SURVEY



# Fortran Program for Correlation of Stratigraphic Time Series

## Part 2. Power Spectral Analysis

*By* BYUNG-DOO KWON, ROBERT F. BLAKELY, *and* ALBERT J. RUDMAN

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DEPARTMENT OF NATURAL RESOURCES
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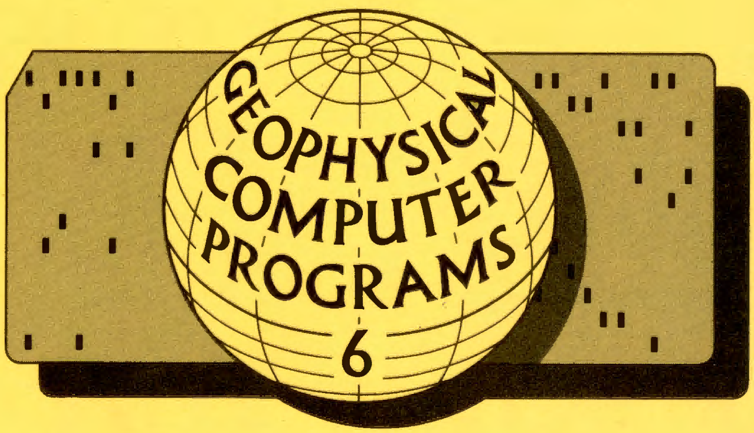

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GEOPHYSICAL COMPUTER PROGRAM 6

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## To the Geophysics Community

This report is one of a series of Geophysical Computer Programs that will be published in the Indiana Geological Survey Occasional Paper Series. Members of the Geophysics Section of the Indiana Geological Survey, with the advice and counsel of an advisory board,* will select and edit submitted papers. At present, programs dealing with the calculation of gravity and magnetic fields over two- and three-dimensional bodies, depth calculations from seismic refraction data, digital filtering, and crosscorrelation and convolution processes are in preparation. Readers are invited to submit programs and manuscripts to the Geophysics Section. The primary purpose of this series will be to make readily available those programs that deal with established geophysical computations.

Although the editors of some journals solicit only new approaches, we will seek to publish programs that also deal with standard and classic problems. Our experience has shown that geophysicists, working alone or at relatively small laboratories, do not always have access to such programs. We also solicit programs implementing new geophysical procedures, but we anticipate that such material will be made available only rarely. Nevertheless, even large laboratories with extensive computer libraries may welcome a study of the other fellow's approach. In the same spirit, we hope that geophysicists will share both their new and standard programs.

The format for this series is intentionally kept simple to encourage others to submit manuscripts. It should contain: (1) a statement to establish the purpose of the program and some discussion of applications; (2) a brief summary of the theory that underlies the algorithm; (3) a discussion of the program, perhaps with the aid of a flow diagram; and (4) presentation of a test case.

Responsibility for distribution of the program cards or furnished tapes will be assumed by the Indiana Geological Survey.

—Albert J. Rudman and Robert F. Blakely, editors

*Norman S. Neidell, Geoquest International; Sigmund Hammer, University of Wisconsin; Judson Mead, Indiana University; Franklin P. Prosser, Indiana University; and Joseph E. Robinson, Syracuse University.

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# Illustrations

# Fortran Program for Correlation of Stratigraphic Time Series Part 2. Power Spectral Analysis

*By* BYUNG-DOO KWON, ROBERT F. BLAKELY, *and* ALBERT J. RUDMAN

## Abstract

Automatic (computer) correlation of geophysical logs is complicated by stratigraphic thickening (or stretch) from one area to another. Previous algorithms compute the stretch with repeated crosscorrelations of the original logs. Program SPECOR presented in this report uses crosscorrelation of the power spectra of the logs to identify the stretch factor between logs in one simplified operation. Computations are performed in the frequency domain with the frequency intervals transformed to a logarithmic scale. Interpolation is required to obtain equally spaced power spectra. Given the stretch, displacement or lag between wells is computed rapidly by correlation processes, without needing to rely on iterative procedures.

## Introduction

Correlation of geophysical logs from two or more wells can be automatically accomplished by a digital computer. The process compares digitized logs by a mathematical technique called "crosscorrelation," which measures the similarity between two signals (logs) as a function of time shift.

In a region of sedimentary formations, thickening and thinning of stratigraphic sequences are common. A comparison of logs from such a region demonstrates stretched (or compacted) log signals. Because conventional crosscorrelation can detect only shift between two signals, the method is modified to consider stretching as well as relative displacement.

In 1973 Rudman and Lankston attempted to solve this problem by comparing autocorrelation and

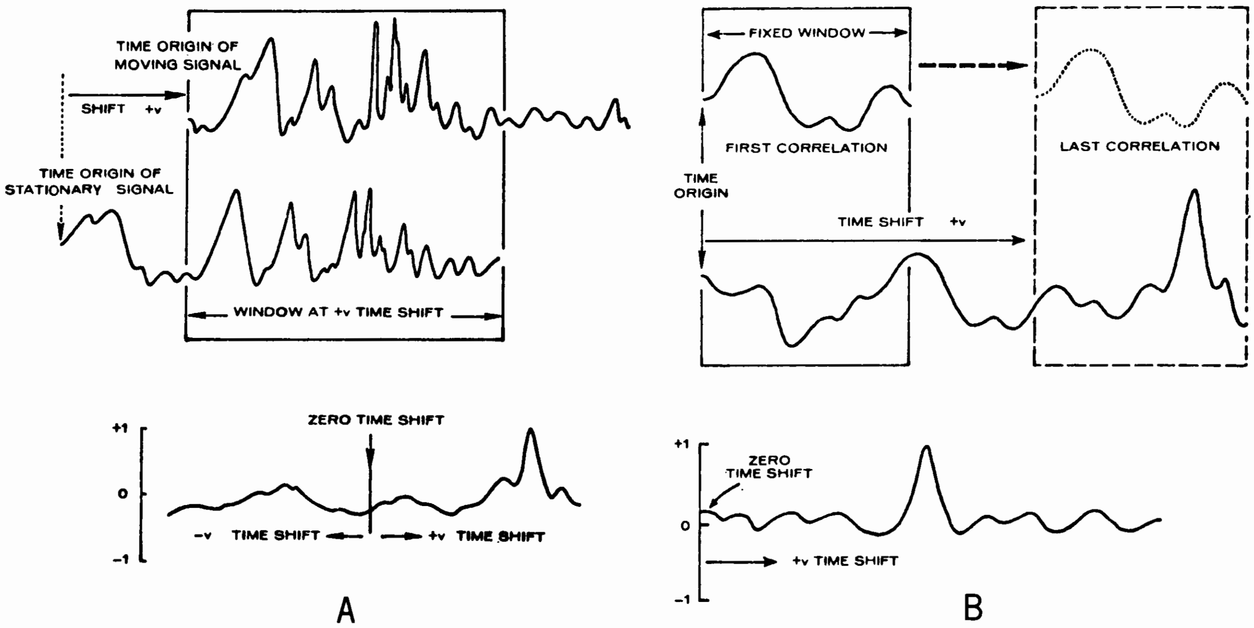



Figure 1. Sketches showing the crosscorrelation process. *A,* With variable window size and normalized crosscorrelation function. *B,* With fixed window size and normalized crosscorrelation function.

crosscorrelation functions of iteratively stretched intervals. In 1975 Rudman, Blakely, and Henderson used as an improved method normalized crosscorrelation functions and frequency-domain operations. The resultant program (COR4LOG) was published in Geophysical Computer Program 3 (Rudman and Blakely, 1976). Although both approaches were successful, iterative stretching and correlation require considerable computing time. If, in addition, the geologist is unsure which log is to be stretched, the procedure must be performed twice.

