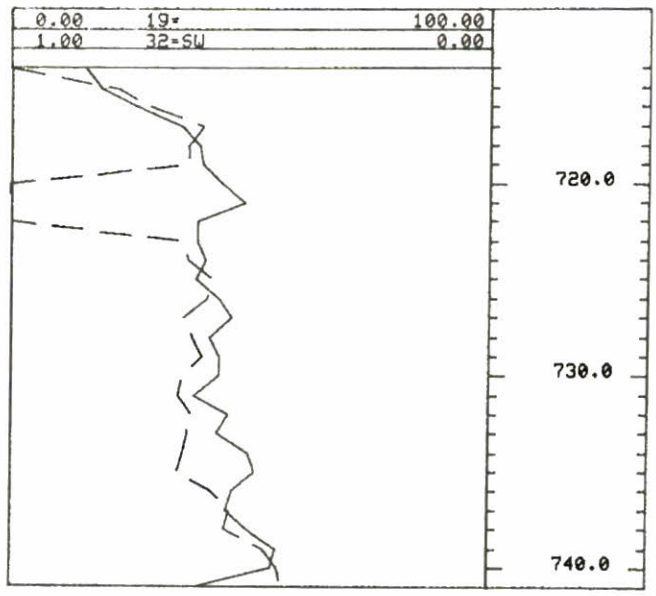
39

```
PROGRAM TO PLOT WELL LOGS
TOTAL INTERVAL AVAILABLE   650.00 TO   750.00
DO YOU WANT THE ENTIRE INTERVAL - YES OR NO
NO
ENTER MINIMUM DEPTH
714.
ENTER MAXIMUM DEPTH
741.
WELL LOGS
 01=DEPTH                02=SP                   03=GR
 04=DENSITY              05=SONIC                06=GNT/SNP %
 07=CNL %                08=NEUTRON COUNT        09=LL8
 10=ILM                  11=ILD                  12=DEEP LATEROLOG
 13=MICRORESISTIVITY     14=AZIMUTH              15=DIP
 16=TEMPERATURE          17=INTEGRATED SONIC     18=CALIPER
 19=                     20=                     21=PETRA SS
 22=PETRA LS             23=PETRA DOL            24=PETRA SH
 25=PETRA AN             26=PETRA HL             27=PETRA CL
 28=PETRA POR            29=PETRA 2POR           30=PHIRA
 31=SX0                  32=SW                   33=K
 34=DI                   35=RT                   36=RX0
 37=RWA                  38=M                    39=N
 40=P                    41=ARCHIE M             42=SYNTH SEISM
 43=MODEL SONIC          44=MODEL INT SONIC      45=
 46=                     47=                     48=
 49=                     50=ALPHA                51=BETA
 52=GAMMA                53=DELTA                54=EPSILON
 55=OMEGA
WILL TRACK 1 AND POSITION 1
BE USED - YES OR NO
YES
ENTER LOG NUMBER - 01 TO 55
19
ENTER TYPE OF SCALING
    1=LINEAR
    2=LOGARITHMIC BASE 10
    3=LOGARITHMIC BASE E
    4=EXPONENTIAL BASE 10
    5=EXPONENTIAL BASE E
1
ENTER LEFTMOST VALUE TO BE PLOTTED
0.
ENTER RIGHTMOST VALUE TO BE PLOTTED
100.
ENTER LINE WEIGHT TO BE USED
       1=SOLID LINE
       2=DASHED LINE
       3=DOTTED LINE
2
```

```
ENTER METHOD OF HANDLING OFF-SCALE DATA
    1=CLIP
    2=REFLECT
1
WILL TRACK 1 AND POSITION 2
BE USED - YES OR NO
YES
ENTER LOG NUMBER - 01 TO 55
32
ENTER TYPE OF SCALING
    1=LINEAR
    2=LOGARITHMIC BASE 10
    3=LOGARITHMIC BASE E
    4=EXPONENTIAL BASE 10
    5=EXPONENTIAL BASE E
1
ENTER LEFTMOST VALUE TO BE PLOTTED
1.0
ENTER RIGHTMOST VALUE TO BE PLOTTED
0.
ENTER LINE WEIGHT TO BE USED
        1=SOLID LINE
        2=DASHED LINE
        3=DOTTED LINE
1
ENTER METHOD OF HANDLING OFF-SCALE DATA
    1=CLIP
    2=REFLECT
1
WILL TRACK 1 AND POSITION 3
BE USED - YES OR NO
NO
WILL TRACK 2 AND POSITION 1
BE USED - YES OR NO
NO
WILL TRACK 3 AND POSITION 1
BE USED - YES OR NO
NO
DO YOU WANT SHADING BETWEEN LOGS - YES OR NO
NO
```

40

WELL NAME: MONROE 1-T




```
DO YOU WANT A DIFFERENT DEPTH - YES OR NO
NO
```

41

gopher menu

```
INPUT NAME OF DESIRED OPTION
BYE
```

CASE STUDY 5: DIPMETER

The Cherokee sandstones of Kansas often take the form of elongate, "shoestring" bodies, whose location and orientation is often difficult to determine without recourse to an extensive drilling program. The dipmeter results of this case study were taken from one of several dipmeter surveys made in a set of neighboring wells through a Cherokee section which contained a productive development of the Bartlesville sandstone.

The purpose of the dipmeter work was to deduce the long-axis orientation of the sandstone and to determine the geographic location of the central axis (the thickest part of the sandstone) as related to existing well control. A successful analysis would enable a more efficient siting of further development wells.

Stratigraphic cross-sections of shoestring sandstones in the area are generally somewhat irregular in shape, although a basic bi-convex profile is suggested by both the increased elevation of marker limestones overlying the sandstones (Van Dyke, 1975) and the erosional lower contacts. As a consequence of this geological model, compactional drape may be anticipated in shale sections immediately above the sandstone, which should dip away from the sandstone medial axis.

The case-study data (Table 9) are taken from C.R.A., Inc. Woodward No. 4, 12-25S-21E, Bourbon County, Kansas, for the section between 500 and 700 feet depth and consist of gamma ray (cps), azimuth and dip values. (While gamma ray is continuously digitally sampled, the dips and azimuths are real values at discrete depths, and are defaulted at intervening depths.)

The Bartlesville sandstone is located between 640-670 feet, with shales below, and a predominantly shale section above, which includes a coal and some thin limestones.

OUTPUT COMMENTARY

1 GOPHER menu. "KERMIT" prompt.

2 KERMIT menu. "DEPTH" prompt. Selection of shale section immediately overlying the sandstone in the depth range 600-640 feet. KERMIT menu. "TADPOLE" prompt. Stipulation of vector plot with linear scale, range 0 to 15 degrees, and one degree tic-mark spacing. (An appropriate scaling convention and range may be deduced from STATISTICS option output.)

3 TADPOLE output.

4 KERMIT menu. "ROSE" prompt.

5 ROSE output. Azimuth frequency plot.

6 KERMIT menu. "POLAR" prompt. A Schmidt net (Lambert Equal-Area) projection is selected. Since the dips in this interval are fairly shallow, the outer boundary of the projection is set at 15 degrees, with reference circles at 5-degree spacing.

7 POLAR output.

8 KERMIT menu. "2DYCL" prompt. The gamma ray is used as a reference log with scaling range set between 0-150 cps.

9 2DCYL output. A transparency of the hard-copy may be rolled on the depth axis to provide a physical model of dip orientations.

10 KERMIT menu. "3DCYL" prompt. Gamma ray reference log. Viewpoint from the south (azimuth 180).

11 3DCYL output. Hypothetical borehole viewed from infinity with traces marked by intersection of dipping planes with the borehole wall. Solid perimeters are on borehole "nearside"; dashed perimeters on borehole "farside." Radial lines mark vectors of maximum dip.

12 KERMIT menu. "3DCYL" prompt. Gamma ray reference log. Viewpoint from the west (azimuth 270).

13 3DCYL output.

14 KERMIT menu. "EIGEN" prompt.

15 EIGEN output. Orientation analysis with results which include orientation tensor, eigenvalues and eigenvectors, azimuth, dip and scattering angle associated with the principal vector.

16 KERMIT menu. "STOP" prompt.

17 GOPHER menu. "BYE" prompt.

REMARKS

In practice, few users would run all the options TADPOLE, ROSE, POLAR, 2DCYL and 3DCYL in conjunction, since they are only alternative graphic convention displays of the same data. Instead, an option selection would be made as dictated by user preference and the nature of the problem at hand. However, all graphic displays show the generally westward orientation of dips in the shales immediately above the sandstone, and this is confirmed by the numerical results of the eigenanalysis.

As an exercise for the user, analysis may be made of dips in the upper part of the section (500-600). These show extremely low values with no systematic preferred orientation. The configuration of dips within the shale immediately overlying the sandstone are therefore consistent with a compactional drape model which places the well location on the western flank of the sandstone body, whose major axis is aligned in a north-south orientation.

As a further exercise, KERMIT may be applied to dips within the sandstone (640-670), which show a marked southward orientation. If these dips discriminate cross-bedding surfaces, they indicate current flow from north to south, depositional origin of the sandstone as a channel, and confirmation of the axis orientation deduced from the overlying shales. The conclusions drawn in this case study are readily compatible with current conceptions of the paleogeography and sedimentology of the Cherokee in this area (Shelton, 1973, p. 64)

