CIRC. 879

GEOLOGICAL SURVEY CIRCULAR 879

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Computer Analysis of Digital Well Logs

Computer Analysis of Digital Well Logs

By James H. Scott

GEOLOGICAL SURVEY CIRCULAR 879

1984

United States Department of the Interior

WILLIAM P. CLARK, *Secretary*

Geological Survey

Dallas L. Peck, *Director*

Free on application to Branch of Distribution, U.S. Geological Survey, 604 South Pickett Street, Alexandria, VA 22304

CONTENTS

ILLUSTRATIONS

TABLE

COMPUTER ANALYSIS OF DIGITAL WELL LOGS

By JAMES H. SCOTT

ABSTRACT

A comprehensive system of computer programs has been developed by the U.S. Geological Survey for analyzing digital well logs. The programs are operational on a minicomputer in a research well-logging truck, making it possible to analyze and replot the logs while at the field site. The minicomputer also serves as a controller of digitizers, counters, and recorders during acquisition of well logs. The analytical programs are coordinated with the data acquisition programs in a flexible system that allows the operator to make changes quickly and easily in program variables such as calibration coefficients, measurement units, and plotting scales. The programs are designed to analyze the following well-logging measurements: natural gamma-ray, neutron-neutron, dual-detector density with caliper, magnetic susceptibility, single-point resistance, self potential, resistivity (normal and Wenner configurations), induced polarization, temperature, sonic delta-*t*, and sonic amplitude.

The computer programs are designed to make basic corrections for depth displacements, tool response characteristics, hole diameter, and borehole fluid effects (when applicable). Corrected well-log measurements are output to magnetic tape or plotter with measurement units transformed to petrophysical and chemical units of interest, such as grade of uranium mineralization in percent eU_3O_8, neutron porosity index in percent, and sonic velocity in kilometers per second.

INTRODUCTION

Well-logging service companies have used truck-mounted computers for field-data acquisition and analysis for several years (Moseley, 1976; Kinkade and others, 1978; Best and others, 1978). These commercial computer-based systems are generally designed for speed, simplicity of operation, efficiency and reliability of data acquisition, and they have turned out to be highly successful for routine well logging. However, they are not flexible enough for research studies where ease of program modification is more important than standardization of results. The U.S. Geological Survey's research well-logging system uses a Hewlett Packard 9845B minicomputer[1] with BASIC programming language, 318K bytes of core memory, and cathode ray tube (CRT) graphics with a capability for hard-copy output of graphics and printed data. Programs and data are stored on cartridge magnetic tapes or flexible disks, and are read into the computer under keyboard or program control.

The general design of the analytical programs is described in the first section of this report. The second section contains detailed descriptions of individual programs with examples of results given for each one.

OVERVIEW OF COMPUTER PROGRAMS

All programs begin with a section that reads the digital field tapes or disks into the computer for rough editing. Invalid numbers and overlapping depth intervals are removed if they exist. A block of calibration information, normally stored at the end of the recorded data, is read, checked for validity, and stored for later use. Acquisition of field data is occasionally terminated prematurely because of a power failure or recording problem, and if this happens, calibration information is not available. This condition is detected by the program, and the user is prompted to enter the necessary calibration values from the keyboard.

Next, the program calls for keyboard entry of depth corrections, if needed, and for keyboard entry of the upper depth of valid data, which gives the user an opportunity to delete invalid data that occur in the vicinity of the borehole fluid level for some logs, particularly electric logs and sonic logs.

[1]Use of trade and company names in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

The new arrays of depths and log readings are computed at evenly spaced depth intervals by interpolation of recorded values at a spacing that is determined by the user. Evenly spaced depth intervals are needed to facilitate subsequent data manipulation of well-log data (such as filtering, applying hole-diameter corrections, drift corrections).

displayed on the CRT and that can be positioned at any point on the log trace. Special-function keys on the computer keyboard are used to move the cursor up and down along the log trace, to delete erroneous data points, or to move them to the left or right of their original position. After editing, the log can be filtered if necessary to remove noise, and then stored on magnetic tape, or output

TABLE 1.—*Log-measurement values and transformed values produced by computer programs*
[API, American Petroleum Institute; SI, International System of Units]

Log type	Log-measurement value	Transformed value
Natural gamma	Counts per second	API units or eU_3O_8 (percent).
Neutron-neutron	Counts per second	API units or porosity (percent).
Dual-detector density	Counts per second	Compensated density grams per cubic centimeter.
Magnetic susceptibility	Centimeter-gram-second (cgs) units (apparent)	Centimeter-gram-second (cgs) or SI units, corrected for drift and hole-diameter variations.
Resistivity	Ohm-meters (apparent)	Ohm-meters corrected for hole diameter and mud resistivity variations.
Sonic velocity	Microseconds per foot	Feet per second or kilometers per second.
Temperature	Ohms or Hertz	Degrees Fahrenheit or degrees Centigrade.
Induced polarization	Millivolts per volt	Millivolts per volt (not transformed).
Self potential	Millivolts	Millivolts (not transformed).
Single-point resistance	Ohms	Ohms (not transformed).

Basic corrections and calibration algorithms are then applied to the interpolated raw data. Depth corrections are applied for the vertical offsets of the various detectors located at different positions on the probes, dead-time corrections are applied to nuclear counting measurements, and linear or nonlinear calibration functions are applied to convert digitizer output units (millivolts) to log measurement units (ohm meters, microseconds per foot). After the basic corrections and calibration algorithms have been applied, the logs are plotted on the CRT and edited, if necessary, while displayed on the CRT. The editing routine provides for keyboard manipulation of a cursor that is also as a paper copy of the CRT plot, or plotted on an *X–Y* plotter. In the next stage of operation, unit conversions are applied to convert the log measurement values to the desired final output values (for example, neutron counts per second to neutron porosity in percent). The measurement units and converted units for all logs discussed in this paper are given in table 1. After the unit conversions are applied, the logs may be replotted on the CRT, edited and (or) filtered again if necessary, and stored on magnetic tape or output as a paper copy of the CRT plot, or replotted on a high-resolution *X–Y* plotter. A generalized flow chart of the computer programs is given in figure 1.