In 1977 Kwon was able to develop mathematical methods to compute a stretch factor and displacement between two sets of well logs without iterative operations. Program SPECOR presented in this publication (appendixes 1 and 2) makes a preliminary determination of the direction and degree of stretching by using the crosscorrelation of power spectra of overall log data. Given the stretch, the displacement between logs is computed by correlation processes in the frequency domain. A comparison was made to test the differences in computing time between programs SPECOR and COR4LOG. Computing times for short logs were 2.626 seconds by SPECOR and 14.248 seconds by COR4LOG.

## Theory

### CROSSCORRELATION PROCESS

Two types of crosscorrelation processes are considered for time series of finite duration. If the length of the two series is the same (fig. 1*A*), the length of interval (window) to be compared is changed with each time shift v. The normalized crosscorrelation function between the two sets of samples within the window, x(n) and y(n + v), is given by

$$R_{xy}(v) = \frac{\sum_{n=1}^{N-v} (x(n) - \bar{x}_o)\,(y(n+v) - \bar{y}_v)}{\sqrt{\sum_{n=1}^{N-v} (x(n) - \bar{x}_o)^2 \sum_{n=1}^{N-v} (y(n+v) - \bar{y}_v)^2}} \qquad (1)$$

defining

$$\bar{x}_o = \frac{1}{N-v} \sum_{n=1}^{N-v} x(n) \qquad \bar{y}_v = \frac{1}{N-v} \sum_{n=v+1}^{N} y(n)$$

$R_{xy}$ lies between −1 and +1. If this quantity is nearly ±1, there is a strong direct or inverse linear correlation within the window. If it is nearly 0, there is no correlation.

If the two series have different lengths (fig. 1*B*), equation 1 is modified to consider only a fixed window size equal to the length of the short series. In this case, the correlation function is obtained by shifting the short series in one direction (cf. Rudman, Blakely, and Henderson, 1975). Both processes are used in predicting stretch factors and in measuring relative displacements between two well logs.

### DISCRETE FOURIER TRANSFORM (DFT) AND ITS OPERATIONAL PROPERTIES

The stretch factor between two logs can be predicted by correlating power spectra of the two logs (rather than correlating the logs themselves). Power spectra are obtained through the Discrete Fourier Transform (DFT) of a series of N samples x(nT), $0 \leq n \leq N-1$, defined as follows

$$X(kW) = \sum_{n=0}^{N-1} x(nT)\; e^{-iWTnk}, \quad 0 \leq n \leq N-1 \qquad (2)$$

where T is a sampling interval in the time or space domain, and the frequency increment W is given as $W = \frac{2\pi}{NT}$. The time series x(nT) may be recovered exactly from the inverse Discrete Fourier Transform

$$x(nT) = \frac{1}{N} \sum_{k=0}^{N-1} X(kW)\; e^{+iWTnk}, \quad 0 \leq n \leq N-1 \qquad (3)$$

$\frac{1}{N}$ is included as a scale factor.

The following DFT properties (Jenkins and Watts, 1968) will be used in our approach in correlating and stretching time series:

(I) Shift of series

If a periodic series x(nT) has Fourier coefficients X(kW), then the DFT of the shifted displaced series x((n + m)T) is expressed as a multiplication of X(kW) and an exponential term which contributes to phase change.

$$\text{DFT}\left\{ x((n+m)T) \right\} = e^{-iWTmk}\, X(kW) \qquad (4)$$

(II) Lengthening of series

Suppose we have samples x(nT), $0 \leq n \leq N-1$, and we create a longer series y(nT), $0 \leq n \leq rN-1$, where r is any integer number and where

$$y(nT) = \begin{cases} x(nT), & 0 \leq n \leq N-1 \\ 0 & , \text{otherwise} \end{cases} \quad (5)$$

The increased length of y(nT) modifies the frequency increment W to W/r and the form of equation 2 is modified as follows

$$y(k\,[W/r]) = \sum_{n=0}^{rN-1} y\,(nT)\; e^{-iWTnk/r} = \sum_{n=0}^{N-1} x(nT)\; e^{-iWTnk/r} \quad (6)$$

(III) Crosscorrelation in the frequency domain

Although the crosscorrelation of two periodic time series involves iterative multiplications and summations, it can also be performed by simple multiplication of their Fourier transforms

$$\text{DFT}\left[\sum_{n=0}^{N-1} x(nT)\;\; y(n+v)T\right] = X^*(kW)\;\; Y(kW) \quad (7)$$

where * implies complex conjugation.

(IV) Power spectrum

The power spectrum of a given series x(nT) is defined as the square of its amplitude spectrum

$$P_X(kW) = \left| X(kW) \right|^2 = X^*(kW)\; X(kW) \quad (8)$$

Comparison of properties III and IV shows that the power spectrum of x(nT) is also the Fourier transform of its autocorrelation function. The unique feature of this spectrum is the loss of phase information; that is, the displacement has been eliminated as a pertinent factor.