o-o-o

Table 9
CASE STUDY 5 : DIPMETER DATA SET

WELL NAME: C.R.A. WOODWARD #4
LOCATION: 12-25S-21E KANSAS
DATE: 10-8-65

01-DEPTH	03-GR	14-AZIMUTH	15-DIP
500.000	120.780*999.000*999.000		
501.000	118.673	121.000	4.700
502.000	122.656*999.000*999.000		
503.000	124.464	100.000	3.700
504.000	125.691*999.000*999.000		
505.000	118.369	156.000	4.500
506.000	117.423*999.000*999.000		
507.000	120.100	132.000	2.600
508.000	113.940*999.000*999.000		
509.000	112.561	122.000	3.700
510.000	114.803*999.000*999.000		
511.000	117.624	0.000	0.000
512.000	119.721*999.000*999.000		
513.000	118.342	107.000	0.800
514.000	111.897*999.000*999.000		
515.000	107.913	27.000	1.900
516.000	108.997*999.000*999.000		
517.000	111.528	158.000	1.200
518.000	114.204	125.000	1.800
519.000	114.563	161.000	1.400
520.000	113.476*999.000*999.000		
521.000	111.232	154.000	1.400
522.000	113.473*999.000*999.000		
523.000	115.713	210.000	0.700
524.000	116.506*999.000*999.000		
525.000	114.552	97.000	0.700
526.000	111.586*999.000*999.000		
527.000	107.031	156.000	1.400
528.000	97.561*999.000*999.000		
529.000	91.562	72.000	2.800
530.000	93.804*999.000*999.000		
531.000	101.392	65.000	1.700
532.000	105.800*999.000*999.000		
533.000	112.085	143.000	1.400
534.000	113.457*999.000*999.000		
535.000	114.106	299.000	0.500
536.000	106.955*999.000*999.000		
537.000	112.516	358.000	2.100
538.000	113.309*999.000*999.000		
539.000	115.980	9.000	1.100
540.000	110.276*999.000*999.000		
541.000	111.792	50.000	1.500
542.000	114.174*999.000*999.000		
543.000	112.947	5.000	1.100
544.000	116.194*999.000*999.000		
545.000	114.101	48.000	1.500
546.000	112.153*999.000*999.000		
547.000	111.648*999.000*999.000		
548.000	115.904*999.000*999.000		
549.000	113.092*999.000*999.000		
550.000	106.385*999.000*999.000		
551.000	102.132*999.000*999.000		
552.000	87.353	291.000	1.600
553.000	86.852	217.000	2.800
554.000	88.081*999.000*999.000		
555.000	93.346	211.000	2.900
556.000	104.664*999.000*999.000		
557.000	106.755*999.000*999.000		
558.000	102.217*999.000*999.000		
559.000	98.978	42.000	1.500
560.000	103.375*999.000*999.000		
561.000	107.771*999.000*999.000		
562.000	105.972*999.000*999.000		
563.000	106.190	321.000	2.500
564.000	106.552*999.000*999.000		
565.000	100.434	249.000	2.200
566.000	103.101*999.000*999.000		
567.000	106.631	313.000	1.500
568.000	111.312*999.000*999.000		
569.000	108.939	236.000	3.400
570.000	110.884*999.000*999.000		
571.000	111.390*999.000*999.000		
572.000	121.105*999.000*999.000		
573.000	151.249*999.000*999.000		
574.000	200.089	86.000	2.700
575.000	226.191	16.000	3.200
576.000	267.390*999.000*999.000		
577.000	234.369	357.000	1.100
578.000	138.946*999.000*999.000		
579.000	128.665	134.000	1.300
580.000	133.626*999.000*999.000		
581.000	127.517	154.000	6.100
582.000	105.022*999.000*999.000		
583.000	103.086*999.000*999.000		
584.000	104.024*999.000*999.000		
585.000	111.859*999.000*999.000		
586.000	111.791*999.000*999.000		
587.000	108.130	62.000	2.500
588.000	105.333*999.000*999.000		
589.000	102.680	82.000	1.700
590.000	106.921*999.000*999.000		
591.000	101.827*999.000*999.000		
592.000	84.386*999.000*999.000		
593.000	112.749	31.000	4.800
594.000	110.814*999.000*999.000		
595.000	107.158	84.000	2.600
596.000	107.665	84.000	7.800
597.000	108.172*999.000*999.000		
598.000	110.114*999.000*999.000		
599.000	109.616*999.000*999.000		
600.000	115.144*999.000*999.000		
601.000	124.544*999.000*999.000		
602.000	125.766*999.000*999.000		
603.000	113.507*999.000*999.000		
604.000	104.118*999.000*999.000		
605.000	105.980	232.000	9.900
606.000	101.660*999.000*999.000		
607.000	104.556*999.000*999.000		
608.000	102.642*999.000*999.000		
609.000	102.703*999.000*999.000		
610.000	99.358*999.000*999.000		
611.000	97.272	316.000	7.800
612.000	94.659*999.000*999.000		
613.000	99.556*999.000*999.000		
614.000	101.985*999.000*999.000		
615.000	104.501	306.000	7.600
616.000	100.073*999.000*999.000		
617.000	98.528	308.000	9.700
618.000	102.521*999.000*999.000		
619.000	96.847	310.000	7.400
620.000	96.703*999.000*999.000		
621.000	102.100*999.000*999.000		
622.000	99.749*999.000*999.000		
623.000	97.613*999.000*999.000		
624.000	93.562*999.000*999.000		
625.000	99.387	176.000	5.300
626.000	99.611*999.000*999.000		
627.000	101.282*999.000*999.000		
628.000	104.895*999.000*999.000		
629.000	103.709*999.000*999.000		
630.000	96.988*999.000*999.000		
631.000	91.356*999.000*999.000		
632.000	83.537*999.000*999.000		
633.000	90.130*999.000*999.000		
634.000	87.112	272.000	8.500
635.000	90.077	262.000	11.600
636.000	75.455*999.000*999.000		
637.000	59.766	248.000	6.200
638.000	55.067	277.000	5.200
639.000	56.213*999.000*999.000		
640.000	62.333*999.000*999.000		
641.000	59.448*999.000*999.000		
642.000	56.275*999.000*999.000		
643.000	59.290*999.000*999.000		
644.000	63.392*999.000*999.000		
645.000	59.642*999.000*999.000		
646.000	61.573	64.000	1.600
647.000	58.841*999.000*999.000		
648.000	62.649	101.000	1.500
649.000	61.193*999.000*999.000		
650.000	57.051*999.000*999.000		
651.000	61.559	200.000	1.700
652.000	67.146*999.000*999.000		
653.000	64.279	172.000	4.800
654.000	62.859*999.000*999.000		
655.000	63.020	193.000	2.900
656.000	60.578*999.000*999.000		
657.000	52.882	168.000	3.600
658.000	54.074*999.000*999.000		
659.000	55.887*999.000*999.000		
660.000	58.736*999.000*999.000		
661.000	62.428*999.000*999.000		
662.000	65.772	176.000	2.800
663.000	65.354*999.000*999.000		
664.000	63.541*999.000*999.000		
665.000	56.710	173.000	4.600
666.000	57.204	177.000	6.400
667.000	61.483	168.000	6.700
668.000	75.303*999.000*999.000		
669.000	84.532*999.000*999.000		
670.000	105.664*999.000*999.000		
671.000	105.741	21.000	3.500
672.000	109.004*999.000*999.000		
673.000	105.492	158.000	2.700
674.000	106.871*999.000*999.000		
675.000	104.926	75.000	1.600
676.000	105.723*999.000*999.000		
677.000	108.803*999.000*999.000		
678.000	102.833*999.000*999.000		
679.000	94.309*999.000*999.000		
680.000	72.975*999.000*999.000		
681.000	91.503	279.000	4.000
682.000	99.472*999.000*999.000		
683.000	102.317	359.000	4.700
684.000	101.341*999.000*999.000		
685.000	102.697	278.000	1.400
686.000	102.598*999.000*999.000		
687.000	103.971*999.000*999.000		
688.000	99.383*999.000*999.000		
689.000	92.195	278.000	3.300
690.000	93.305*999.000*999.000		
691.000	97.181	285.000	1.400
692.000	95.452*999.000*999.000		
693.000	81.220	149.000	0.900
694.000	65.482*999.000*999.000		
695.000	104.031	331.000	0.920
696.000	127.883	94.000	1.400
697.000	123.934	62.000	1.700
700.000	96.145*999.000*999.000		

(1)

gopher menu

```
INPUT NAME OF DESIRED OPTION
KERMIT
```

---

(2)

```
KERMIT DIPMETER ANALYSIS MODULE

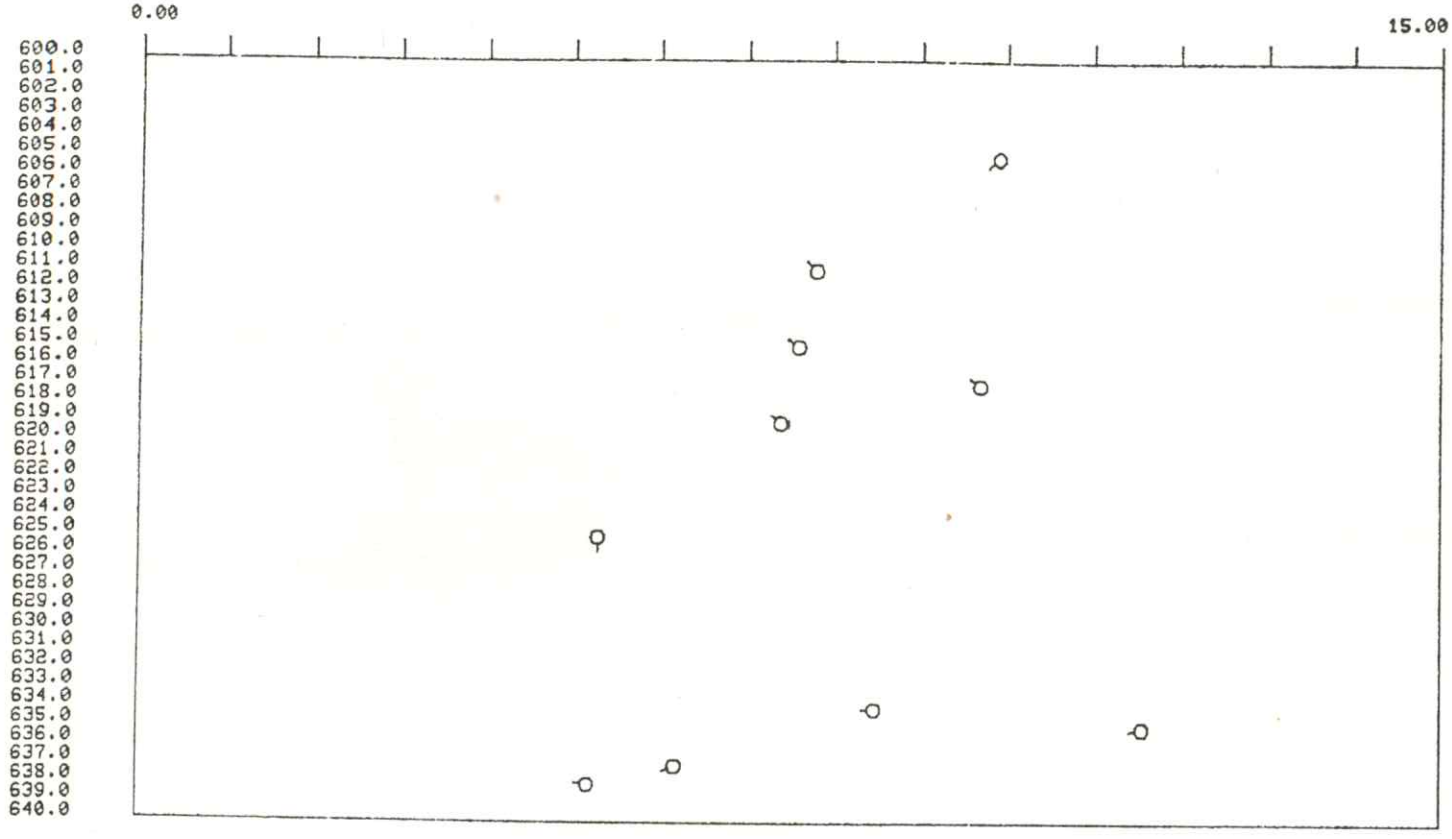
     DEPTH ------ SELECT DESIRED DEPTH INTERVAL
     TADPOLE ---- VECTOR PLOT
     ROSE ------- AZIMUTH FREQUENCY PLOT
     POLAR ------ SCHMIDT OR WULFF POLAR PLOT
     2DCYL ------ PLANAR CYLINDRICAL PLOT
     3DCYL ------ PERSPECTIVE CYLINDRICAL PLOT
     EIGEN ------ EIGENVECTOR ORIENTATION ANALYSIS
     STOP ------- KERMIT EXIT

INPUT NAME OF DESIRED OPTION
DEPTH
TOTAL INTERVAL AVAILABLE   500.00 TO   700.00
SELECTED INTERVAL  500.00 TO   700.00
DO YOU WANT THE SELECTED INTERVAL - YES OR NO
NO
ENTER MINIMUM DEPTH DESIRED
600.
ENTER MAXIMUM DEPTH DESIRED
640.
KERMIT DIPMETER ANALYSIS MODULE

     DEPTH ------ SELECT DESIRED DEPTH INTERVAL
     TADPOLE ---- VECTOR PLOT
     ROSE ------- AZIMUTH FREQUENCY PLOT
     POLAR ------ SCHMIDT OR WULFF POLAR PLOT
     2DCYL ------ PLANAR CYLINDRICAL PLOT
     3DCYL ------ PERSPECTIVE CYLINDRICAL PLOT
     EIGEN ------ EIGENVECTOR ORIENTATION ANALYSIS
     STOP ------- KERMIT EXIT

INPUT NAME OF DESIRED OPTION
TADPOLE
DO YOU WANT A LOGARITHMIC OR A LINEAR SCALE
LINEAR
ENTER MINIMUM DIP VALUE DESIRED
0.
ENTER MAXIMUM DIP VALUE DESIRED
15.
ENTER SPACING BETWEEN TIC MARKS
1.
```