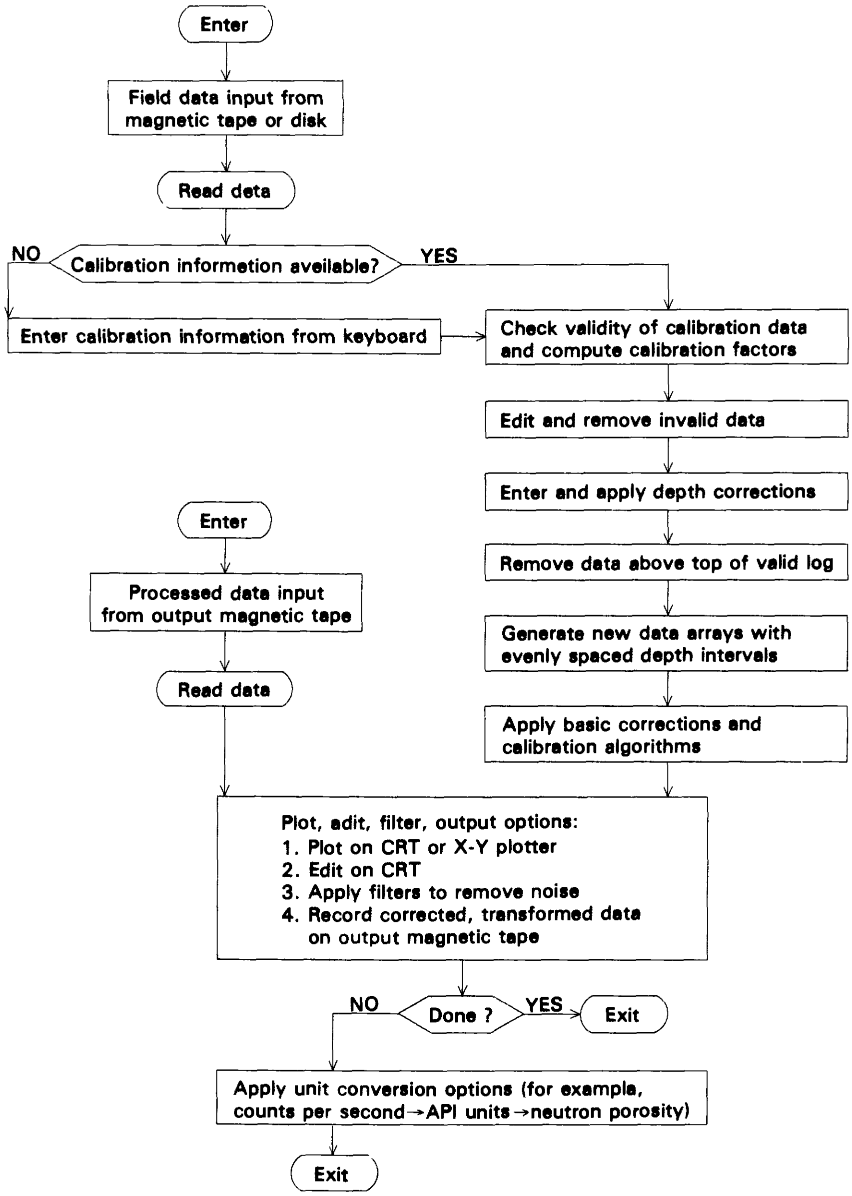

FIGURE 1.—Generalized flow chart of computer programs for analyzing digital well logs. CRT, cathode ray tube; API, American Petroleum Institute.

DETAILED DESCRIPTIONS OF COMPUTER PROGRAMS

1. Natural gamma-ray and neutron-neutron log program

Gamma-ray (total count) and neutron-neutron (porosity) log analyses are combined in one program because digital field logs are obtained with a probe that simultaneously measures both parameters. The gamma-ray measurement is made with an NaI(Tl) detector mounted near the top of the probe and the neutron measurement is made with an He-3 tube that detects neutrons scattered back to the detector from an Am(Be) source attached to the bottom of the probe, 40 cm (centimeters) below the detector. After field data are read into the computer from magnetic tape, the program compares the calibration check count rates with count rates known to be valid from previous calibration runs to assure that the probe sensitivity was within statistically acceptable limits when the field measurements were made. Then the logs are scanned and invalid or redundant data points are deleted. Depth corrections are made for the different vertical positions of the two detectors on the probe, and for any changes that might be needed in the zero-depth reference point (such as casing collar versus ground level). New arrays at evenly spaced depth intervals are generated and dead-time corrections are applied using values of dead time determined by the two-source method (Scott, 1980). Dead-time corrections are made rapidly by use of matrix arithmetic operations available in the BASIC programming language. Only three program steps are needed to correct an array of observed count-rate values X, for dead time, T:

1. MAT $X=(1)/X$,
2. MAT $X=X-(T)$, and
3. MAT $X=(1)/X$.

When step 3 is executed, the corrected count rates are stored in array X. These matrix statements

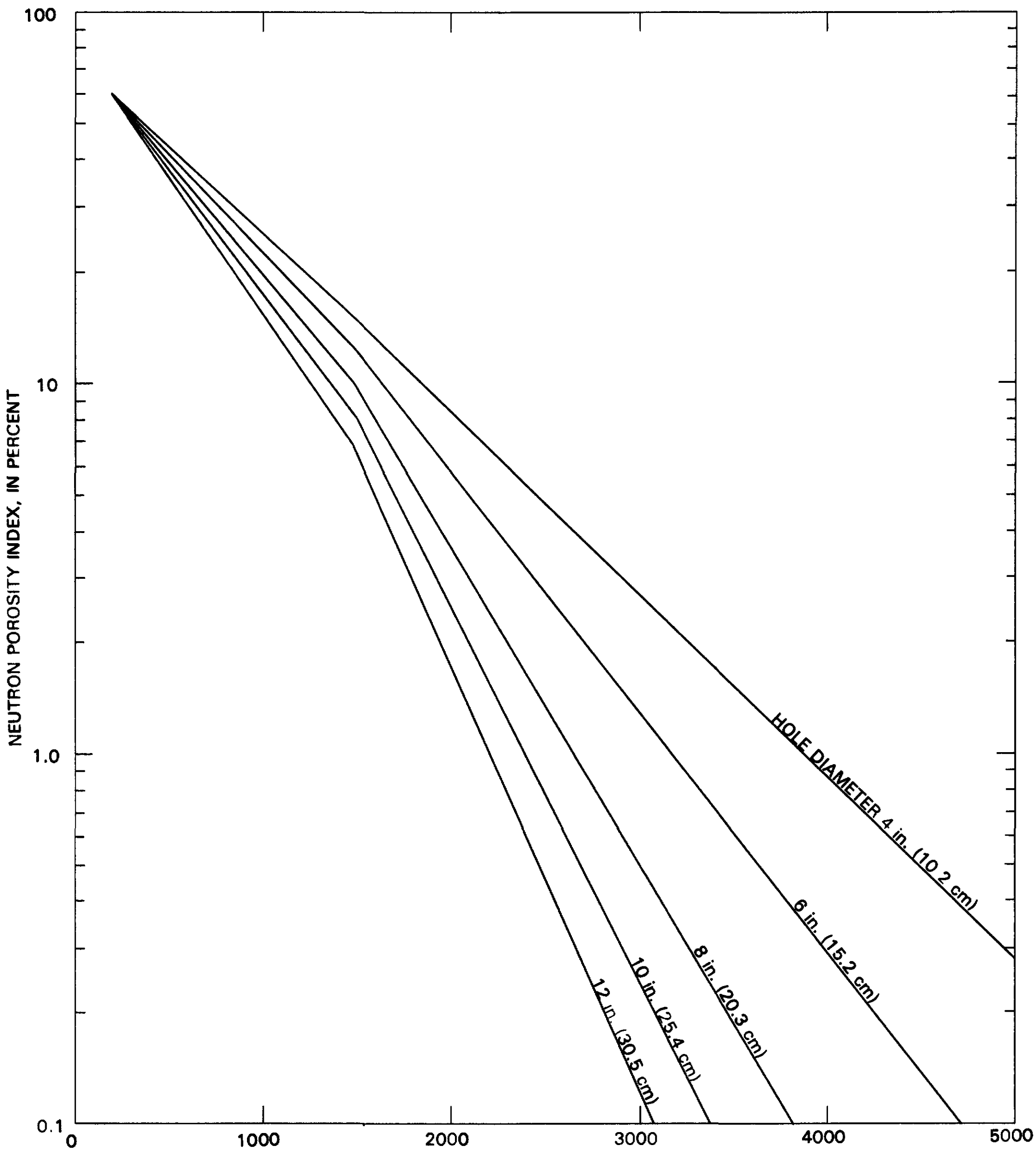

FIGURE 2.—Graph showing calibration information used to transform neutron API (American Petroleum Institute) units to porosity index, for holes of various diameters in inches (in.) and centimeters (cm).

are equivalent to the much slower FOR-NEXT loop evaluation of the standard form of the dead-time correction formula:

$$X(I)=X(I)/(1-X(I)*T)$$

Corrections for down-hole dividers that reduce the observed count rate by dividing by 2, 4, or 8, are also made at this time. After these corrections are made the user can plot, edit, apply a smoothing filter to reduce statistical noise, and then re-record the log data on an output tape in units of counts per second.

In the next section of the program, the user can convert the gamma-ray log values from units of counts per second to API (American Petroleum Institute) units or to eU_3O_8 grade (percent), and the neutron-neutron log values from counts per second to API units or neutron porosity index (percent). Transformation of the gamma-ray and neutron-neutron logs to API units is accomplished with conversion factors established by empirical calibration of the logging probes in the API test pits at the University of Houston (American Petroleum Institute, 1974). API units are converted to porosity index (percent) by use of empirical calibration data obtained from the Birdwell-SSC test pits in Tulsa (Seismograph Service Corporation, 1973). Figure 2 gives an example of calibration data used to convert neutron API units to porosity. Because the conversion to porosity index depends on hole diameter, the program requires that the user either (1) specify a constant value of hole diameter, or (2) read a caliper log into the computer from an output tape. The program makes the conversion to porosity index by interpolating values between curves relating API units to porosity index for various values of hole diameter (see fig. 2). Transformation of the gamma-ray log units from counts per second to percent eU_3O_8 is accomplished by an iterative numerical modeling procedure known as GAMLOG (Scott, 1962, 1963) for which coefficients have been derived for digitizing intervals of 0.2, 0.5, and 1.0 ft, for mud-filled and air-filled boreholes. The calibration factors relating count rate to percent eU_3O_8 (for an infinitely thick slab of uranium ore) and for making corrections for mud-filled holes of varying diameter were obtained from the U.S. Department of Energy-Bendix calibration pits in Grand Junction, Colo. (Mathews and others, 1978).