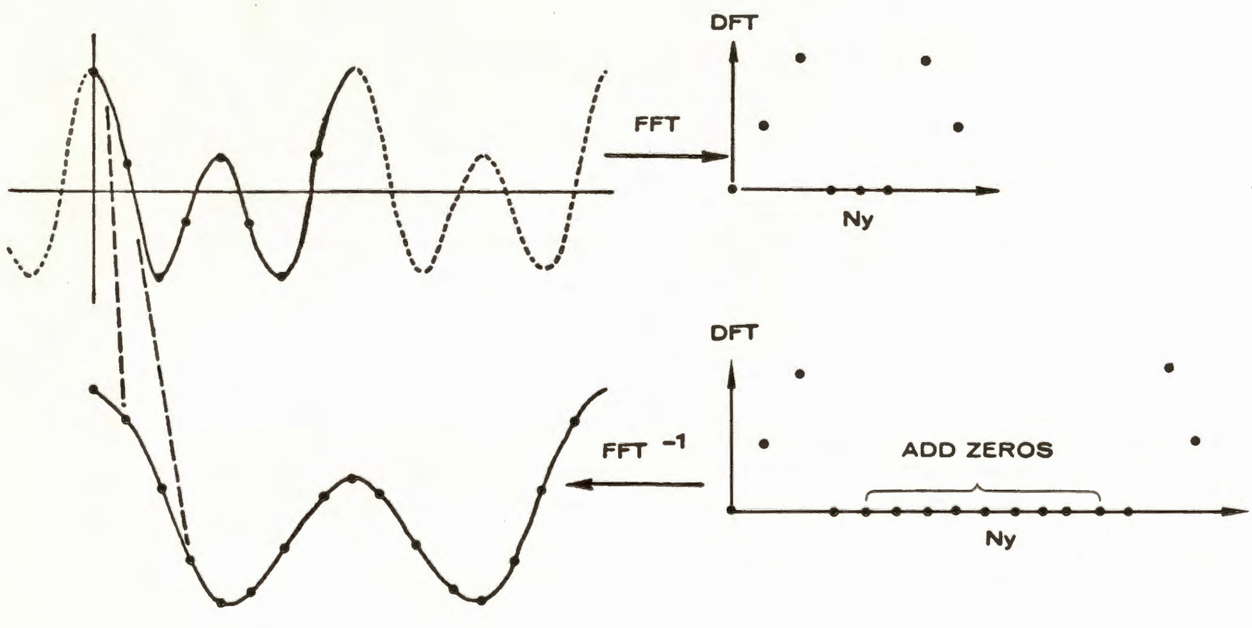



Figure 2. Interpolation (stretching) technique using FFT (Fast Fourier Transform). A signal of eight samples (heavy lines) is stretched to a signal of 16 samples by inserting eight zeros in the frequency domain. The Nyquist frequency (Ny) is identified on the Discrete Fourier Transform (DFT) plot.

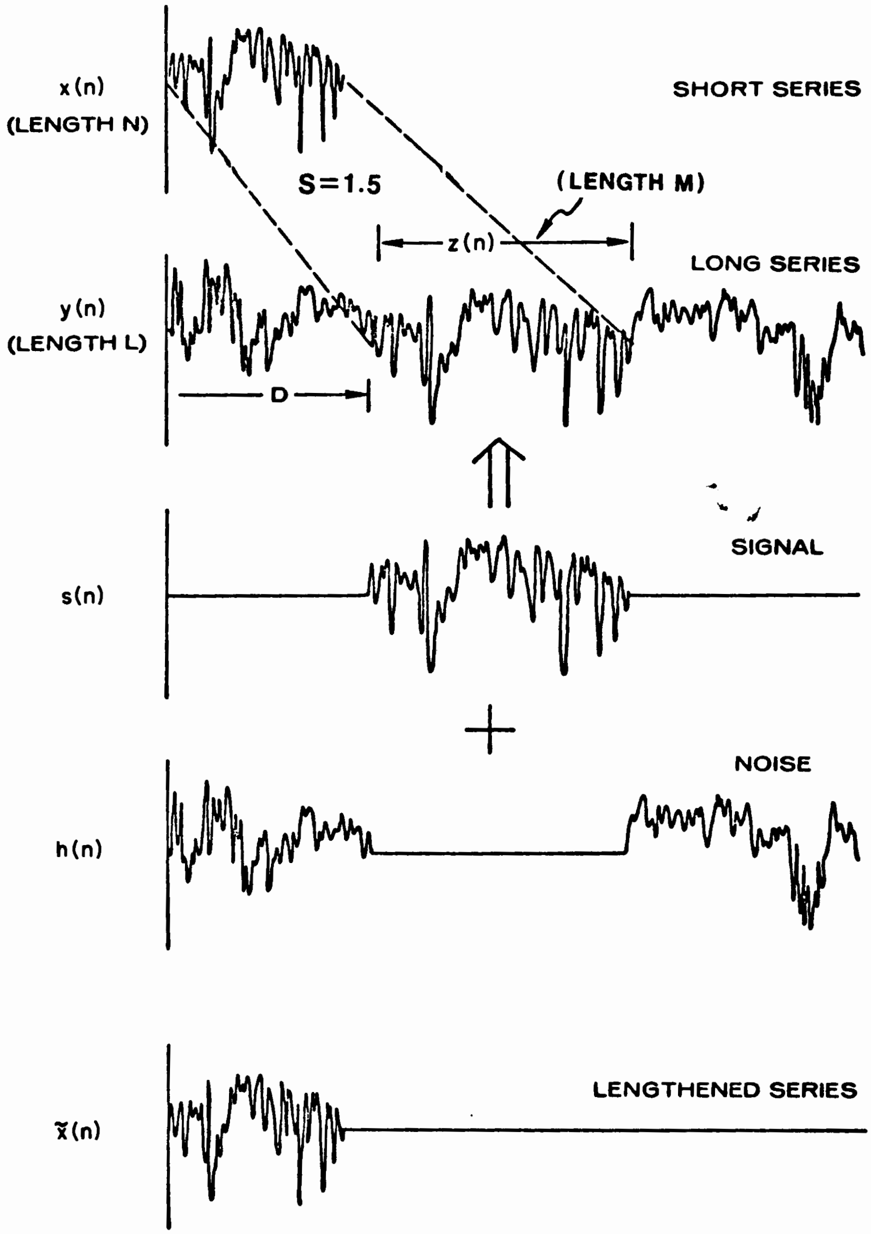



Figure 3. Model data used to demonstrate crosscorrelation of a series x(n) with a series y(n) comprised of a signal s(n) and (noncorrelative) noise h(n). Z(n) is equivalent to the short series x(n) with a stretch factor S $(=\frac{M}{N})$ and displacement D. Lengthened series $\bar{x}(n)$ is required in the correlation process used.

### INTERPOLATION BY DFT (STRETCHING)

Simple and accurate stretching of well logs can be achieved in the frequency domain (Rudman, Blakely, and Henderson, 1975) by modifying the DFT of the log. In this study the DFT was obtained by a Fast Fourier Transform (FFT) algorithm. A band-limited time series with N samples (no frequency components above the Nyquist frequency) can be stretched to M points, $M > N$, by inserting $(M - N)$ zeros in the middle of the DFT values (fig. 2). Because no new frequencies were added above the Nyquist, the inverse transform gives a time series of length M. The heavy line indicates the input signal, and the dashed line is a reminder that the DFT is computed, assuming the signal is cyclically repeated in both directions. In effect, this procedure interpolates $(M - N)$ new data points into the original time series.

### PREDICTION OF STRETCHING WITH POWER SPECTRA

Consider a time series x(n) of N samples as the short log from one well and a long series y(n) of L samples from another well (fig. 3). A part of the long series y(n) is called z(n) and is equivalent to the short series x(n) with a stretch factor $S\ (= \frac{M}{N})$ and displacement D. The long series y(n) can be represented as a sum of two series: signal s(n), which represents the lengthened series of z(n), and noise series h(n). For computational convenience, the lengthened series $\bar{x}(n)$ with length L is used instead of x(n).

The relationship between Z(k) and S(k) is complicated by the additional zeros in z(n). These effectively change the phase and modify the frequency scaling. (See DFT property II.) But phase change problems are avoided by computing power spectra related by the following equation:

$$P_S\ (k) = P_Z\ (k/S') \tag{9}$$

where the scaling factor $S'$ is equal to L/M. A similar relationship is derived between $P_{\bar{x}}$ and $P_x$:

$$P_{\bar{x}}\ (k) = P_x\ (k/S'') \tag{10}$$

Here, the scaling factor $S''$ is equal to L/N.