WELL NAME: C.R.A. WOODWARD #4
LOCATION: 12-25S-21E KANSAS
DATE: 10-8-65



KERMIT DIPMETER ANALYSIS MODULE

4

```
DEPTH ------ SELECT DESIRED DEPTH INTERVAL
TADPOLE ---- VECTOR PLOT
ROSE ------- AZIMUTH FREQUENCY PLOT
POLAR ------ SCHMIDT OR WULFF POLAR PLOT
2DCYL ------ PLANAR CYLINDRICAL PLOT
3DCYL ------ PERSPECTIVE CYLINDRICAL PLOT
EIGEN ------ EIGENVECTOR ORIENTATION ANALYSIS
STOP ------- KERMIT EXIT

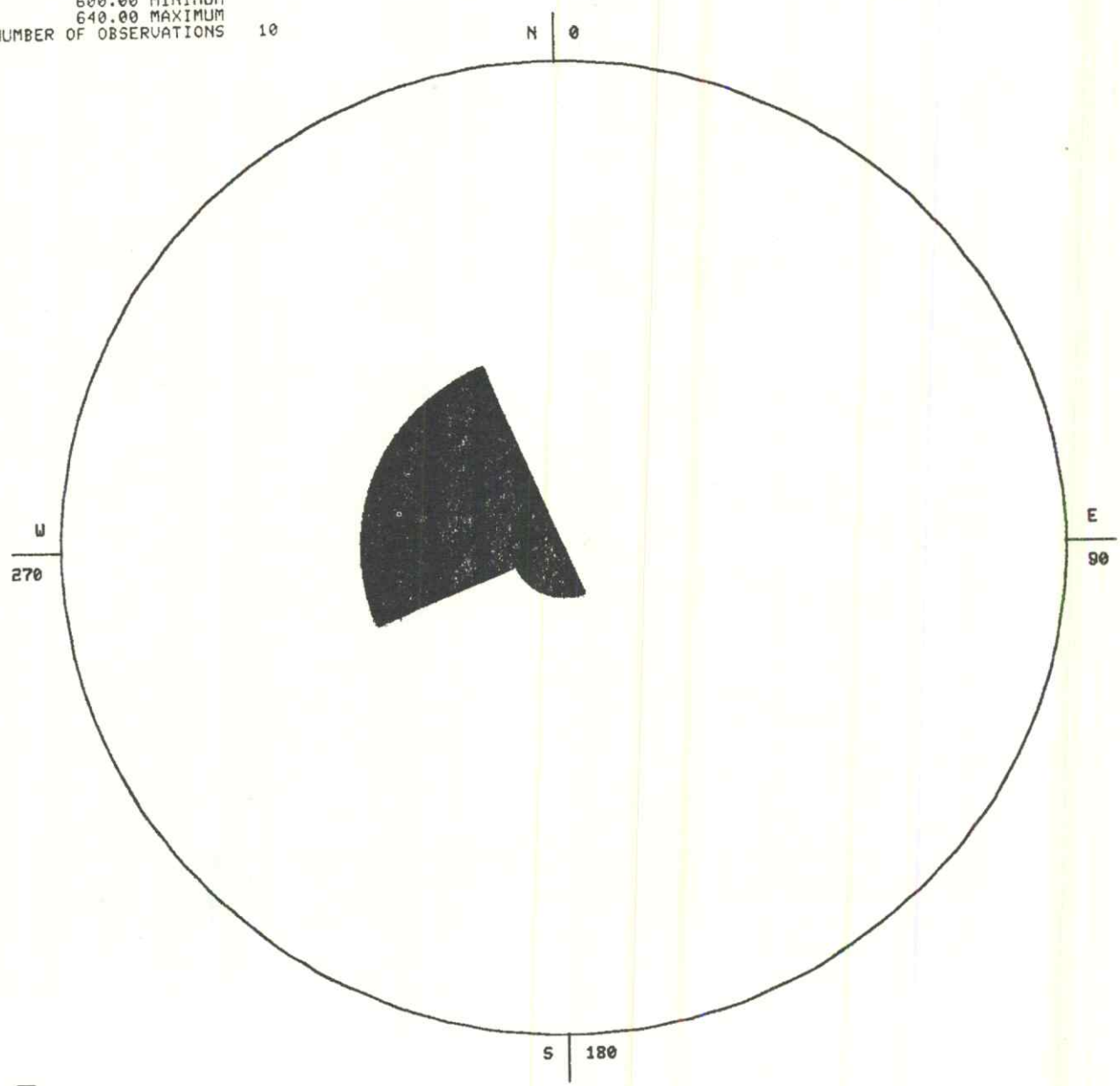
INPUT NAME OF DESIRED OPTION
ROSE
```

ROSE DIAGRAM FOR AZIMUTHS

5

WELL NAME: C.R.A. WOODWARD #4
LOCATION : 12-25S-21E KANSAS
DATE : 10-8-65

INTERVAL
600.00 MINIMUM
640.00 MAXIMUM
NUMBER OF OBSERVATIONS 10



```
KERMIT DIPMETER ANALYSIS MODULE

    DEPTH ------ SELECT DESIRED DEPTH INTERVAL
    TADPOLE ---- VECTOR PLOT
    ROSE ------- AZIMUTH FREQUENCY PLOT
    POLAR ------ SCHMIDT OR WULFF POLAR PLOT
    2DCYL ------ PLANAR CYLINDRICAL PLOT
    3DCYL ------ PERSPECTIVE CYLINDRICAL PLOT
    EIGEN ------ EIGENVECTOR ORIENTATION ANALYSIS
    STOP ------- KERMIT EXIT

INPUT NAME OF DESIRED OPTION
POLAR
DO YOU WANT TO PLOT A SCHMIDT NET (LAMBERT
   EQUAL AREA) OR A WULFF NET (STEREOGRAPHIC)
SCHMIDT
ENTER MAXIMUM DIP TO BE USED
15.
ENTER SPACING FOR CIRCLES
5.
```

6

```
WELL NAME:  C.R.A. WOODWARD #4
LOCATION :  12-25S-21E  KANSAS
DATE     :  10-8-65

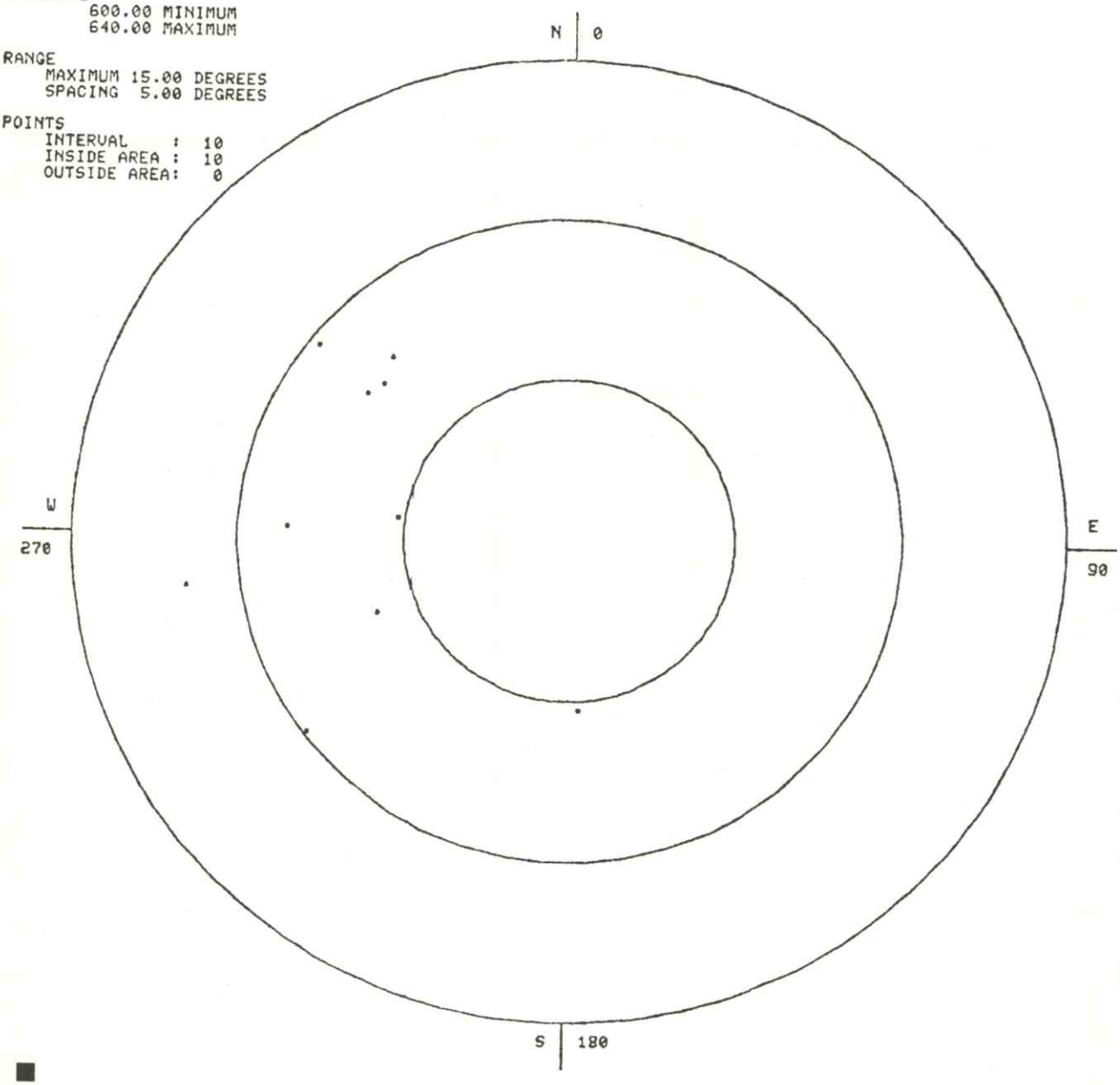
SCHMIDT NET

INTERVAL
        600.00 MINIMUM
        640.00 MAXIMUM

RANGE
    MAXIMUM 15.00 DEGREES
    SPACING  5.00 DEGREES

POINTS
    INTERVAL     :  10
    INSIDE AREA  :  10
    OUTSIDE AREA:   0
```