The GAMLOG procedure sometimes produces negative U_3O_8 grade values as the result of statistical fluctuation in count rate, particularly when small (0.2 ft) digitizing intervals are used. An iterative routine is appended to the GAMLOG section of the program to test for the presence of negative grade values, and if any are found, to redistribute them along adjacent points of the log to avoid this physically impossible condition.

After the gamma-ray and neutron-neutron logs are transformed to API, eU_3O_8, or porosity units, the user can plot, edit, and filter the logs, and (or) record them on output tape.

The filtering routine that is used in this program is a Hamming smoothing filter described by Blackman and Tukey (1958) that conserves area under the curve. The number of points comprising the filter is selected by the user; values of 5–11 have been found to be most effective in practical application.

Examples of unit conversion of analyzed gamma-ray and neutron-neutron logs are given in figure 3.

2. Dual-detector density and caliper log program

This program analyzes gamma-gamma log density measurements and caliper log-hole diameter measurements made with a combination probe. The probe utilizes two collimated gamma-ray detectors spaced at 17 and 37 cm from a gamma-ray source (125 mCi Cs–137), and a single caliper arm that presses the detectors against the hole wall and measures hole diameter. The program starts by reading the digitized caliper and gamma-ray well-logging data from magnetic tape, and reading in calibration information that is recorded at the end of the logging data. Calibration information consists of count-rate values obtained when the probe is placed in density calibration test blocks, one aluminum and the other Plexiglas, having effective densities of 2.62 and 1.28 g/cm^3 (grams per cubic centimeter), respectively. The program compares the calibration count rates with values obtained with the same probe previously, shortly after calibration runs were made in test pits at the Denver Federal Center, Colo. (Snodgrass, 1976). If the observed count rates agree with the previously obtained values within reasonable limits of statistical error, the calibration coefficients obtained during the previous calibration runs in the test pits are used to convert log count rates to apparent density values. If not, the user is offered the opportunity of using new calibration coefficients that are computed from the count rates obtained in the aluminum and Plexiglas blocks.

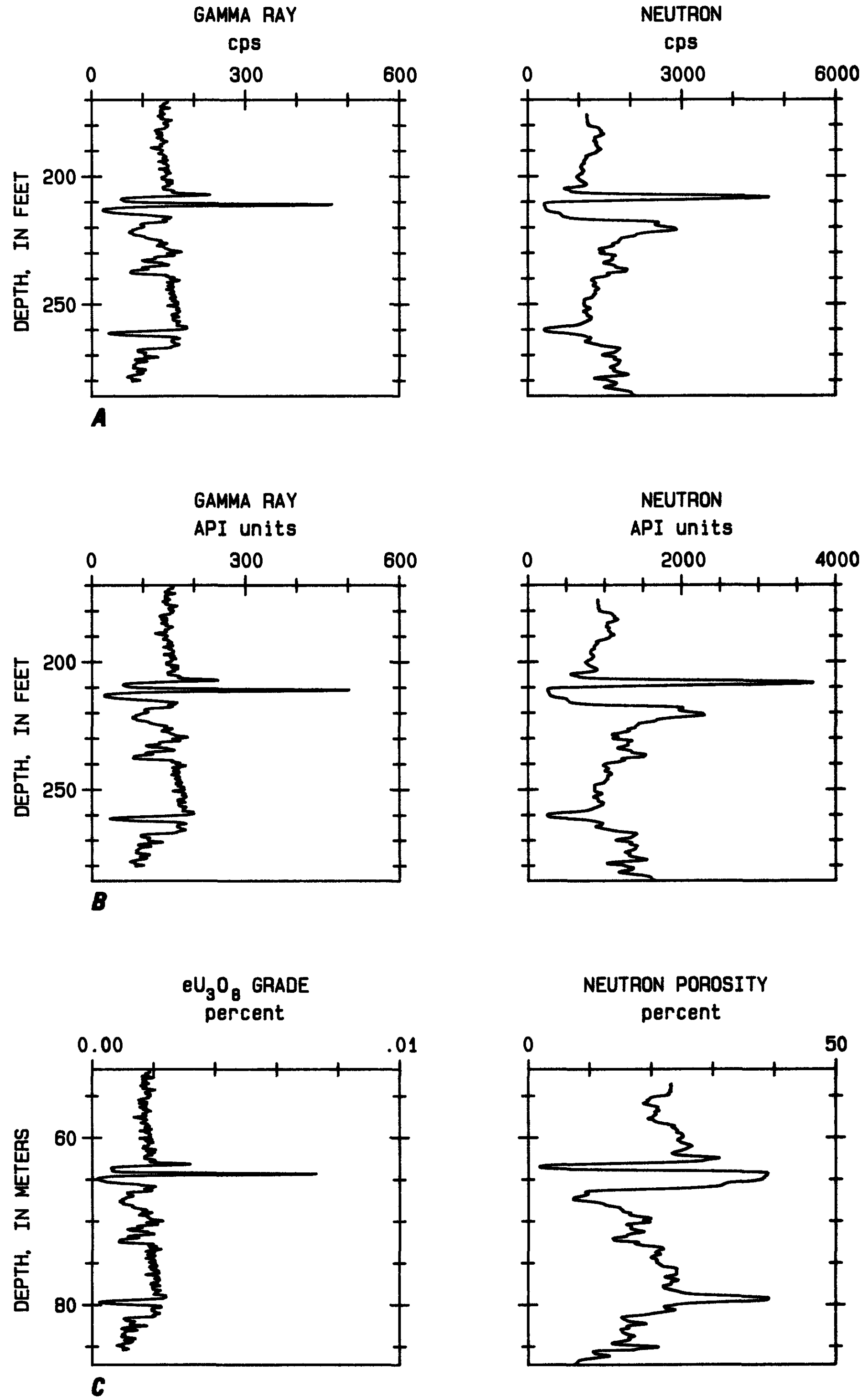

FIGURE 3.—Examples of computer plots of natural gamma-ray and neutron-neutron logs: *A*, count rate, in counts per second (cps); *B*, American Petroleum Institute (API) units; *C*, uranium grade in percent eU_3O_8 and neutron porosity index in percent.

After the calibration coefficients are determined, the program searches for and removes any invalid data or redundant depth values. Depth corrections are then made for the offset positions of the various detectors on the probe and for error in the zero-depth reference point, if any. The caliper log values, digitized by a 5½ digit DVM and recorded in millivolts, are converted to inches by fitting a polynomial curve to calibration readings stored at the end of the field-data tape. The order of the polynomial can be selected by the user. The caliper arm on the logging probe is pivoted at the top and swings out under spring pressure to make contact with the hole wall. When the arm is fully extended, the depth of the caliper measurement is shallower than when the arm is compressed against the probe, because of the geometry of the pivoting motion of the caliper arm. A depth correction is made by the program for this error by use of the following formula:

$$Z_c = Z_a - (L - \sqrt{L^2 - (C-D)^2})$$

where Z_c is corrected depth,
Z_a is apparent depth,
L is length of caliper arm,
C is caliper measurement (hole diameter), and
D is probe diameter.

New arrays of caliper and gamma-ray detector count-rate values are generated at evenly spaced depth intervals, and then corrections are applied for dead-time errors and downhole scaling of count rate (division by 8 in the probe). At this point the user can plot, edit, and filter the corrected near- and far-detector count rate and caliper logs, and (or) record them on output tape.