### LOGARITHMIC SCALING OF FREQUENCIES

Although computation of power spectra loses phase (displacement in the time domain), there is still the problem of scaling in the frequency domain. But if we transform the frequencies into a logarithmic scale, the multiplication factors $S'$ and $S''$ in equations 9 and 10 are converted into additive factors.

$$P_S\ (\log k) = P_Z\ (\log k - \log S') \tag{11}$$

$$P_{\bar{x}}\ (\log k) = P_x\ (\log k - \log S'') \tag{12}$$

Logarithmic scaling of frequencies modifies the power spectra by a frequency delay of log $S'$ or log $S''$. The factors $S'$ and $S''$ can be obtained by crosscorrelation processes used to detect such lag (delay) values.

Unfortunately, the values of logarithmic power spectra are not at the evenly spaced intervals required for computer correlation processes. We have used Lagrange's interpolation method (Hamming, 1962) to obtain equally spaced power spectra $P'_{\bar{x}}(i)$ and $P'_y(i)$. Assuming there is no correlative noise spectrum in $P'_{\bar{x}}(i)$, we equate $P'_y$ and $P'_s$. The crosscorrelation function of these spectra is given by

$$Rp'_{\bar{x}}p'_y\ (-v) \simeq \sum_{i=1}^{N-v} P'_{\bar{x}}(i+v)\ P'_s(i) \tag{13}$$

where v is a positive integer and i is a dummy variable for the interpolated spectrum.

Using equations 9 and 10 to transform equation 13 to logarithms, we obtain

$$\begin{aligned} Rp'_{\bar{x}}p'_y\ (-v) &= \sum_{i=1}^{N-v} P'_x(i - \tfrac{1}{I}\log S'' + v)\ P'_Z(i - \tfrac{1}{I}\log S') \\ &= \sum_{i=1}^{N-v} P'_x(i - \tfrac{1}{I}\log S'' + v)\ P_X(i - \tfrac{1}{I}\log S') \end{aligned} \tag{14}$$

where I is the interpolation interval. The maximum coefficient $Rp'_{\bar{x}}p'_y\ (-v)$ can be found if

$$v = \frac{1}{I}\log S'' - \frac{1}{I}\log S' = \frac{1}{I}\log\left(\frac{S''}{S'}\right) = \frac{1}{I}\log\left(\frac{M}{N}\right) \tag{15}$$

where $S' = \frac{L}{M}$ and $S'' = \frac{L}{N}$.

Similarly, +v's are obtained when the $P'_{\bar{x}}(i)$ is shifted to the right against a stationary $P'_{\bar{x}}(i)$ and the short series is assumed to be a stretched part of the long series. The maximum coefficient $Rp'_{\bar{x}}p'_y\ (+v)$ can be found if

$$v = \frac{1}{I} \log \left(\frac{M}{N}\right) \qquad (16)$$

Once the shift v is known for the maximum correlation coefficient, the stretch factor S, either $\frac{M}{N}$ or $\frac{N}{M}$, can be deduced from

$$S = 10^{vI} \qquad (17)$$

CROSSCORRELATION OF STRETCHED LOGS

Given the stretch factor S between two logs, we can stretch or resample the log using the frequency interpolation method. Crosscorrelation of such stretched logs then determines the relative displacement D between the short log and the identical part of the long log.

## Results

A density log from a drill hole of the Deep Sea Drilling Project (fig. 4*A*) provides a long series of 350 points (Log 2) and is used as a test case (appendixes 3 and 4). This log is stretched 1.35 times, and a part of the stretched log is chosen for the short series of 130 points (Log 1). The logs are next filtered by taking their derivatives to attenuate low-frequency components (fig. 4*B*). Power spectra of these logs are computed by FFT, and the components above the Nyquist frequency are ignored (fig. 4*C*). Note that the power spectrum for Log 1 is for a series lengthened to have the same number of data points as Log 2 (that is, $\bar{x}$ in fig. 3). Plots of the two power spectra show a similarity in shape, but a prominent scaling effect of frequencies is observed (stretching of Log 1 emphasizes the low-frequency spectra).

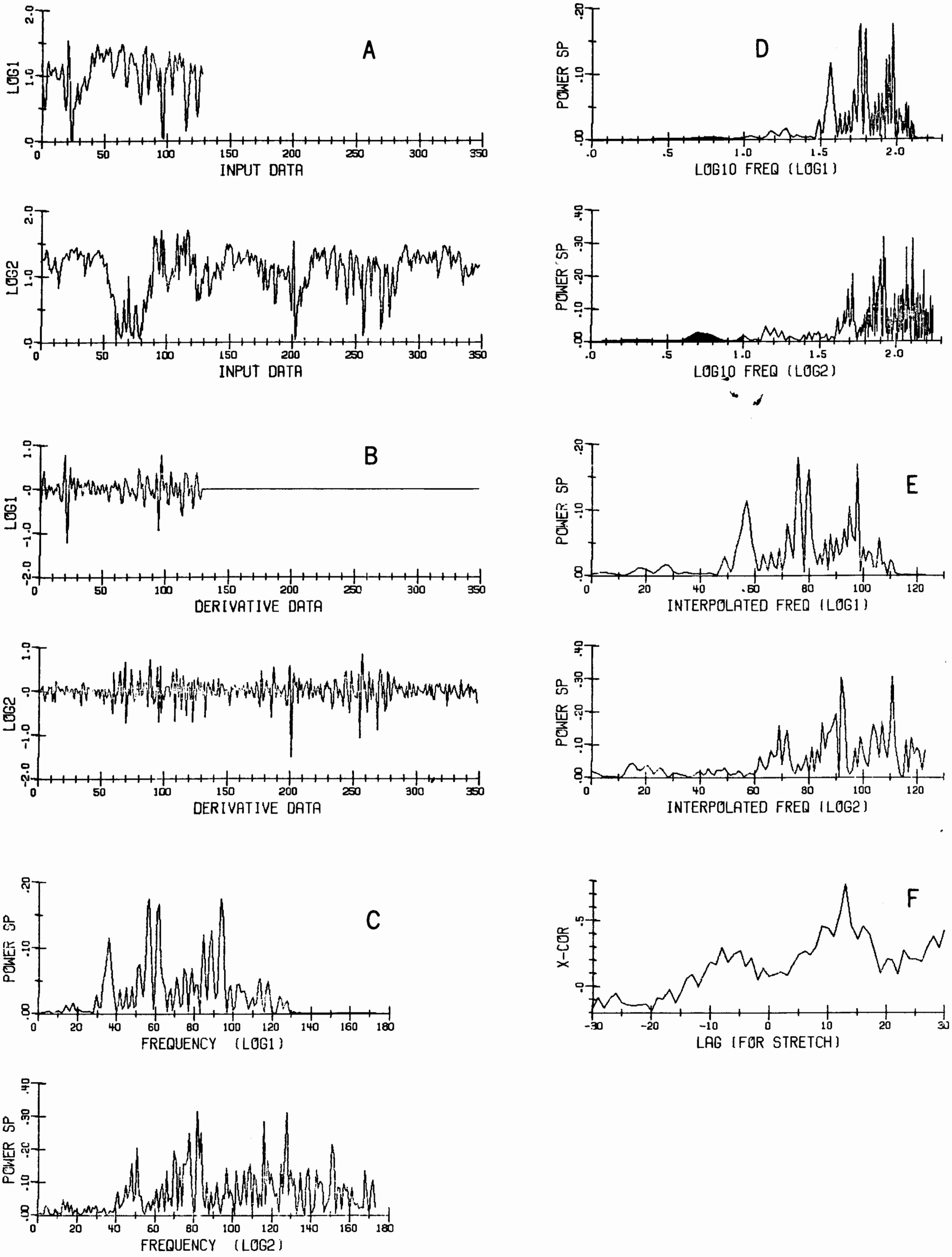
A transform to logarithmic frequencies converts the scaling effect into a shift between the two spectra (fig. 4*D*). In the logarithmic scale, the number of known components in each logarithmic cycle is different, for example, 10 in the first cycle, 90 in the second cycle, and 900 in the third cycle. In this study, we interpolate 100 samples in each cycle by using Lagrange's interpolation method and a sampling interval of $I = 0.01$. This assigns maximum importance to the data points in the second cycle.