7



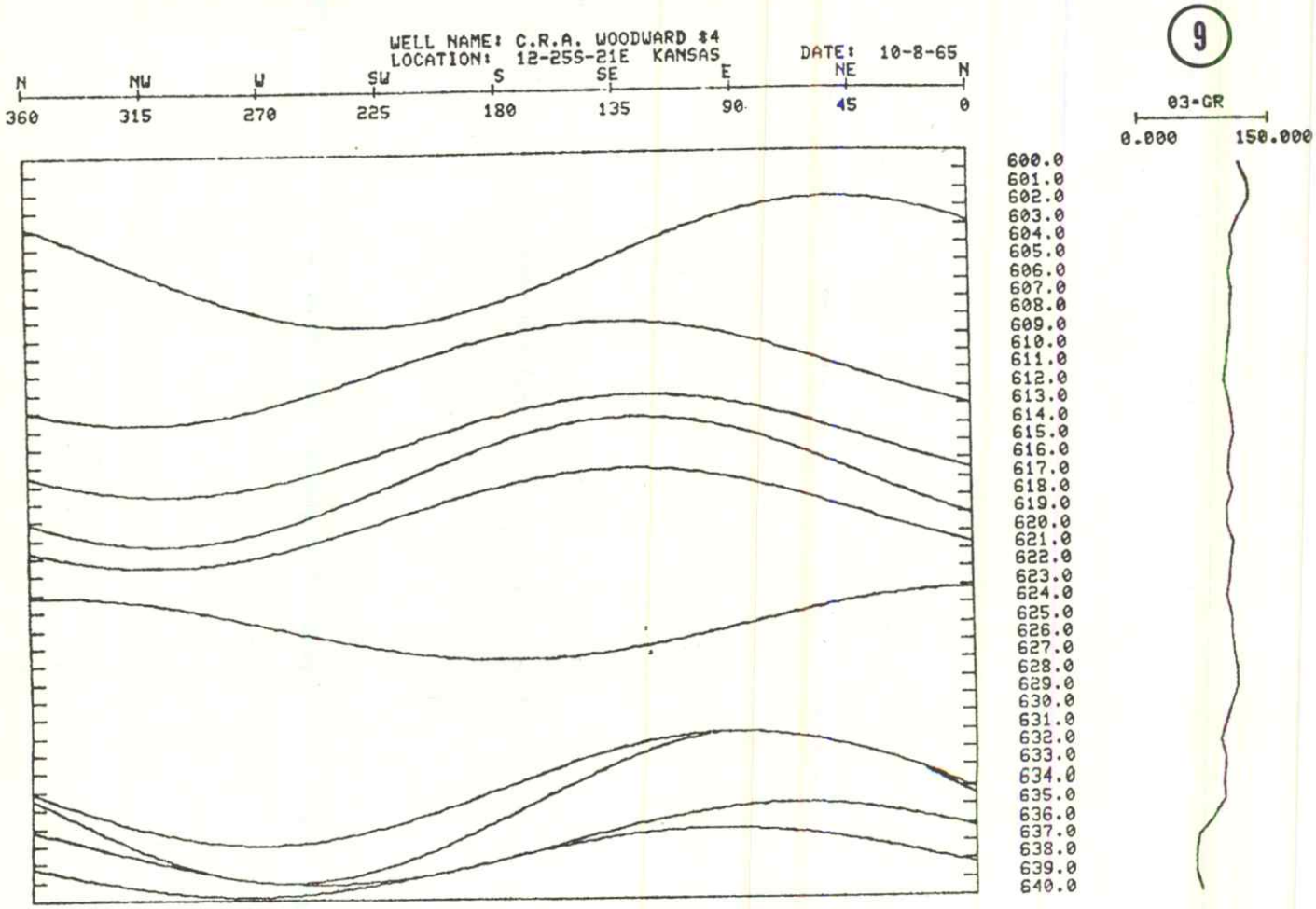
8

```
KERMIT DIPMETER ANALYSIS MODULE

    DEPTH ------ SELECT DESIRED DEPTH INTERVAL
    TADPOLE ---- VECTOR PLOT
    ROSE ------- AZIMUTH FREQUENCY PLOT
    POLAR ------ SCHMIDT OR WULFF POLAR PLOT
    2DCYL ------ PLANAR CYLINDRICAL PLOT
    3DCYL ------ PERSPECTIVE CYLINDRICAL PLOT
    EIGEN ------ EIGENVECTOR ORIENTATION ANALYSIS
    STOP ------- KERMIT EXIT

INPUT NAME OF DESIRED OPTION
2DCYL
SELECT WELL LOG TO BE DISPLAYED
 01=DEPTH              02=SP                 03=GR
 04=DENSITY            05=SONIC              06=GNT/SNP %
 07=CNL %              08=NEUTRON COUNT      09=LL8
 10=ILM                11=ILD                12=DEEP LATEROLOG
 13=MICRORESISTIVITY   14=AZIMUTH            15=DIP
 16=TEMPERATURE        17=INTEGRATED SONIC   18=CALIPER
 19=                   20=                   21=PETRA SS
 22=PETRA LS           23=PETRA DOL          24=PETRA SH
 25=PETRA AN           26=PETRA HL           27=PETRA CL
 28=PETRA POR          29=PETRA 2POR         30=PHIRA
 31=SX0                32=SW                 33=K
 34=DI                 35=RT                 36=RX0
 37=RWA                38=M                  39=N
 40=P                  41=ARCHIE M           42=SYNTH SEISM
 43=MODEL SONIC        44=MODEL INT SONIC    45=
 46=                   47=                   48=
 49=                   50=ALPHA              51=BETA
 52=GAMMA              53=DELTA              54=EPSILON
 55=OMEGA
03
SELECT MINIMUM VALUE DESIRED
0.
SELECT MAXIMUM VALUE DESIRED
150.
```

9



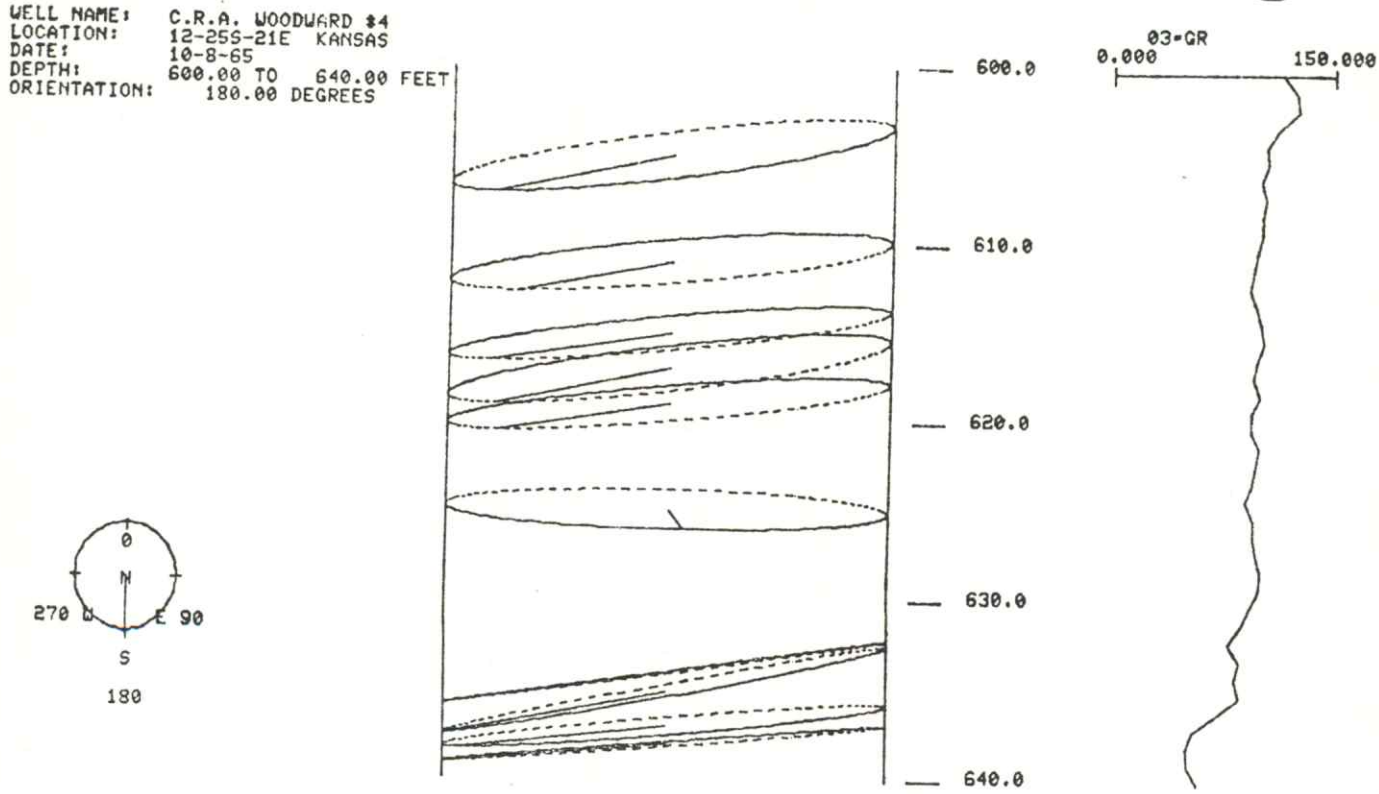
(10)

```
KERMIT DIPMETER ANALYSIS MODULE

    DEPTH ------ SELECT DESIRED DEPTH INTERVAL
    TADPOLE ---- VECTOR PLOT
    ROSE ------- AZIMUTH FREQUENCY PLOT
    POLAR ------ SCHMIDT OR WULFF POLAR PLOT
    2DCYL ------ PLANAR CYLINDRICAL PLOT
    3DCYL ------ PERSPECTIVE CYLINDRICAL PLOT
    EIGEN ------ EIGENVECTOR ORIENTATION ANALYSIS
    STOP ------- KERMIT EXIT

INPUT NAME OF DESIRED OPTION
3DCYL
ANGLE OF ROTATION
180.
SELECT WELL LOG TO BE DISPLAYED
 01=DEPTH              02=SP                 03=GR
 04=DENSITY            05=SONIC              06=GNT/SNP %
 07=CNL %              08=NEUTRON COUNT      09=LL8
 10=ILM                11=ILD                12=DEEP LATEROLOG
 13=MICRORESISTIVITY   14=AZIMUTH            15=DIP
 16=TEMPERATURE        17=INTEGRATED SONIC   18=CALIPER
 19=                   20=                   21=PETRA SS
 22=PETRA LS           23=PETRA DOL          24=PETRA SH
 25=PETRA AN           26=PETRA HL           27=PETRA CL
 28=PETRA POR          29=PETRA 2POR         30=PHIRA
 31=SX0                32=SW                 33=K
 34=DI                 35=RT                 36=RX0
 37=RWA                38=M                  39=N
 40=P                  41=ARCHIE M           42=SYNTH SEISM
 43=MODEL SONIC        44=MODEL INT SONIC    45=
 46=                   47=                   48=
 49=                   50=ALPHA              51=BETA
 52=GAMMA              53=DELTA              54=EPSILON
 55=OMEGA
03
ENTER LEFTMOST VALUE
0.
ENTER RIGHTMOST VALUE
150.
```