The next section of the program converts the near- and far-detector gamma-gamma logs from units of count rate to apparent-density (g/cm^3), and applies hole-diameter corrections to the converted values. The user can again plot, edit, filter, and re-record the converted apparent-density data. The final section of the program applies a density compensation algorithm using the near- and far-detector apparent density values as input. The compensation algorithm and its development are described by Scott (1977, 1978b). After the compensated density values are computed, the user can plot, edit, filter, and record the final logs on output tape. This final set of corrected and compensated logs includes compensated density (g/cm^3), amount of compensation (g/cm^3), and caliper (inches or centimeters). Figure 4 presents examples of dual-detector density logs in the three stages of analysis.

3. Magnetic susceptibility and conductivity log programs

This program analyzes the magnetic susceptibility and conductivity logs obtained with a probe that makes both measurements by use of a single induction coil connected in a Maxwell bridge (Scott and others, 1981). The program reads the two-channel logging data stored on magnetic tape in the form of digitized voltage outputs of phase discriminators that separate the magnetic susceptibility response from the conductivity response of the probe. Invalid raw data values and overlapping depth values are removed, and depth corrections are made for zero reference-depth offset, if any. Next, a calibration factor is computed as a function of the logging sensitivity scale and a calibration check value obtained by switching a capacitor of known value into a loop surrounding the coil in the probe. The magnetic susceptibility log, initially recorded in millivolts, is converted to relative micro cgs (centimeter-gram-second) units by multiplication by the computed calibration factor. Minimum and maximum values of the converted magnetic susceptibility log and the conductivity log are determined, and appropriate plotting multiplication by the computed calibration factor. Minimum and maximum values of the converted magnetic susceptibility log and the conductivity log are determined, and appropriate plotting scales and ranges are computed. Next, the program prompts the user to enter measurement-drift correction tie points at depths of his choice. Measurement drift is caused by temperature variation of the sensing coil. If laboratory measurements of magnetic susceptibility are available from drill core or cuttings, these values may be used to establish drift-correction tie points. If not, the user must estimate values based on his knowledge of the lithology, or by arbitrarily assigning zero values of magnetic susceptibility to the lowest points along the log trace. If the drift of the log is linear with depth, which is usually true, only two tie points are needed—one near the top and the other near the bottom of the log. If the drift is not linear, more tie points are needed. The drift correction is made by forcing the log trace to pass through the specified values of magnetic susceptibility at the tie points. Values in between the tie points are interpolated linearly if only two tie

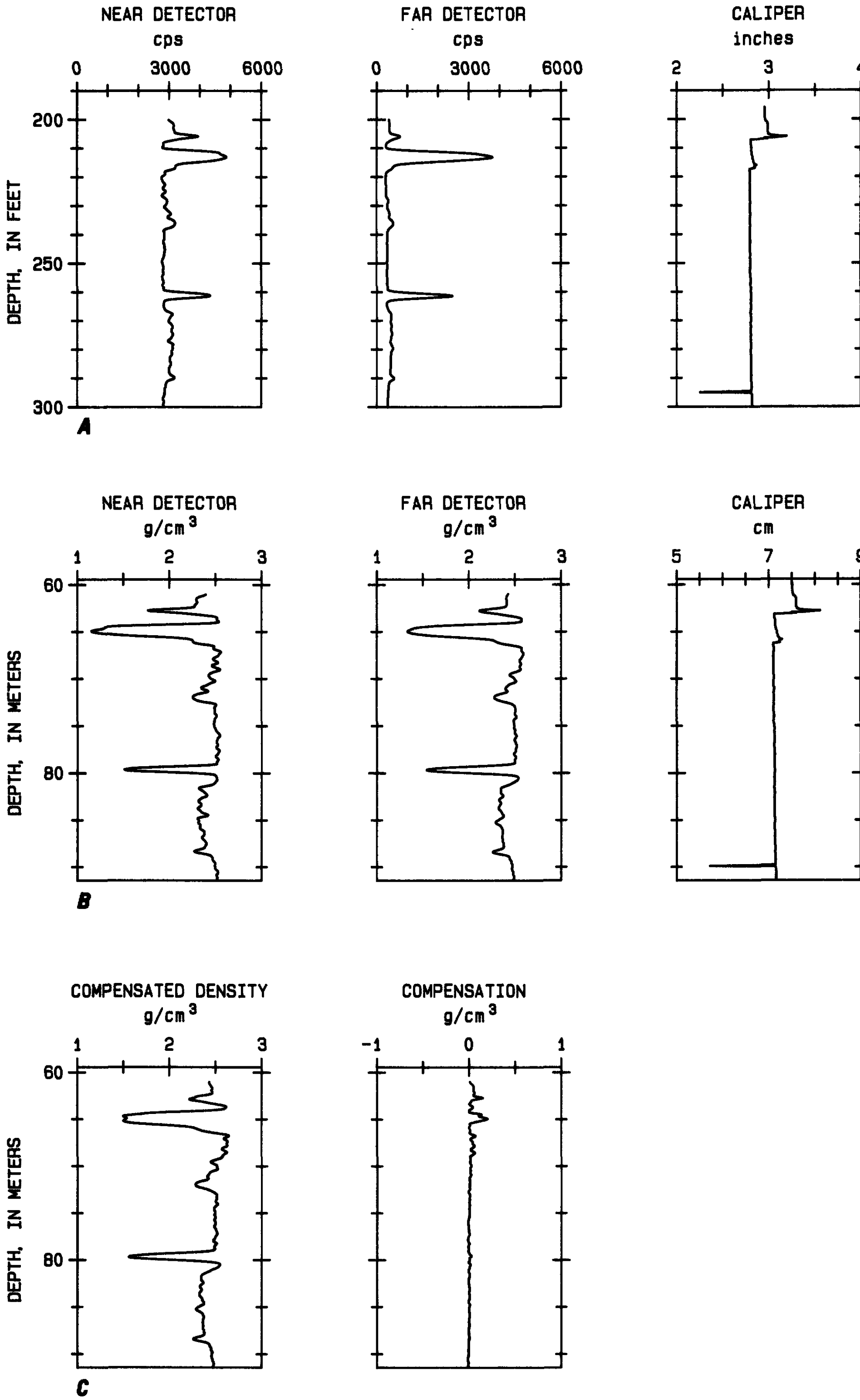

FIGURE 4.—Examples of computer plots of dual-detector density and caliper logs: *A*, gamma-gamma count rate, in counts per second (cps), and caliper in inches; *B*, apparent density in grams per cubic centimeter (g/cm^3), and caliper, in centimeters (cm); *C*, compensated density,in grams per cubic centimeter (g/cm^3), and compensation in grams per cubic centimeter (g/cm^3).

points are used, and by use of a spline curve fitted to the tie points if more than two points are available. Values above and below the top and bottom tie points are drift-corrected by linear extrapolation of data at the two tie points closest to the top and bottom of the log. After the drift correction is made, the user is prompted to plot, then to edit and (or) filter the magnetic susceptibility log, and to record it on output tape if desired.

The next section of the program corrects the magnetic susceptibility log for hole diameter, a correction that is established empirically by use of test pits such as those available at the Denver Federal Center, Colo. (Snodgrass, 1976). An example of empirical hole-diameter correction data is given in figure 5. Values of hole diameter are input to the computer by reading a caliper log output tape, or if a caliper log is not available, by entering a constant value of hole diameter from the keyboard.

conductivity log is plotted in relative form, and is not analyzed quantitatively in the present program because of lack of reliable calibration information.

Figure 6 gives examples of magnetic susceptibility and conductivity logs before and after corrections for drift and hole-diameter variations have been applied.