Because interpolation of 100 samples from 10 known spectrum components is unreliable and time consuming, we simply ignore the first cycle. Theoretically we can use any part of these spectra for correlation purposes, but we prefer to use the entire spectrum to get maximum reliability. Sampling interval I may be adjusted to get desirable resolution of the stretch factor. Lagrange's interpolation with a 3rd degree polynomial is used to recover these logarithmically scaled power spectra (fig. 4*E*).

The crosscorrelation of these two interpolated power spectra is made with a variable window size (fig. 1*A*). Because the ratio of thickening to thinning of beds, in general, is not very large and rarely exceeds a ratio of 2, we set the maximum shift $\pm(v) = \pm(30)$, which corresponds to the stretch factor $S = 2$. (See equation 17.) Although we can use higher values of v to identify larger stretch factors, the reliability of the correlation coefficient may decrease if the length of shift exceeds 25 percent of the sample size. The normalized crosscorrelation function of these two interpolated power spectra clearly gives a distinct value at $-v = +13$ (fig. 4*F*), which corresponds to a stretch factor $S = 1.35$ for Log 1.

Correlation of the density logs is completed by using a fixed window size (fig. 1*B*). The relative displacement D was determined by crosscorrelation of Log 1 with a version of Log 2 stretched by 1.35. The equivalent parts of logs are indicated by tie lines (fig. 5*A*). The crosscorrelation plot (fig. 5*B*) shows the maximum peak at a lag of 250, which is also 1.35 times the actual displacement (185 units). Care must be taken in visually relating the lag number of the maximum correlation value to the actual lag value when Log 1 is a stretched series.

Figure 4 (*on facing page*). Output plot of a test case for program SPECOR. (See appendix 4.) *A*, Log 2 is the original density log (Kennedy and others, 1969, p. 321-324). Log 1 is a part of Log 2 stretched 1.35 times. (See fig. 5.) *B*, Derivatives of the log data. Log 1 is extended to the same length as Log 2 by adding zeros. *C*, Power spectra of derivative log data. *D*, Power spectra with logarithmically spaced frequencies. *E*, Interpolated power spectra using a method with an interval of .01. Spectra in the first logarithmic cycle (0 to 1.0) are ignored. *F*, Normalized crosscorrelation of interpolated power spectra. The peak at +13 indicates a stretch S = 1.35 for Log 1.


A
LOG1
INPUT DATA
LOG2
INPUT DATA
B
LOG1
DERIVATIVE DATA
LOG2
DERIVATIVE DATA
C
POWER SP
FREQUENCY (LOG1)
POWER SP
FREQUENCY (LOG2)
D
POWER SP
LOG10 FREQ (LOG1)
POWER SP
LOG10 FREQ (LOG2)
E
POWER SP
INTERPOLATED FREQ (LOG1)
POWER SP
INTERPOLATED FREQ (LOG2)
F
X-COR
LAG (FOR STRETCH)

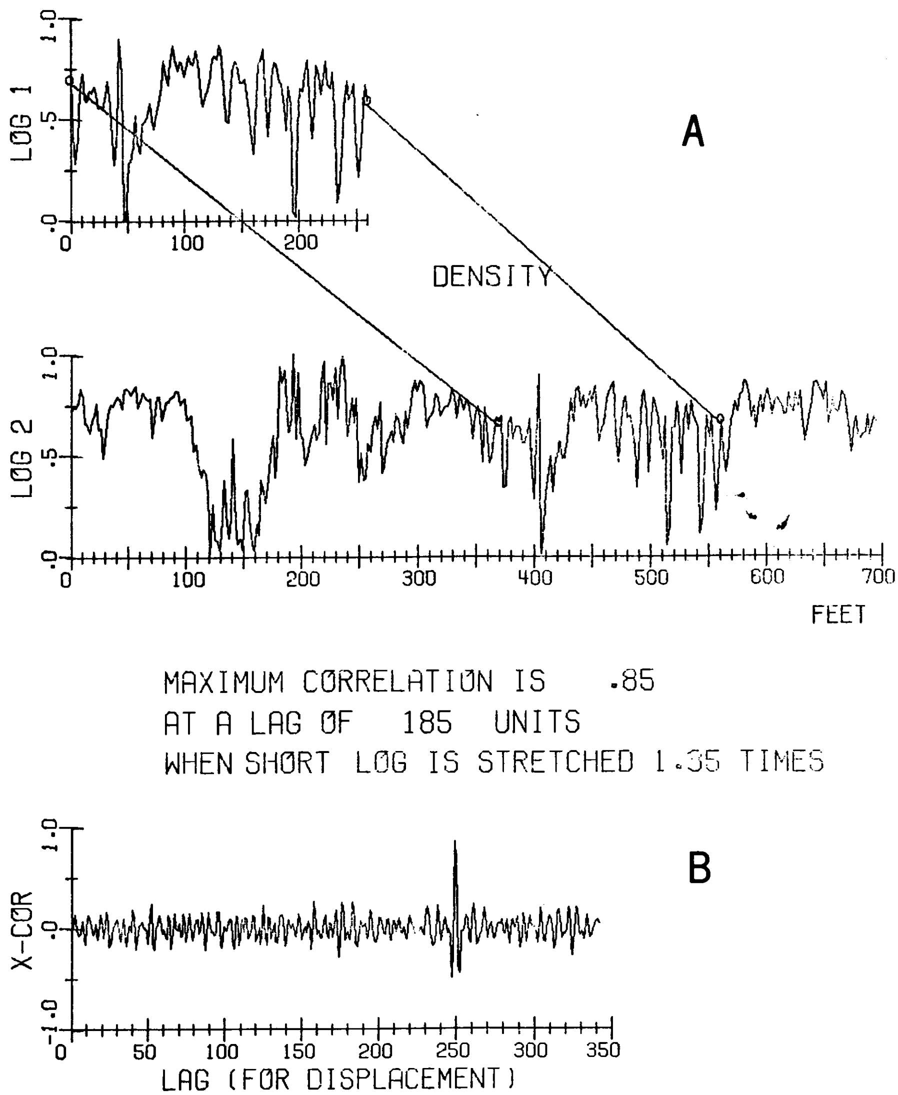



Figure 5. Output plot of a test case for program SPECOR. (See appendix 4.) *A,* Computer correlation of density logs showing a stretch of 1.35 for Log 1. The tie lines show correlations. *B,* Crosscorrelation function of stretched logs with the peak at a lag of 250 (1.35 times the actual displacement of 185 units).