(11)



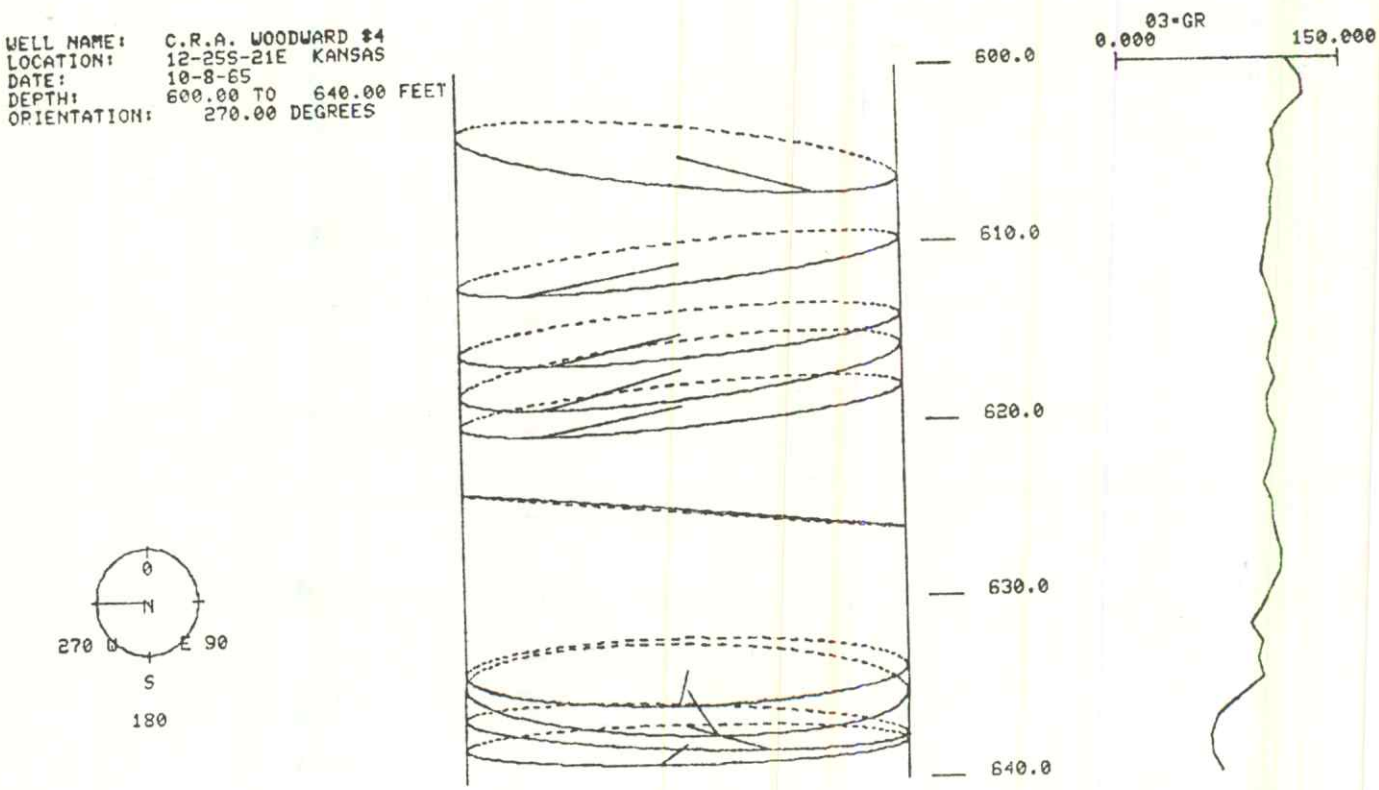
12

```
KERMIT DIPMETER ANALYSIS MODULE

    DEPTH ------ SELECT DESIRED DEPTH INTERVAL
    TADPOLE ---- VECTOR PLOT
    ROSE ------- AZIMUTH FREQUENCY PLOT
    POLAR ------ SCHMIDT OR WULFF POLAR PLOT
    2DCYL ------ PLANAR CYLINDRICAL PLOT
    3DCYL ------ PERSPECTIVE CYLINDRICAL PLOT
    EIGEN ------ EIGENVECTOR ORIENTATION ANALYSIS
    STOP ------- KERMIT EXIT

INPUT NAME OF DESIRED OPTION
3DCYL
ANGLE OF ROTATION
270.
SELECT WELL LOG TO BE DISPLAYED
 01=DEPTH              02=SP                 03=GR
 04=DENSITY            05=SONIC              06=GNT/SNP %
 07=CNL %              08=NEUTRON COUNT      09=LL8
 10=ILM                11=ILD                12=DEEP LATEROLOG
 13=MICRORESISTIVITY   14=AZIMUTH            15=DIP
 16=TEMPERATURE        17=INTEGRATED SONIC   18=CALIPER
 19=                   20=                   21=PETRA SS
 22=PETRA LS           23=PETRA DOL          24=PETRA SH
 25=PETRA AN           26=PETRA HL           27=PETRA CL
 28=PETRA POR          29=PETRA 2POR         30=PHIRA
 31=SX0                32=SW                 33=K
 34=DI                 35=RT                 36=RX0
 37=RWA                38=M                  39=N
 40=P                  41=ARCHIE M           42=SYNTH SEISM
 43=MODEL SONIC        44=MODEL INT SONIC    45=
 46=                   47=                   48=
 49=                   50=ALPHA              51=BETA
 52=GAMMA              53=DELTA              54=EPSILON
 55=OMEGA
03
ENTER LEFTMOST VALUE
0.
ENTER RIGHTMOST VALUE
150.
```

13



```
KERMIT DIPMETER ANALYSIS MODULE

    DEPTH ------ SELECT DESIRED DEPTH INTERVAL
    TADPOLE ---- VECTOR PLOT
    ROSE ------- AZIMUTH FREQUENCY PLOT
    POLAR ------ SCHMIDT OR WULFF POLAR PLOT
    2DCYL ------ PLANAR CYLINDRICAL PLOT
    3DCYL ------ PERSPECTIVE CYLINDRICAL PLOT
    EIGEN ------ EIGENVECTOR ORIENTATION ANALYSIS
    STOP ------- KERMIT EXIT

INPUT NAME OF DESIRED OPTION
EIGEN
```

14

```
WELL NAME:  C.R.A. WOODWARD #4
LOCATION:   12-25S-21E  KANSAS
DATE:       10-8-65
MINIMUM DEPTH:       600.00
MAXIMUM DEPTH:       640.00
NUMBER OF MEASURMENTS:  10

ORIENTATION TENSOR
    0.0145   -0.0017   -0.1085
   -0.0017    0.0055    0.0110
   -0.1085    0.0110    0.9798

EIGENVALUES     EIGENVECTORS
    0.9920         -0.1103     0.0113     0.9938
    0.0055         -0.1785     0.9834    -0.0310
    0.0024          0.9777     0.1809     0.1065

PRINCIPAL VECTOR
    AZIMUTH              275.86 DEGREES
    DIP                    6.37 DEGREES
    SCATTERING ANGLE       5.10 DEGREES
```

15

■

```
KERMIT DIPMETER ANALYSIS MODULE

    DEPTH ------ SELECT DESIRED DEPTH INTERVAL
    TADPOLE ---- VECTOR PLOT
    ROSE ------- AZIMUTH FREQUENCY PLOT
    POLAR ------ SCHMIDT OR WULFF POLAR PLOT
    2DCYL ------ PLANAR CYLINDRICAL PLOT
    3DCYL ------ PERSPECTIVE CYLINDRICAL PLOT
    EIGEN ------ EIGENVECTOR ORIENTATION ANALYSIS
    STOP ------- KERMIT EXIT

INPUT NAME OF DESIRED OPTION
STOP
```

16

---

gopher menu

17

```
INPUT NAME OF DESIRED OPTION
BYE
```

CASE STUDY 6: SYNTHETIC SEISMIC MODELING

An extract from the results of a seismic line shot in Nemaha County, Kansas, is shown in Figure 22. This processed record section shows a sequence of distinctive reflection events which define a broad anticlinal structure. The Beck A-1 well (used in case studies 2 and 3) is located approximately 100 yards north of the center of the section. The sonic log recorded in the well is an excellent source of data for operations with the SNARK module of KOALA. In this case study, SNARK will be used both to generate a well synthetic seismogram to provide stratigraphic identification of the record section events, and as a means to model a hypothetical seismic record for a section to the north.

The formation tops from the Beck A-1 well (measured in feet from KB) are listed below:

Lansing (Pennsylvanian)	982
Base Kansas City (Pennsylvanian)	1294
Mississippian	1604
Kinderhook (Mississippian)	1653
Hunton (Siluro-Devonian)	1832
Maquoketa (Ordovician)	2399
Viola (Ordovician)	2448
Simpson sand (Ordovician)	2642
Precambrian granite	2708

The most striking feature of this record is the extremely shallow depth (by Kansas standards) of the Precambrian, which reflects the location of the well on the Nemaha Ridge, a prominent, but constricted, anticlinal structure which traverses north-south across Kansas. The well is close to the eastern margin of this feature which is defined by the Humboldt Fault. In a well less than 2 miles to the east, the Precambrian is downthrown by 700 feet.

Case-study data for the sonic log are listed from a depth of 300-2738 feet (Table 10); readings not recorded for the initial 300 feet are set to default values.

OUTPUT COMMENTARY

1 GOPHER menu. "SNARK" prompt.

2 SNARK menu. "SEISM" prompt. A synthetic seismogram based on the well sonic log record (channel 05) is requested, using a first-order Ricker wavelet with 30 hertz frequency.

3 SEISM output. Input Ricker wavelet profile. Synthetic seismogram indexed with two-way travel time in milliseconds (left scale) and cross-referenced with equivalent depths in feet (right scale). Parallel trace of interval velocity, also graphed on two-way travel time scale. Since the initial sonic log value occurs at 300 feet, the origin for the travel time is set at this depth.
Identification of stratigraphic tops on the velocity profile and their corresponding "events" on the seismogram have been added manually. The section is a good subject for seismic modeling, since the stratigraphic units provide a succession of distinctive velocity contrasts and corresponding reflections.