4. Resistivity and single-point resistance log program

This program analyzes resistivity logs made with either the normal or the Wenner configuration (Dobrin, 1952) using electrode spacings of 8, 16, 32, and (or) 64 in. (20.3, 40.6, 81.3, and (or) 162.6 cm), and a single-point resis tance log made with the same probe. The program reads the four-channel resistivity log data and the single-point resistance log data from magnetic tape where it is stored in the form of digitized voltage output of a four-channel solid-state resistivity module

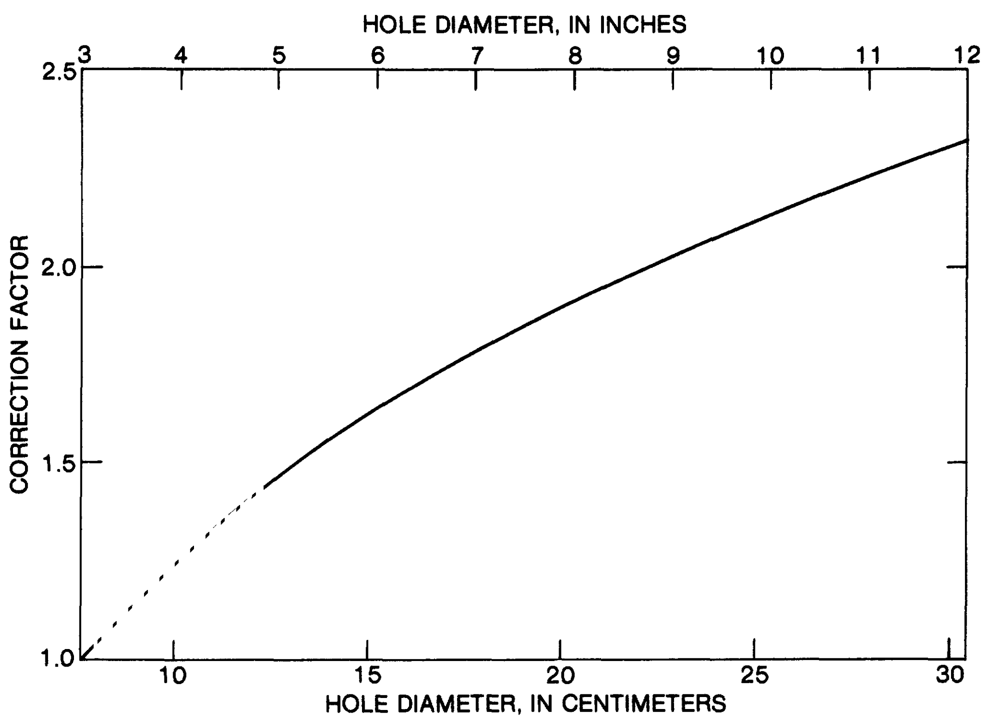

FIGURE 5.—Graph showing empirical hole-diameter correction data for magnetic susceptibility logs.

After the hole-diameter corrections are completed, the user can reapply the drift correction, and then plot, edit, filter and (or) record the analyzed data on output tape. This completes the analysis of the magnetic susceptibility log. The (Scott and Farstad, 1977) that has been modified to provide single-point resistance log output on a fifth channel. The single-point resistance log is computed by dividing digitized samples of the voltage and current transmitted to the current elec-

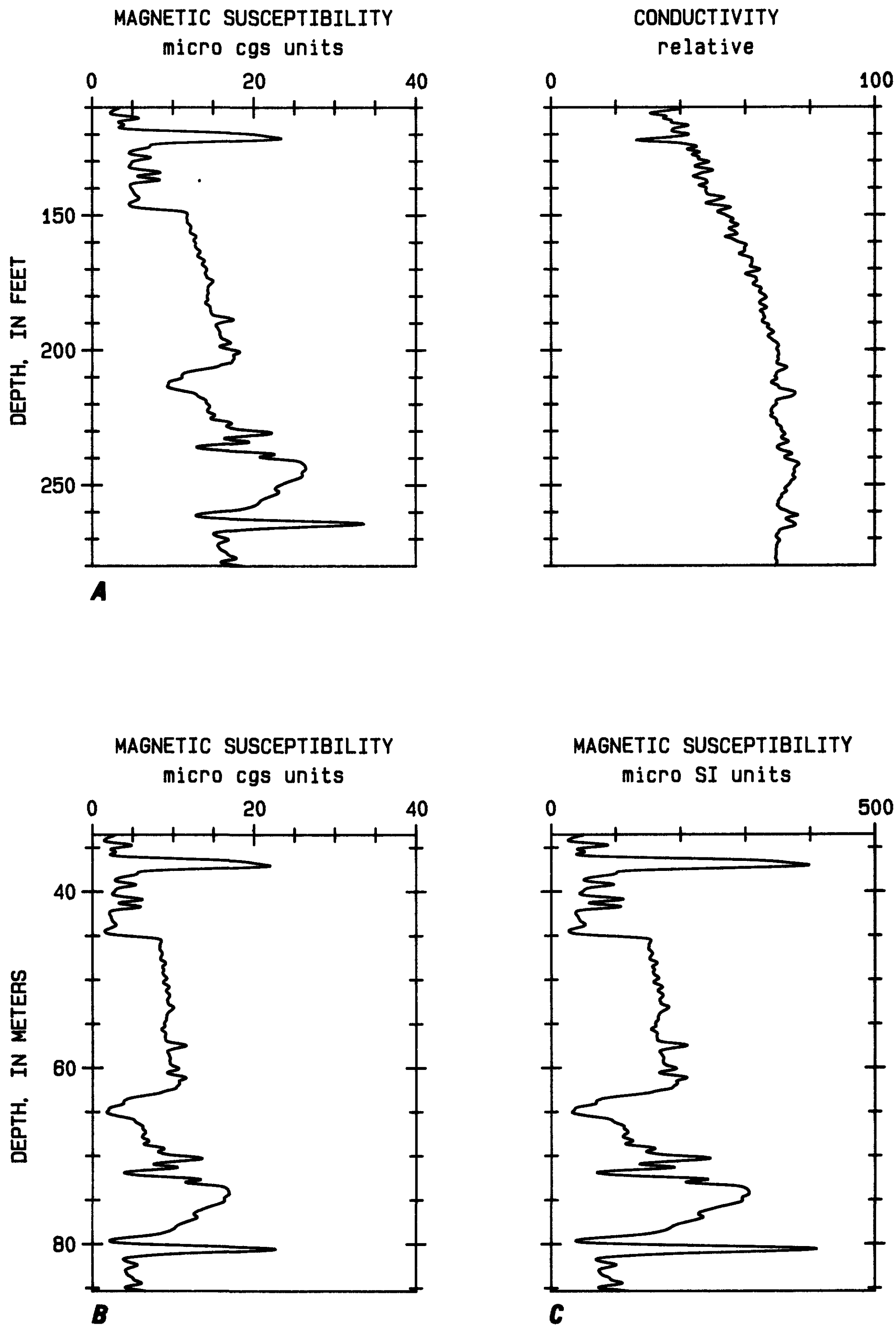

FIGURE 6.—Examples of computer plots of magnetic susceptibility and conductivity logs: *A*, observed susceptibility in centimeter-gram-second (cgs) units and relative conductivity; *B*, susceptibility in centimeter-gram-second (cgs) units, corrected for drift only; *C*, susceptibility in International System of Units (SI), corrected for drift and hole diameter.