## Discussion

Emperical results of model data show that use of power spectra is highly effective in predicting stretch values. Geologic variations complicate the actual logs, however, and they seldom preserve identical forms from well to well. It follows that the value of the maximum correlation coefficient will be smaller when applied to noisy field data versus model data. In many field-data studies several comparable peak values are observed from correlation of power spectra. The final decision of which peak value yields the correct stretch factor may be made by comparing the largest coefficient obtained from crosscorrelation of each set of such stretched logs. Techniques of filtering and proper selection of parts of logs may sharpen the correct peak value and improve the results, but these aspects are not included in program SPECOR presented here.

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## Appendix 1. Fortran IV Program SPECOR

Program SPECOR contains many comment cards identifying the purpose of each section. The main calling program (flow diagram shown in appendix 2) uses 12 subroutines and five Calcomp subroutines. Subroutine FOURT is a Fast Fourier Transform algorithm for any number of data (written by Norman Brenner at the MIT Lincoln Laboratory, 1967).

```
      PROGRAM SPECOR (INPUT,TAPE3,TAPE4,PLOT,OUTPUT,TAPE5=INPUT,
     +TAPE6=OUTPUT,TAPE10=PLOT)
*-
*-
*-      PROGRAM SPECOR UTILIZES TWO NORMALIZED CROSS-CORRELATION
*-  PROCESSES TO DETERMINE THE STRETCH FACTOR AND RELATIVE
*-  DISPLACEMENT BETWEEN TWO DIGITIZED LOGS.  CROSS-CORRELATION
*-  (WITH VARIABLE WINDOW SIZE) OF THE POWER SPECRA OF TWO LOGS
*-  IDENTIFIES THE DIRECTION AND AMOUNT OF STRETCH BETWEEN LOGS.
*-  THE PROCESS INVOLVES THE COMPUTATIONS OF POWER SPECTRA IN THE
*-  FREQUENCY DOMAIN WITH THE FREQUENCY INTERVALS TRASFORMED TO A
*-  LOGARITHMIC SCALE.  LAGRANCE'S METHOD OF INTERPOLATION OBTAINS
*-  EQUALLY SPACED POWER SPECTRA FOR CORRELATION.  USING TOP TWO
*-  PEAK VALUES OF THE CROSS-CORRELATION FUNCTION OF POWER SPECTRA,
*-  LOGS ARE THEN STRETCHED BY THE FFT (FAST FOURIER TRANSFORM)
*-  INTERPOLATION METHOD.  THE LARGEST COEFFICIENT OBTAINED FROM
*-  CROSS-CORRELATION (WITH FIXED WINDOW SIZE) OF EACH SET OF SUCH
*-  STRETCHED LOGS DETERMINES THE OPTIMUM DISPLACEMENT AND STRETCH.
*-      OUTPUTS CONSIST OF A LINE PRINTER LIST OF THE INPUT DATA,
*-  COEFFICIENTS OF THE CROSS-CORRELATION FUNCTION OF POWER SPECTRA
*-  AND THE OPTIMUM STRETCH AND DISPLACEMENT VALUES.  THE RESULTS
*-  OF INTERMEDIATE STEPS ARE PRINTED OUT AS OPTIONAL.  A CALCOMP
*-  PLOT SHOWS THE INITIAL LOGS AND TIE LINES CONNECTING EQUIVALENT
*-  PARTS OF THE LOGS.  THE CORRELATION FUNCTION OF STRETCHED LOGS
*-  WITH THE OPTIMUM STRETCH IS ALSO PLOTTED.  THE RESULTS OF EVERY
*-  PROCESS INVOLVED IN THE COMPUTATION OF THE CROSS-CORRELATION
*-  FUNCTION OF POWER SPECTRA ARE PLOTTED AS OPTIONAL.
*-
*-  THE INPUT CARDS ARE
*-  1. NUMBER OF DATA SETS TO BE CORRELATED.  FORMAT(I5)
*-  2. DESCRIPTION OF INPUT DATA.  FORMAT(8A10)
*-  3. NAME OF LOG.  FORMAT(A10)
*-  4. LS = NUMBER OF DATA POINTS OF THE SHORT LOG.
*-     LL = NUMBER OF DATA POINTS OF THE LONG LOG.
*-     IDER = 1  DERIVATIVE IS WANTED TO COMPUTE POWER SPECTRA
*-          = 0  DERIVATIVE IS NOT WANTED.
*-     IORG = 1  ORIGINAL DATA IS WANTED FOR STRETCHING AND
*-               FOLLOWING CORRELATION.
*-          = 0  DERIVATIVE DATA IS WANTED FOR STRETCHING AND
*-               FOLLOWING CORRELATION.
*-     SMAX = MAXIMUM ANTICIPATED STRETCH VALUE. TYPIACL VALUE = 2.0
*-     SINT = DIGITIZATION INTERVAL.
*-     DEPTH1 = DEPTH OF THE SHORT LOG.
*-     DEPTH2 = DEPTH OF THE LONG LOG.
*-     PLRES = (IF NONZERO, ORIGINAL LOGS, TIE LINES AND THE
*-              NORMALIZED CROSS-CORRELATION FUNCTION WITH THE
*-              OPTIMUM STRETCH ARE PLOTTED)
*-     PLALL = (IF NOZERO,  RESULTS OF EVERY INTERMEDIATE STEP INVOLED
*-              IN THE CORRELATION OF POWER SPECTRA ARE PLOTTED)
*-     PRALL = (IF NONZERO, DERIAVATIVES OF LOG DATA, POWER SPECTRA
*-              AND INTERPOLATED SPECTRA ARE ALL PRINTED OUT)
*-                          FORMAT(4I5,7F5.0)
*-  5. DATA VALUES OF TWO LOGS ARE READ.  THE ORDER IS SHORT LOG AND