(*) (As an intermediate step in SNARK processing, a comparison is made between the synthetic seismogram and its equivalent position on the field record (center of the section). This comparison requires a slight downward shift of the seismogram relative to the record, since the seismogram zero-time is referenced to a depth of 300 feet, while the seismic record datum (zero-time) is located at 1100 feet asl (a depth of 178 feet in the well). Events on the synthetic seismogram may be readily matched with their equivalents on the field record, demonstrating that SNARK modeling can provide useful "quick-look" synthetic seismograms, in spite of the computational simplifications imposed by the short time constraints of interactive processing.

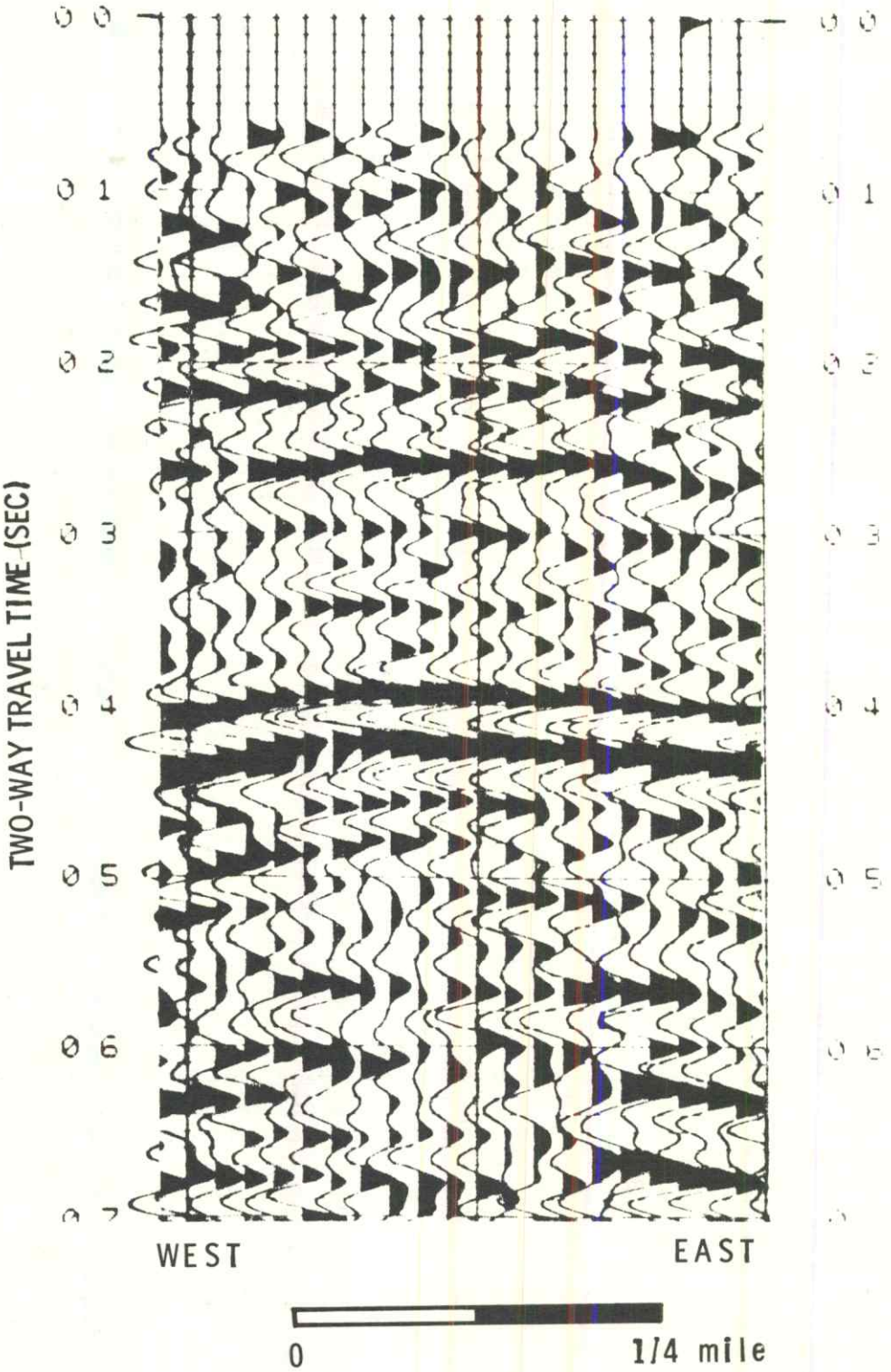


Figure 22: Seismic record, Nemaha County, Kansas

The Precambrian reflection is relatively subdued when compared with the prominent Viola reflection which is caused by the marked velocity contrast with the overlying Maquoketa Shale. The Viola ("Trenton") is widely recognized as "an outstanding reflector of seismic waves" (Lyons, 1966) over large areas of the United States, and has historical interest, since the first oil well to be drilled on a structure mapped by a reflection seismograph was completed in the Viola in 1928.)

4 SEISM option. The user elects to store the integrated sonic and synthetic seismogram amplitudes computed by SEISM in channels 17 and 42.

5 SNARK menu. "MODEL" prompt. A short distance to the north (25 miles), lower Paleozoic units have been stripped from the Nemaha Ridge, and the Pennsylvanian rests directly on the Precambrian. In a "northerly" well (Heiman-1), the stratigraphic sequence was reported as:

Lansing	724
Granite wash	889
Precambrian granite	900

Since no sonic log was recorded in this well, a model sonic log was prepared, based on Beck A-1 data. This consists of two "quotes," one from Lansing and shallower units, the other from the Precambrian section, separated by a Granite wash "constant" interval, based on a representative Granite wash transit time drawn from the Beck A-1 well.

6 SNARK menu. "SEISM" prompt. A synthetic seismogram is requested, based on the model sonic log profile from the northern section, using a 30 hertz, first-order Ricker wavelet.

7 SEISM output. Synthetic seismogram of the model section, with the same representation convention of the earlier synthetic.

8 SEISM option. The user elects to store the integrated model sonic and model synthetic seismogram amplitudes computed by SEISM in channels 44 and 42, respectively.

9 SNARK menu. "STOP" prompt.

10 GOPHER menu. "BYE" prompt.

REMARKS

The case study provides a basic demonstration of the operational characteristics of SNARK and its performance related to a real example.

The SNARK module should never be viewed as a substitute for more advanced (and time-consuming) algorithms, which are readily available in all major oil companies and other institutions. The short "real time" imposed by an interactive medium restricts SNARK to a simple modeling procedure. However, the intelligent user should recognize the potential of SNARK to explore a variety of hypotheses or scenarios in a general reconnaissance, and follow more promising leads with the refinement provided by more sophisticated batch programs, where this is deemed necessary.

o-o-o

Table 10
SYNTHETIC SEISMIC DATA

WELL NAME: CITIES SERVICE BECK A-1 SW-SE-SE 14-5S-12E
LOCATION: NEMAHA CO., KANSAS
DATE: JAN. 11, 1978

01-DEPTH	05-SONIC
300.000	132.735
301.000	131.101
302.000	130.754
303.000	129.417
304.000	130.160
305.000	129.961
306.000	126.396
307.000	124.167
308.000	125.851
309.000	130.506
310.000	133.973
311.000	134.716
312.000	135.954
313.000	136.350
314.000	137.241
315.000	137.539
316.000	138.678
317.000	141.846
318.000	143.580
319.000	113.173
320.000	107.289
321.000	101.406
322.000	104.358
323.000	93.710
324.000	104.060
325.000	123.375
326.000	134.270
327.000	137.836
328.000	135.954
329.000	135.062
330.000	136.499
331.000	136.647
332.000	136.845
333.000	138.975
334.000	106.190
335.000	84.140
336.000	85.502
337.000	96.484
338.000	99.505
339.000	85.836
340.000	90.590
341.000	91.185
342.000	98.811
343.000	109.756
344.000	104.556
345.000	108.567
346.000	106.240
347.000	115.748
348.000	107.824
349.000	88.015
350.000	86.133
351.000	89.600
352.000	105.150
353.000	110.449
354.000	102.822
355.000	90.590
356.000	88.609
357.000	93.364
358.000	97.821
359.000	98.911
360.000	95.493
361.000	92.076
362.000	93.463
363.000	101.881
364.000	107.725
365.000	98.217
366.000	92.770
367.000	98.118
368.000	89.947
369.000	79.101
370.000	102.773
371.000	103.021
372.000	107.936
373.000	114.596
374.000	116.912
375.000	114.881
376.000	114.304
377.000	115.179
378.000	116.054
379.000	125.653
380.000	110.994
381.000	104.655
382.000	104.853
383.000	93.364
384.000	99.406
385.000	109.508
386.000	107.527
387.000	103.021
388.000	106.240
389.000	122.038
390.000	127.386
391.000	125.752
392.000	128.030
393.000	129.961
394.000	122.582
395.000	117.630
396.000	123.573
397.000	125.603
398.000	128.426
399.000	131.299
400.000	134.518
2670.000	70.484
2671.000	79.299
2672.000	92.175
2673.000	94.552
2674.000	92.101
2675.000	88.089
2676.000	84.078
2677.000	81.379
2678.000	75.288
2679.000	71.771
2680.000	70.682
2681.000	69.592
2682.000	72.960
2683.000	74.049
2684.000	71.771
2685.000	70.533
2686.000	74.297
2687.000	78.705
2688.000	81.230
2689.000	82.865
2690.000	82.370
2691.000	79.101
2692.000	80.438
2693.000	81.280
2694.000	83.459
2695.000	81.775
2696.000	80.191
2697.000	81.973
2698.000	84.796
2699.000	80.389
2700.000	78.853
2701.000	73.455
2702.000	71.375
2703.000	76.922
2704.000	85.985
2705.000	89.154
2706.000	81.478
2707.000	69.989
2708.000	55.131
2709.000	51.169
2710.000	51.070
2711.000	51.368
2712.000	51.368
2713.000	52.160
2714.000	52.160
2715.000	51.368
2716.000	51.368
2717.000	50.971
2718.000	51.962
2719.000	53.249
2720.000	53.844
2721.000	52.952
2722.000	52.160
2723.000	53.150
2724.000	52.160
2725.000	52.259
2726.000	52.210
2727.000	52.358
2728.000	53.150
2729.000	54.438
2730.000	53.150
2731.000	52.754
2732.000	53.051
2733.000	52.754
2734.000	51.813
2735.000	51.912
2736.000	53.150
2737.000	52.952
2738.000	53.547
2739.000	52.754
2740.000	52.000
2741.000	52.000
2742.000	52.000
2743.000	52.000
2744.000	52.000
2745.000	52.000
2746.000	52.000
2747.000	52.000
2748.000	52.000
2749.000	52.000
2750.000	52.000
2751.000	52.000
2752.000	52.000
2753.000	52.000
2754.000	52.000
2755.000	52.000
2756.000	52.000
2757.000	52.000
2758.000	52.000
2759.000	52.000
2760.000	52.000
2761.000	52.000
2762.000	52.000
2763.000	52.000
2764.000	52.000
2765.000	52.000
2766.000	52.000
2767.000	52.000
2768.000	52.000
2769.000	52.000
2770.000	52.000