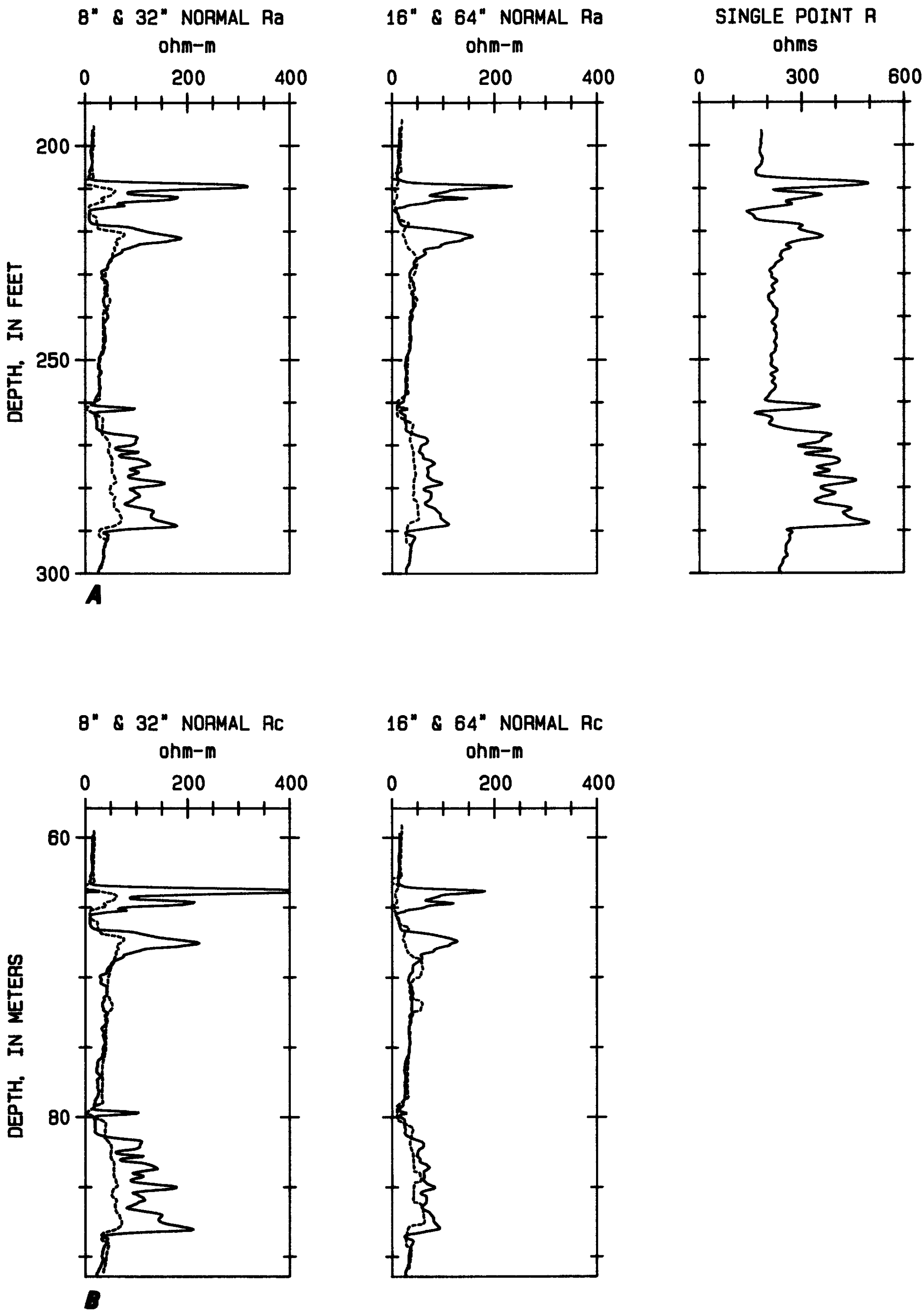

FIGURE 7.—Examples of computer plots of resistivity and single-point resistance logs: *A*, Apparent resistivity (Ra) 8-inch and 32-inch (8″ & 32″) normal spacings, in ohm-meters (ohm-m), for 16-inch and 64-inch (16″ & 64″) normal spacings, in ohm-meters (ohm-m), and single-point resistance (R), in ohms; *B*, resistivity corrected for borehole-fluid and hole-diameter effects (Rc) for 8-inch and 32-inch (8″ & 32″) normal spacings, in ohm-meters (ohm-m), and for 16-inch and 64-inch (16″ & 64″) normal spacings, in ohm-meters (ohm-m).

trode on the logging probe. After resistivity and resistance logs are read into the computer, invalid data and overlapping depth values are removed and depth corrections are made. Scale factors are computed from the transmitter and receiver range- switch settings that are recorded on the field tape, and the four digitized voltage outputs from the resistivity module are converted to apparent resistivity values for the four electrode spacings. Appropriate scales and ranges are computed for plotting, and the user is prompted to plot, edit, and filter the logs and then record the processed logs on output tape if desired.

The next section of the program applies corrections for the presence of fluid in the borehole. The user is required to enter values of borehole fluid resistivity, probe diameter, and hole diameter from the keyboard. These parameters and the electrode spacing are used to compute the correction. If the hole diameter varies significantly, as is usually true, a caliper log may be read into the computer from an output tape to provide a value of hole diameter for every resistivity reading in the hole. The correction algorithm is based on resistivity departure curves published as a correction chart entitled, "Normal device, no invasion" by the Schlumberger Well Surveying Corporation (1949). The curves can only be expected to remove first-order effects, because they are based on the simplifying assumptions that the layer thickness is infinite and that there is no invasion of drilling fluid into the formation. The numerical algorithm was developed and described by Scott (1978a). After the correction algorithm has been applied, the user can again plot, edit and (or) filter the logs, then record them on output tape.

Figure 7 gives examples of analyzed resistivity and single-point resistance logs before and after applying corrections to the resistivity logs for borehole fluid resistivity and hole diameter.

5. Sonic velocity and amplitude log program

This program analyzes continuous velocity logs made with a two-receiver probe and a module that computes the reciprocal velocity (delta-*t*) of the sonic pulse traveling between the two receivers and measures the relative amplitude of the first arrival compressional-wave energy picked up by one or the other of the two receivers. The program reads the digitized delta-*t* and relative amplitude values from magnetic tape, edits invalid and redundant values, and then offers the user an opportunity to plot, edit, and filter the raw data. A special filtering routine is available in this program for removing invalid delta-*t* values that are caused by errors in the electronic detection of first-arrival energy at the two receivers. This type of error, known as cycle skipping, is common in boreholes where fractured rock or severe rugosity causes poor signal-to-noise response of one or both of the receivers. The filtering technique works as follows. First, starting at the top of the log and working downward, a moving average is obtained over a specified number of points in a manner similar to the application of a boxcar filter, but with one important difference—the center point is not included in the average. Then a test is made to see if the value of the center point deviates more than a specified amount from the value of the average. If the value of the center point is beyond the specified limit, it is considered to be in error because of cycle skipping, and is replaced by the average value of the nearest two valid adjacent points. This simple scheme is about 90 percent effective in identifying and removing invalid data points caused by cycle skipping. In most applications, effective cycle-skip removal has been accomplished by using filter half-widths of 5–10 points and delta-*t* deviation test limits of 10–20 microseconds/ft. After cycle-skipping errors have been removed, the log may be replotted, and any remaining cycle-skip points that are identified visually by the user can be deleted manually by the editing routine that is programmed for use with the CRT plot of the log.

The next part of the program converts the delta-*t* values to velocity in units of either feet per second or kilometers per second, selectable by the user. After the conversion is complete, the user can replot, re-edit or refilter the logs with a Hamming smoothing filter, then record the final data on output tape. Figure 8 gives an example of a noisy delta-*t* log before and after cycle-skip filtering, and then after conversion to velocity units.

6. Temperature log program

This program analyzes digitized absolute temperature logs and computes differential temperature logs from them. The program reads the absolute temperature log from magnetic tape, edits and removes invalid and redundant data, and then computes a differential temperature log using a depth-lag interval specified by the user, after which the logs may be plotted, then optionally edited and (or) smoothed by a Hamming filter as