*-     LONG LOG.  FORMAT(F10.3)
*
```

```
*-
*-    THIS PROGRAM IS WRITTEN BY BYUNG-DOC KWON, GEOLOGY DEPARTMENT,
*-    INDIANA UNIVERSITY, BLOOMINGTON, INDIANA.
*-
*-
      DIMENSION RLOG1(800),RLOG2(800),YIP1(800),YIP2(800)
      DIMENSION CLOG1(800),CLOG2(800),WORK(1600)
      DIMENSION XCORL(100),XCORS(100),TITLE(10)
      COMPLEX CLOG1,CLOG2
      DATA LONG /5H LONG/
      DATA SHORT /5HSHORT/
*-
*- READ THE NUMBER OF DATA SETS TO BE CORRELATED
*-
      READ(5,301) NSET
      DO 290 IJ=1,NSET
      CLTM1=SECOND(A)
*-
*- INITIALIZE ALL ARRAYS TO ZERO
*-
      DO 10 I=1,800
      RLOG1(I)=RLOG2(I)=YIP1(I)=YIP2(I)=WORK(I)=WORK(I+800)=0.0
      CLOG1(I)=CLOG2(I)=CMPLX(0.0,0.0)
10    CONTINUE
      DO 20 I=1,100
20    XCORL(I)=XCORS(I)=0.0
*-
*- READ AND WRITE PARAMETERS AND LOG DATA
*-
      READ(5,298) (TITLE(I),I=1,8)
      READ(5,298) ITITLE
      READ(5,301) LS,LL,IDER,IORG,SMAX,SINT,DEPTH1,DEPTH2,PLRES,
     +PLALL,PRALL
      READ(5,302) (RLOG1(I),I=1,LS)
      READ(5,302) (RLOG2(I),I=1,LL)
*-
*- KEEP THE ORIGINAL DATA IN TAPE3 FOR PLOT
*-
      WRITE(3) (RLOG1(I),I=1,LS)
      WRITE(3) (RLOG2(I),I=1,LL)
      WRITE(6,299) (TITLE(I),I=1,8)
      WRITE(6,300) ITITLE
      WRITE(6,303) LS,LL,IDER,IORG,SMAX,SINT,DEPTH1,DEPTH2
      WRITE(6,304)
      DO 30 I=1,LS
30    WRITE(6,305) I,RLOG1(I),RLOG2(I)
      LS1=LS+1
      DO 40 I=LS1,LL
40    WRITE(6,306) I,RLOG2(I)
*-
*- CHECK WHETHER DERIVATIVE IS WANTED
*-
      IF(IDER.EQ.0) GO TO 80
      CALL DERIVAT (RLOG1,LS)
      RLOG1(LS+1)=0.0
      CALL DERIVAT (RLOG2,LL)
      IF (PRALL.EQ.0.0) GO TO 70
      WRITE(6,307)
      DO 50 I=1,LS
50     WRITE(6,305) I,RLOG1(I),RLOG2(I)
      LS1=LS+1
      DO 60 I=LS1,LL
60    WRITE(6,306) I,RLOG2(I)
70    CONTINUE
```

```
*-
*- KEEP THE DERIVATIVE DATA FOR PLOT
*-
      WRITE(3) (RLOG1(I),I=1,LL)
      WRITE(3) (RLOG2(I),I=1,LL)
80    CONTINUE
*-
*- CONSTRUCT COMPLEX SERIES AND DO FOURIER TRANSFORM
*-
      DO 90 I=1,LL
      CLOG1(I)=CMPLX(RLOG1(I),0.0)
      CLOG2(I)=CMPLX(RLOG2(I),0.0)
90    CONTINUE
      CALL FOURT (CLOG1,LL,1,-1,1,WORK)
      CALL FOURT (CLOG2,LL,1,-1,1,WORK)
*-
*- COMPUTE POWER SPECTRA (THE SECOND HALF ABOVE NYQUIST FREQUENCY
*- IS IGNORED)
*-
      NYQ=LL/2+1
      DO 100 I=2,NYQ
      RLOG1(I-1)=(REAL(CLOG1(I))**2+AIMAG(CLOG1(I))**2)/FLOAT(LL)
      RLOG2(I-1)=(REAL(CLOG2(I))**2+AIMAG(CLOG2(I))**2)/FLOAT(LL)
100   CONTINUE
      NN=NYQ-1
      IF (PRALL.EQ.0.0) GO TO 120
      WRITE(6,308)
      DO 110 I=1,NN
110   WRITE(6,309) I,CLOG1(I+1),RLOG1(I),CLOG2(I+1),RLOG2(I)
120   CONTINUE
*-
*- KEEP THE POWER SPECTRA IN TAPE3 FOR PLOT
*-
      WRITE(3) (RLOG1(I),I=1,NN)
      WRITE(3) (RLOG2(I),I=1,NN)
*-
*- TRANSFORM THE FREQUENCIES INTO A LOGARITHMIC SCALE
*-
      DO 130 I=1,NN
130   WORK(I)=ALOG10(FLOAT(I))
      WRITE(3) (WORK(I),I=1,NN)
*-
*- OBTAIN EQUALLY SPACED POWER SPECTRA USING LAGRANGE'S
*- INTERPOLATION METHOD
*-
      JLAST=NN-2
      DELT=0.01
      CALL INTPOL3 (WORK,RLOG1,RLOG2,YIP1,YIP2,10,JLAST,NLAST,DELT)
*-
*- KEEP INTERPOLATED SPECTRA IN TAPE3 FOR PLOT
*-
      WRITE(3) (YIP1(I),I=1,NLAST)
      WRITE(3) (YIP2(I),I=1,NLAST)
      IF (PRALL.EQ.0.0) GO TO 150
      WRITE(6,310)
      DO 140 I=1,NLAST
140   WRITE(6,305) I,YIP1(I),YIP2(I)
150   CONTINUE
```

```
*-
*- CROSS-CORRELATE INTERPOLATED POWER SPECTRA TO OBTAIN
*- STRETCH VALUES
*-
      LAGMAX=ALOG10(SMAX)/DELT+1.5
      CALL CROSS1 (YIP1,YIP2,XCCRL,NLAST,LAGMAX)
      CALL CROSS1 (YIP2,YIP1,XCORS,NLAST,LAGMAX)
      WRITE(6,313)
      DO 160 I=1,LAGMAX
      K1=-I+1
      K2=I-1
160   WRITE(6,312) K1,XCORL(I),K2,XCORS(I)
      WRITE(6,311)
      LAGTOT=2*LAGMAX-1
      DO 170 I=1,LAGMAX
      WORK(I)=FLOAT(-LAGMAX+I)
170   YIP1(I)=XCORL(LAGMAX-I+1)
      DO 180 I=2,LAGMAX
      WORK(LAGMAX+I-1)=FLOAT(I-1)
180   YIP1(LAGMAX+I-1)=XCORS(I)
*-
*- KEEP THE CROSS-CORRELATION FUNCTION OF POWER SPECTRA IN TAPE3
*- FCR PLOT
*-
      WRITE(3) (WORK(I),I=1,LAGTCT)
      WRITE(3) (YIP1(I),I=1,LAGTCT)
*-
*- FIND THE MAXIMUM PEAK IN THE CORRELATION FUCTION OF POWER SPECTRA
*- AND COMPUTE CORRESPONDING STRETCH FACTOR
*-
      CALL MAX (YIP1,1,LAGTOT,I1,PCMAX1)
      XLAG1=WORK(I1)
      DEL1=ABS(XLAG1)*DELT
      ST1=10.**DEL1
*-
*- FIND SECOND PEAK IN THE CORRELATION FUNCTION OF POWER SPECTRA