(1)

gopher menu

```
INPUT NAME OF DESIRED OPTION
SNARK
```

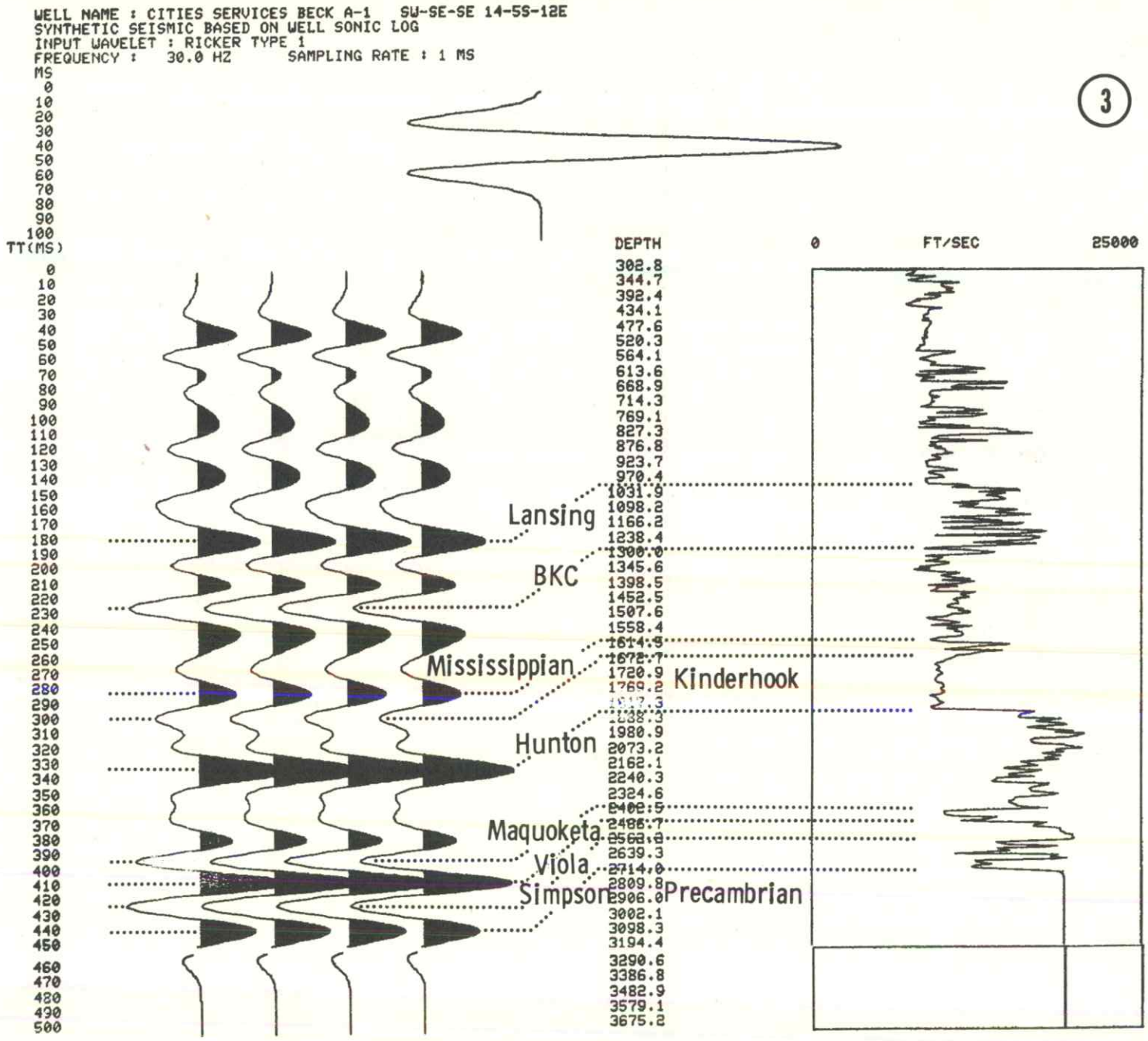
---

(2)

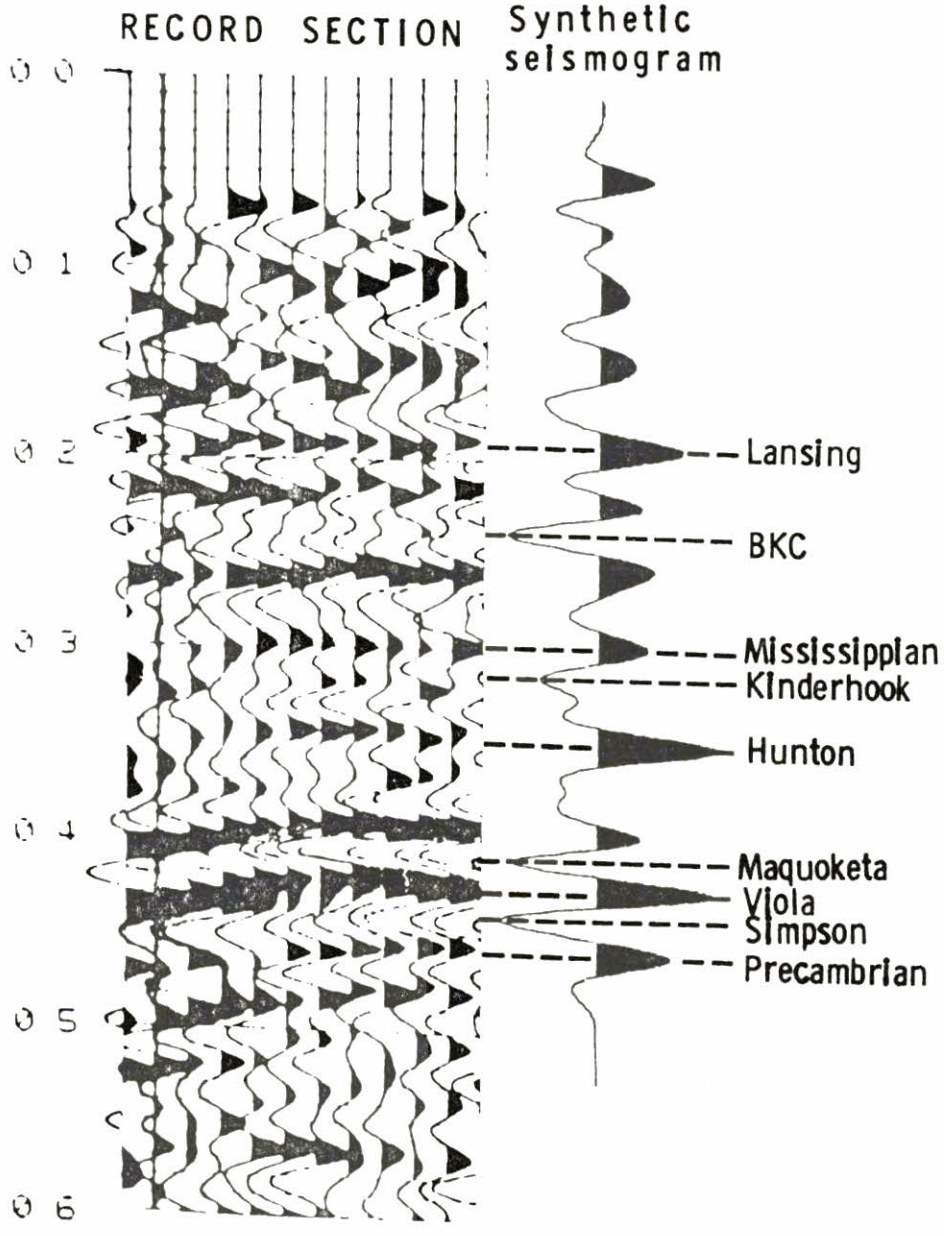
```
SNARK SYNTHETIC SEISMIC MODULE

    SEISM ---- SYNTHETIC SEISMIC COMPUTED FROM
               WELL SONIC LOG(05), INTEGRATED
               SONIC(17), OR MODEL SONIC LOG(43)
    MODEL ---- CREATION OF A SONIC LOG(43) FOR A
               HYPOTHETICAL MODEL SECTION
    STOP ----- EXIT SNARK MODULE

INPUT NAME OF DESIRED OPTION
SEISM
DO YOU WANT A SYNTHETIC SEISMOGRAM
BASED ON THE WELL SONIC LOG(05), INTEGRATED
SONIC(17), OR MODEL SONIC LOG(43) ---
ENTER NUMBER OF DESIRED CHANNEL
05
INPUT FREQUENCY IN HZ FOR THE
FIRST ORDER RICKER WAVELET
30.
```


WELL NAME : CITIES SERVICES BECK A-1 SW-SE-SE 14-5S-12E
SYNTHETIC SEISMIC BASED ON WELL SONIC LOG
INPUT WAVELET : RICKER TYPE 1
FREQUENCY : 30.0 HZ SAMPLING RATE : 1 MS
MS
TT(MS)
DEPTH
0
FT/SEC
25000
Lansing
BKC
Mississippian
Kinderhook
Hunton
Maquoketa
Viola
Simpson
Precambrian

3


RECORD SECTION
Synthetic seismogram
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Lansing
BKC
Mississippian
Kinderhook
Hunton
Maquoketa
Viola
Simpson
Precambrian

```
DO YOU WANT TO STORE CREATED LOGS - YES OR NO
YES
```

4

```
SNARK SYNTHETIC SEISMIC MODULE

    SEISM ---- SYNTHETIC SEISMIC COMPUTED FROM
               WELL SONIC LOG(05), INTEGRATED
               SONIC(17), OR MODEL SONIC LOG(43)
    MODEL ---- CREATION OF A SONIC LOG(43) FOR A
               HYPOTHETICAL MODEL SECTION
    STOP ----- EXIT SNARK MODULE

INPUT NAME OF DESIRED OPTION
MODEL
A MODEL SEISMIC LOG(43) WILL BE CONSTRUCTED FROM:
    QUOTES ------ DEPTH INTERVALS FROM THE
                  SONIC WELL LOG(05)
    CONSTANTS --- USER-STIPULATED TRANSIT TIMES
                  FOR MODEL DEPTH INTERVALS
HOW MANY QUOTES WILL BE USED
    A MAXIMUM OF 9 IS ALLOWED
    IF NONE, ENTER 0
2
QUOTE 1
DEPTH OF TOP OF INTERVAL IN WELL
300.
DEPTH OF BOTTOM OF INTERVAL IN WELL
1147.
DEPTH OF TOP OF INTERVAL IN MODEL SECTION
41.
QUOTE 2
DEPTH OF TOP OF INTERVAL IN WELL
2708.
DEPTH OF BOTTOM OF INTERVAL IN WELL
2738.
DEPTH OF TOP OF INTERVAL IN MODEL SECTION
900.
HOW MANY CONSTANTS WILL BE USED
    A MAXIMUM OF 9 IS ALLOWED
    IF NONE, ENTER 0
1
CONSTANT 1
DEPTH OF TOP OF INTERVAL IN MODEL SECTION
889.
DEPTH OF BOTTOM OF INTERVAL IN MODEL SECTION
899.
TRANSIT TIME (MICROSECONDS PER FOOT)
70.
```