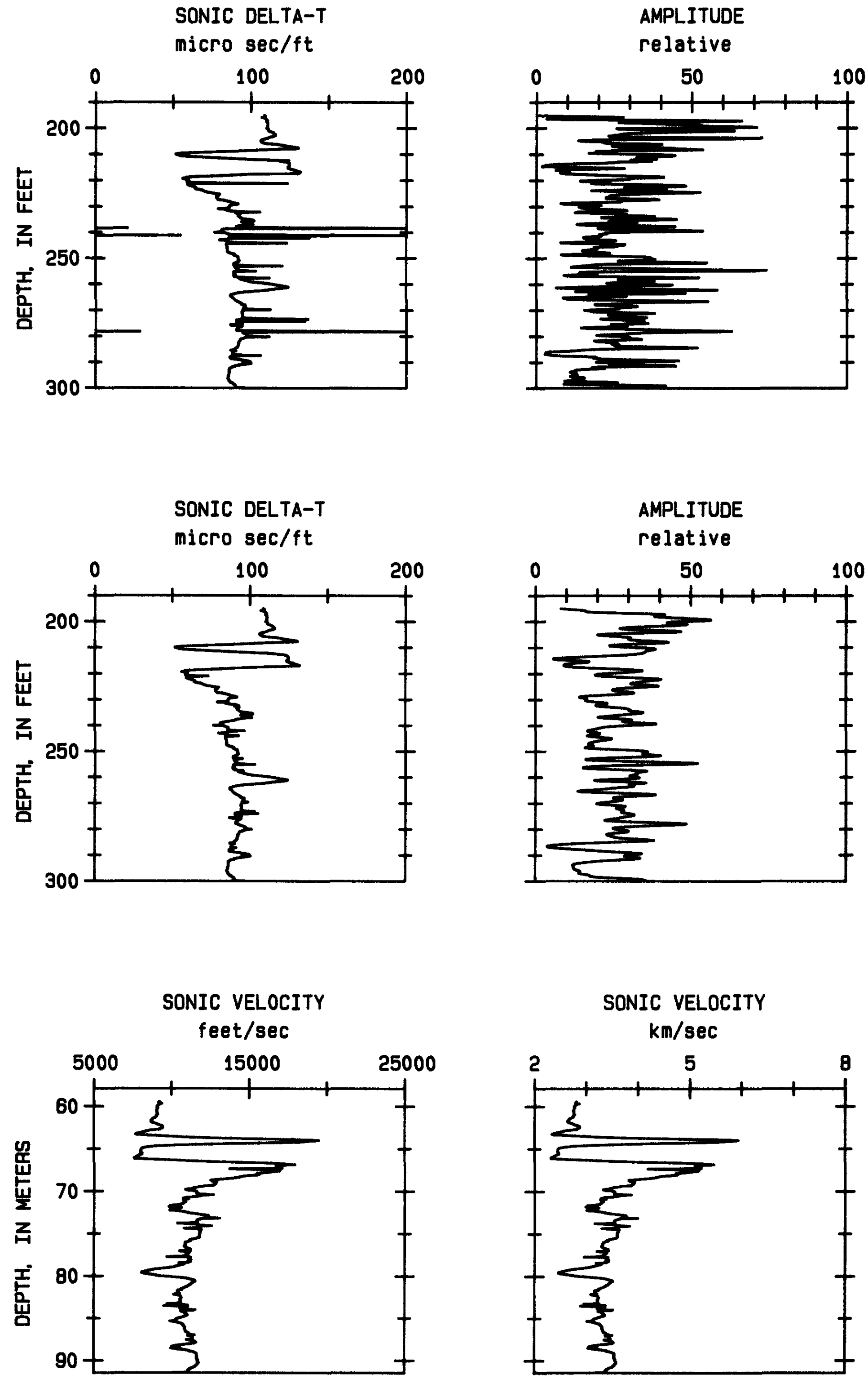

FIGURE 8.—Examples of computer plots of sonic velocity and amplitude logs: *A*, Unfiltered sonic transit time (delta-*t*), in microseconds per foot (micro sec/ft), and relative amplitude; *B*, Filtered sonic transit time (delta-*t*) in microseconds per foot (micro sec/ft), and smoothed relative amplitude; *C*, Filtered transit time data converted to sonic velocity in feet per second (ft/sec) and kilometers per second (km/sec).

desired. The user may record both the absolute and differential temperature logs on output tape after any stage of editing and smoothing. Figure 9 gives an example of an absolute temperature log and the corresponding computed differential temperature log.

7. Induced polarization, resistivity, and self-potential log program

This program applies corrections and plots logs made with a digital IP (induced polarization) measurement system. In addition to the IP log, resistivity and self-potential values are recorded on

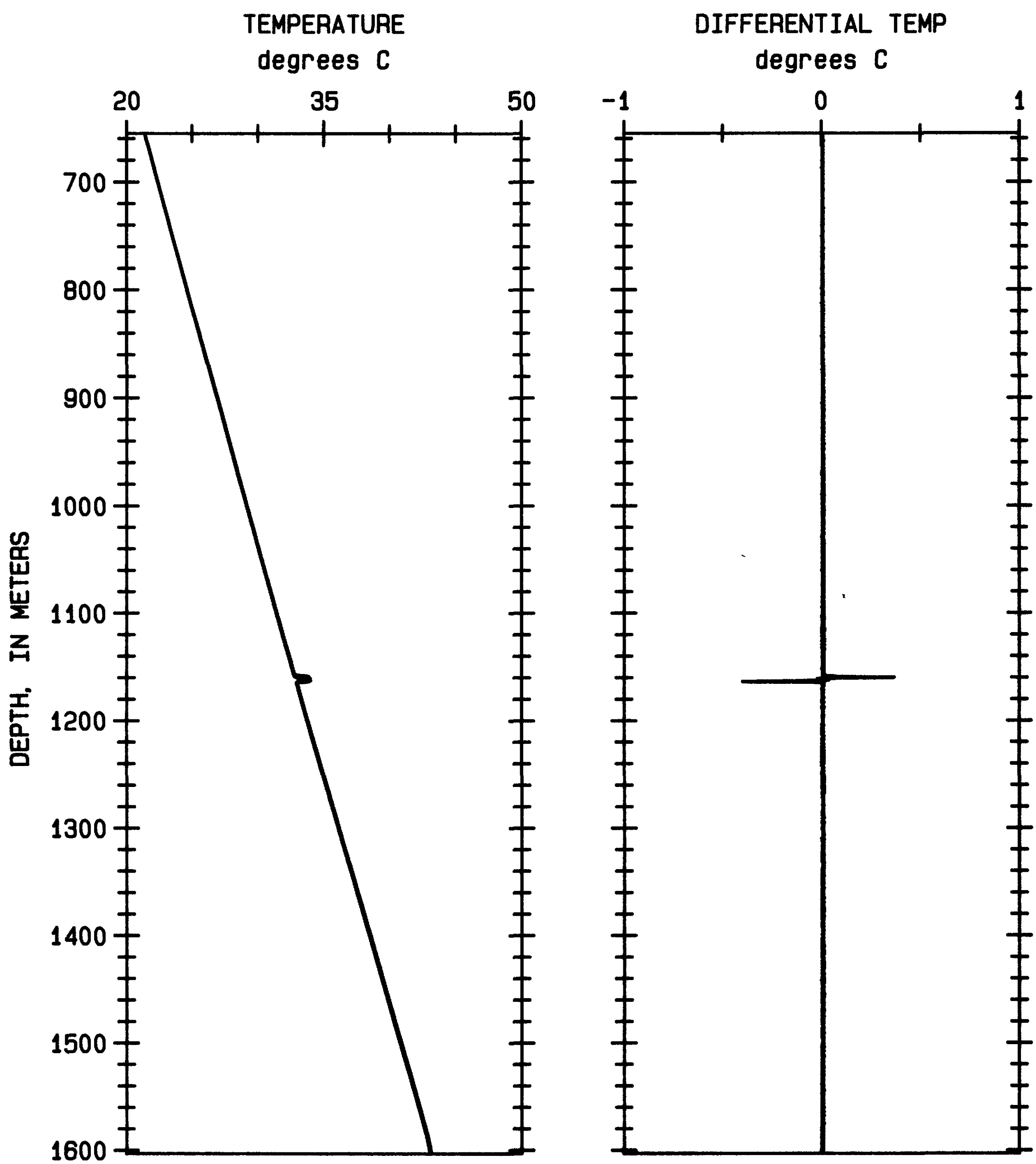

FIGURE 9.—Example of a computer plot of an absolute temperature log in degrees centigrade (C), and differential temperature (temp) log in degrees centigrade (C), computed at a depth lag interval of 1 ft.

magnetic tape as subsidiary logs because these measurements are needed by the logging module to compute IP values electronically. The program reads the field logs from magnetic tape, culls out invalid and redundant data, and then applies scale factors computed from module range-switch settings and electrode spacings. The program prompts the user to select options for plotting, editing, and filtering the data, then recording the reduced data on output tape if desired. An example of a plot of IP, resistivity, and self-potential logs is given in figure 10.