5

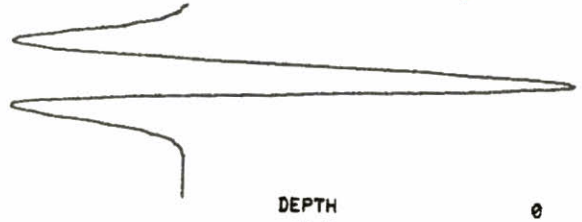
```
SNARK SYNTHETIC SEISMIC MODULE

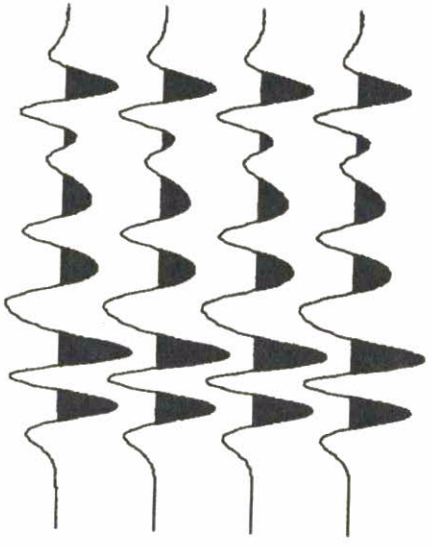
    SEISM ---- SYNTHETIC SEISMIC COMPUTED FROM
               WELL SONIC LOG(05), INTEGRATED
               SONIC(17), OR MODEL SONIC LOG(43)
    MODEL ---- CREATION OF A SONIC LOG(43) FOR A
               HYPOTHETICAL MODEL SECTION
    STOP ----- EXIT SNARK MODULE

INPUT NAME OF DESIRED OPTION
SEISM
DO YOU WANT A SYNTHETIC SEISMOGRAM
BASED ON THE WELL SONIC LOG(05), INTEGRATED
SONIC(17), OR MODEL SONIC LOG(43) ---
ENTER NUMBER OF DESIRED CHANNEL
43
INPUT FREQUENCY IN HZ FOR THE
FIRST ORDER RICKER WAVELET
30.
```

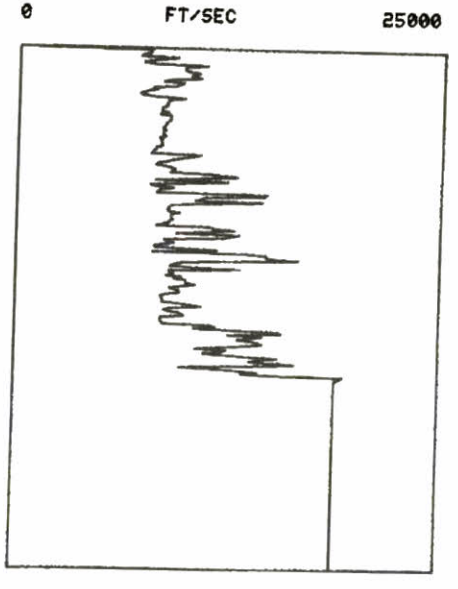
6

WELL NAME : CITIES SERVICES BECK A-1 SW-SE-SE 14-5S-12E
SYNTHETIC SEISMIC BASED ON MODEL SONIC LOG
INPUT WAVELET : RICKER TYPE 1
FREQUENCY : 30.0 HZ SAMPLING RATE : 1 MS





TT(MS)	DEPTH
0	43.8
10	85.7
20	133.4
30	175.1
40	218.6
50	261.3
60	305.1
70	354.6
80	409.9
90	455.3
100	510.1
110	568.3
120	617.8
130	664.7
140	711.4
150	772.9
160	839.2
170	910.5
180	1005.0
190	1099.5
200	1194.0
210	1288.5
220	1383.0
230	1477.5
240	1572.0
250	1666.5
260	1761.0
270	1855.5



8

```
DO YOU WANT TO STORE CREATED LOGS - YES OR NO
/ES
```

9

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SNARK SYNTHETIC SEISMIC MODULE

    SEISM ---- SYNTHETIC SEISMIC COMPUTED FROM
               WELL SONIC LOG(05), INTEGRATED
               SONIC(17), OR MODEL SONIC LOG(43)
    MODEL ---- CREATION OF A SONIC LOG(43) FOR A
               HYPOTHETICAL MODEL SECTION
    STOP ----- EXIT SNARK MODULE

INPUT NAME OF DESIRED OPTION
STOP
```

10

gopher menu

```
INPUT NAME OF DESIRED OPTION
BYE
```

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APPENDIX I

CONSTANT DESIGNATIONS

01 = Minimum depth of digitized record (feet)

02 = Maximum depth of digitized record (feet)

03 = Digital sampling rate (feet)

04 = Ground elevation (feet)

05 = Latitude (degrees)

06 = Longitude (degrees)

07 = Mud resistivity (ohm-m)

08 = Temperature of mud resistivity measurement (degrees Fahrenheit)

09 = Mud filtrate resistivity (ohm-m)

10 = Temperature of mud filtrate resistivity measurement (degrees Fahrenheit)

11 = Mud-cake resistivity (ohm-m)

12 = Temperature of mud-cake resistivity measurement (degrees Fahrenheit)

13 = Bottom-hole temperature (degrees Fahrenheit)

14 = Mean annual surface temperature (degrees Fahrenheit)

15 = Temperature gradient (degrees Fahrenheit per hundred foot depth)

16 = Time constant for gamma ray log (seconds)

17 = Time constant for neutron log (seconds)

18 = Logging speed for gamma ray (feet per minute)

19 = Logging speed for neutron (feet per minute)

20 = Total depth of well (feet)

21 to 60 = Optional User Constants

CHANNEL DESIGNATIONS

01 = Depth (feet)

02 = Spontaneous potential (millivolts)

03 = Gamma ray (counts)

04 = Density (grams per cc)

05 = Sonic (microseconds per foot)

06 = GNT or SNP neutron (percent)

07 = CNL neutron (percent)

08 = Raw neutron (counts)

09 = Laterolog-8 (ohm-m)

10 = Medium induction (ohm-m)

11 = Deep induction (ohm-m)

12 = "Deep laterolog" (ohm-m)

13 = Microresistivity (ohm-m)

14 = Dipmeter azimuth (degrees)

15 = Dipmeter dip (degrees)

16 = Temperature (degrees Fahrenheit)

17 = Integrated sonic (two-way travel time milliseconds)

18 = Caliper (inches)

19 = OPTIONAL

20 = OPTIONAL

21 = Quartz (fraction)

22 = Calcite (fraction)

23 = Dolomite (fraction)

24 = Shale (fraction)

25 = Anhydrite (fraction)

26 = Halite (fraction)

27 = Coal (fraction)

28 = Porosity (fraction)

29 = Secondary porosity (fraction)

30 = Water-filled porosity (fraction)

31 = Flushed-zone water saturation (fraction)

32 = Virgin formation water saturation (fraction)

33 = Permeability index (millidarcies)

34 = Diameter of invasion (inches)

35 = Small slam estimate of virgin formation resistivity (ohm-m)

36 = Small slam estimate of flushed-zone resistivity (ohm-m)

37 = Reconnaissance (apparent) water resistivity (ohm-m)

38 = Litho-porosity M (fraction)

39 = Litho-porosity N (fraction)

40 = Litho-porosity P (fraction)

41 = Archie cementation exponent

42 = Synthetic seismogram amplitude

43 = Model sonic (microseconds per foot)

44 = Model integrated sonic (two-way travel time milliseconds)

45 to 49 = OPTIONAL

50 to 55 = GREEK CHANNELS for storage of error diagnostics from PETRA and statistical output from MERLIN options

APPENDIX 2

Physical Properties of Common Geological Components

	ρ_{ma}	Δ_t	CNL%	SNP/GNT%
SILICATES				
Quartz	2.65	55.1	-2	-1
Garnet	4.31		7	3
Hornblende	3.20	43.8	8	4
Tourmaline	3.02		22	16
Zircon	4.50		-3	-1
CARBONATES				
Calcite	2.71	47.5	-1	0
Dolomite	2.87	43.5	1	2
Ankerite	2.86		1	0
Siderite	3.89		12	5
OXIDES				
Hematite	5.18	44.2	11	4
Magnetite	5.08	73.8	9	3
Limonite	3.59	56.9	60+	50+
SULPHIDES				
Sulphur	2.02	122.	-3	-2
Pyrite	4.99	39.4	-3	-2
Sphalerite	3.85		-3	-3
Chalcopyrite	4.07		-2	-3
Galena	6.39		-3	-3
CLAY MINERALS (WET)				
Kaolinite	2.41		37	34
Chlorite	2.76		52	37
Illite	2.52		30	20
Montmorillonite	2.12		44	40
MICAS				
Muscovite	2.82	54.9	20	12
Glauconite	2.55		39	23
Biotite	3.00	55.	21	11
FELDSPARS				
Orthoclase	2.52	69.2	-3	-2
Albite	2.59	50.2	-2	-1
Anorthite	2.74	45.4	-2	-1

EVAPORITES				
Halite	2.04	66.7	-3	-2
Anhydrite	2.98	51.8	-2	-1
Gypsum	2.35	52.5	60+	50+
Trona	2.08	65.	35	24
Sylvite	1.86	74.	-3	-2
Carnallite	1.57	80.7	60+	40+
Polyhalite	2.79	57.5	25	14
Barite	4.09		-2	-1
COALS				
Anthracite	1.47	105.	38	37
Bituminous	1.24	120.	60+	50+
Lignite	1.19	160.	52	47
FLUIDS				
Fresh water	1.00	189.	100	100
Average oil	0.85	238.	109	109
Methane	Dependent on temperature and pressure			

CAVEAT!
This table was compiled from a variety of sources. Almost all the values have ranges associated with them, which are generally narrow for rigorously defined minerals, but highly variable for other components (e.g. clay minerals, coals). The user should view all these quantities as "average" estimates.

MANUAL POSTSCRIPT

In these concluding remarks, we suggest the next logical step beyond KOALA. KOALA has been designed for the analysis of logs on a borehole-by-borehole basis. Multiple well studies may be incorporated easily as an extension of the system by either of the following methods:

1 In cases where a specific subsurface unit is of interest, the digitized traces of the unit may be loaded as a single KOALA well file. The "embedded file" would consist of "unit blocks" separated by default value segments. Under this organization, any movement along the depth axis would be a translation across "space" when crossing one or more default segments, or a shift in depth within the same unit block. The interactive character of the system can then be extended to analyses in three dimensions.

2 For more comprehensive studies, a library of KOALA files may be maintained either on disc or stored on magnetic tape, where each file corresponds to a single well. The CONSTANTS area is a useful repository for properties derived from KOALA analyses which are considered useful for mapping purposes. A retrieval function (which could be designated VULTURE) may be programmed to collect the geographical coordinates and variable of interest from each KOALA file and coordinated with an automated contouring package for the production of maps.

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