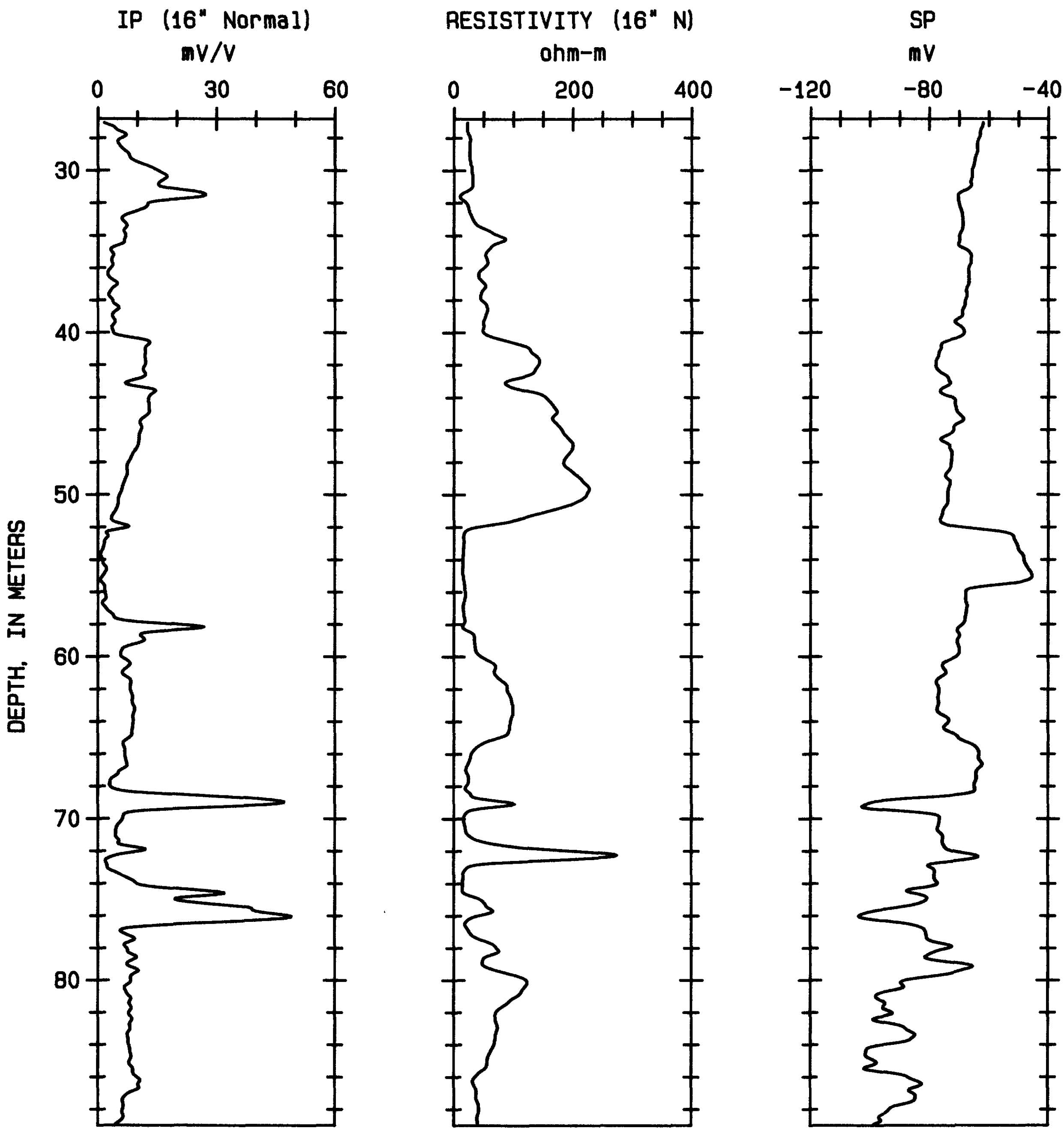

FIGURE 10.—Example of a computer plot of an induced polarization (IP) log in millivolts per volt (mV/V), resistivity, for a 16-inch normal (16″N) electrode configuration, in ohm-meters (ohm-m), and self-potential (SP) in millivolts (mV).

SUMMARY AND CONCLUSIONS

Interactive computer programs for analyzing digital well logs have been developed by the U.S. Geological Survey for use with a research well-logging system. The programs are implemented on a small computer that is installed in the field logging truck, making it possible and practical to analyze field logs at the well site if desired. The programs provide the user with the capability of applying corrections for changes in calibration, for applying digital smoothing filters, for correcting measurement drift, and for editing data displayed on the computer CRT. The programs are easily modified to accomodate unique conditions that are apt to occur in research logging. Computation is staged in such a manner that the effects of transformation from observed measurement units to computer units, and the effects of filtering and editing may be observed by making successive plots on the computer CRT. The user has the option of making paper copies of the CRT plots whenever he desires to do so. Plotting units and scales for depths and log parameters are flexible and can be changed by the user to fit his or her needs, whether they be to obtain a quick plot of data analyzed in the field or to make a finished copy for publication. Analyzed logs may be recorded on output magnetic tapes and these tapes may be read back by the computer program for reanalysis and replotting at any future date.

Experience in using these analytical programs on a small desktop computer, in contrast to using similar programs on a large timeshare computer, indicates that the desktop computer installed in the research logging truck offers the following advantages:

1. The desktop computer has turned out to be more reliable and has had far less "down" time than the large timeshare computer.
2. With greater flexibility and facility for operator interaction, the desktop computer programs yield better results with less user time and effort.
3. Analysis is possible and practical at the well site.
4. A cost reduction of about 50 percent per analyzed log is realized with the desktop computer as compared with the timeshare computer if the purchase and maintenance costs of the desktop computer are spread out over a 5-year period.

REFERENCES CITED

American Petroleum Institute, 1974, Recommended practice for standard calibration and format for nuclear well logs: Dallas, Tex., American Petroleum Institute, API RP 33, 13 p.

Best, D. L., Gardner, J. S., and Dumanoir, J. L., 1978, A computer-processed wellsite log computation: SPWLA (Society of Professional Well Log Analysts) 19th Annual Logging Symposium, June 13–16, 1978, El Paso, Tex., Transactions, p. Z1–Z32.

Blackman, R. B., and Tukey, J. W., 1958, The measurement of power spectra: New York, Dover Publications, p. 95–100.

Dobrin, M. B., 1952, Introduction to geophysical prospecting: New York, McGraw-Hill, p. 372–376.

Kinkade, R., West, J., and Hallenburg, J., 1978, The Compu-Log concept and practice: SPWLA 19th Annual Logging Symposium, June 13–16, 1978, El Paso, Tex., Transactions, p. S1–S9.

Mathews , M. A., Kiozumi, C. J., and Evans, H. B., 1978, DOE-Grand Junction logging model data synopsis: U.S. Department of Energy, Bendix Field Engineering Corporation report GJBX–76(78), 52 p.

Moseley, L. M., 1976, Field evaluation of direct digital well logging: SPWLA 17th Annual Logging Symposium, June 9–12, Denver, Colo., Transactions, p. NN1–NN11.

Schlumberger Well Surveying Corporation, 1949, Resistivity departure curves: Schlumberger Well Surveying Corporation, p. 9.

Scott, J. H., 1962, The GAMLOG computer program: U.S. Atomic Energy Commission Report RME–143, 43 p.

Scott, J. H., 1963, Computer analysis of gamma-ray logs: Geophysics, v. 28, no. 3, p. 457–465.

———1977, Borehole compensation algorithms for a small-diameter, dual-detector density well-logging probe: SPWLA 18th Annual Logging Symposium, June 5–8, 1977, Houston, Tex., Transactions, p. S1–S17.

———1978a, A FORTRAN algorithm for correcting normal resistivity logs for borehole diameter and mud resistivity: U.S. Geological Survey Open-File Report 78–779, 12 p.

———1978b, A computer program for borehole compensation of dual-detector density well logs: U.S. Geological Survey Open-File Report 78–515, 7 p.

———1980, Pitfalls in determining the dead time of nuclear well-logging probes: SPWLA 21st Annual Logging Symposium, July 8–11, 1980, Lafayette, La., Transactions p. H1-H11.

Scott, J. H., and Farstad, A. J., 1977, Electrical resistivity well-logging system with solid-state electronic circuitry: U.S. Geological Survey Open-File Report 77–144, 24 p.

Scott, J. H., Seeley, R. L., and Barth, J. J., 1981, A magnetic susceptibility well-logging system for mineral exploration: SPWLA 22d Annual Logging Symposium, June 23–26, 1981, Mexico City, Mex., Transactions, p. CC1–CC21.

Seismograph Service Corporation, 1973, Birdwell builds pits, clients benefit: SEIS News, January-February, 1973, 4 p.

Snodgrass, J. J., 1976, Calibration models for geophysical borehole logging: U.S. Bureau of Mines Report of Investigations 8148, 21 p.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984-7"7-