*- AND COMPUTE CORRESPCNDING STRETCH FACTOR
*-
      CALL SCAN (YIP1,I1,LAGTCT)
      CALL MAX (YIP1,1,LAGTCT,I2,PCMAX2)
      XLAG2=WORK(I2)
      DEL2=ABS(XLAG2)*DELT
      ST2=10.**DEL2
*-
*- FROM TWO PEAK VALUES, FIND THE OPTIMUM DISPLACEMENT AND STRETCH
*-
      IF(XLAG1.GT.0.0) GC TC 1S0
*-
*- STRETCHING AND CORRELATION& THE FIRST PEAK ASSUMES THE LONG LOG
*- (LOG2) IS STRETCHED
*-
      WRITE(6,315) ST1
      CALL STXCO1 (RLOG1,RLOG2,CLOG1,WORK,YIP1,LS,LL,ST1,ML1,ID1,
     +CMAX1,IDER,IORG)
      IF (XLAG2.GT.0.0) GO TO 210
      GC TO 200
```

```
*-
*- STRETCHING AND CORRELATION& THE FIRST PEAK ASSUMES THE SHORT
*- (LOG1) IS STRETCHED.
*-
190    WRITE(6,314) ST1
       CALL STXCO2 (RLOG1,RLOG2,CLOG1,WORK,YIP1,LS,LL,ST1,ML1,ID1,
      +CMAX1,IDER,IORG)
       IF(XLAG2.GT.0.0) GO TO 210
*-
*- STRETCHING AND CORRELATION& THE SECOND PEAK ASSUMES THE LONG LOG
*- (LOG2) IS STRETCHED.
*-
200    WRITE(6,317) ST2
       CALL STXCO1 (RLOG1,RLOG2,CLOG2,WORK,YIP2,LS,LL,ST2,ML2,ID2,
      +CMAX2,IDER,IORG)
       GO TO 220
*-
*- STRETCHING AND CORRELATION& THE SECOND PEAK ASSUMES THE SHORT LOG
*- (LOG1) IS STRETCHED.
*-
210    WRITE(6,316) ST2
       CALL STXCO2 (RLOG1,RLOG2,CLOG2,WORK,YIP2,LS,LL,ST2,ML2,ID2,
      +CMAX2,IDER,IORG)
*-
*- COMPARE THE COEFICIENTS OBTAINED FROM CORRELATIONS  TWO SETS OF
*- OF STRETCHED LOGS.
*-
220    IF(CMAX1.LT.CMAX2) GO TO 230
       CMAX=CMAX1
       ST=ST1
       ML=ML1
       ID=ID1
       WRITE(4) (YIP1(I),I=1,ML)
       IF(XLAG1.GT.0.0) GO TO 240
       GO TO 260
230    CMAX=CMAX2
       ST=ST2
       ML=ML2
       ID=ID2
       WRITE(4) (YIP2(I),I=1,ML)
240    IF(XLAG2.GT.0.0) GO TO 250
       GO TO 260
*-
*- THE FINAL RESULT SUGGESTS THAT THE SHORT LOG (LOG1) IS STRETCHED.
*- PLOT THE CORRELATION RESULT.
*-
250    ID=FLOAT(ID)/ST+0.5
       WRITE(6,318) ST,CMAX,ID
       IDEND=FLOAT(ID)+(FLOAT(LS)/ST)
       CLTM2=SECOND(A)
       IF (PLRES.EQ.0.0) GO TO 270
       CALL PLOTRES (RLOG1,RLOG2,WORK,YIP1,LS,LL,SINT,ST,ID,IDEND,
      +CMAX,ML,ITITLE,SHORT,DEPTH1,DEPTH2)
       GO TO 270
*-
*- THE FINAL RESULT SUGGESTS THAT THE LONG LOG (LOG2) IS STRETCHED.
*- PLOT THE CORRELATION RESULT.
*-
260    WRITE(6,319) ST,CMAX,ID
       IDEND=FLOAT(ID)+(FLOAT(LS)*ST)
       CLTM2=SECOND(A)
       IF(PLRES.EQ.0.0) GO TO 270
```

```
*-
*- PLOT INPUT DATA AND CORRELATION RESULTS
*-
       CALL PLOTRES (RLOG1,RLOG2,WORK,YIP1,LS,LL,SINT,ST,ID,IDEND,
      +CMAX,ML,ITITLE,LCNG,DEPTH1,DEPTH2)
270    IF(PRALL.EQ.0.0) GO TO 280
*-
*- PLOT THE RESULTS OF EVERY STEP INVOLVED IN THE CORRELATION PROCESS
*- OF POWER SPECTRA
*-
       CALL PLOTALL (RLOG1,RLOG2,YIP1,YIP2,WORK,LL,LS,NN,
      +NLAST,IDER,LAGTOT)
280    CONTINUE
       CTOT=CLTM2-CLTM1
       WRITE(6,889) CTOT
889    FORMAT(* TOTAL COMPUTING TIME =*,F10.3,*SECONDS*)
       REWIND 3
       REWIND 4
290    CONTINUE
*-
*- FORMATS
*-
298    FORMAT(8A10)
299    FORMAT(1H1,8A10,//)
300    FORMAT(3X,A10)
301    FORMAT(4I5,7F5.0)
302    FORMAT(F10.3)
303    FORMAT(3X,*LS=*,I5,3X,*LL=*,I5,3X,*IDER=*,I2,3X,*IORG=*,I2,
      +3X,*SMAX=*,F5.1,3X,*SINT=*,F5.1,/,3X,*DEPTH OF LOG 1 =*
      +,F6.1,* FEET*,/3X,*DEPTH OF LOG 2 =*,F6.1,* FEET*,//)
304    FORMAT(1H0,10X,*INPUT  DATA*,//,10X,*LOG 1      LOG 2*,/)
305    FORMAT(I5,2F10.3)
306    FORMAT(I5,10X,F10.3)
307    FORMAT(//,8X,*DERIVATIVED DATA*,//,10X,*LOG 1      LOG 2*,/)
308    FORMAT(//,30X,*FOURIER  TRANSFORM*,//,15X,*LOG 1*,35X,*LOG 2*,
      +//,10X,*REAL*,3X,*IMAGINARY*,2X,*POWER SPECTRUM*,7X,*REAL*,3X,
      +*IMAGINARY*,2X,*POWER SPECTRUM*,/)
309    FORMAT(I5,3F10.3,10X,3F10.3)
310    FORMAT(//,10X,*INTERPOLATED POWER SPECRUM  (  START FROM 10TH OF
      +ORIGINAL  )*,//,10X,*LOG 1      LOG 2*)
311    FORMAT(///*  STRETCH FACTOR FOUND FROM CORRELATION OF POWER SPECTR
      +A*)
312    FORMAT(10X,I5,F15.3,22X,I5,F15.3)
313    FORMAT(//,20X,*     NORMALIZED CORRELATION COEFFICIENTS*,/,
      +10X,*( ASSUME LONG LOG IS STRETCHED )*,10X,
      +*( ASSUME SHORT LOG IS STRETCHED )*,//,8X,*LAG NUMBER*,
      +5X,*VALUE OF COEFFICIENT*,7X,*LAG NUMBER*,5X,
      +*VALUE OF COEFFICIENT*,/)
314    FORMAT(//,*  FIRST CHOICE  - SHORT LOG IS STRETCHED*,F6.2,
      +*  TIMES*)
315    FORMAT(//,*  FIRST CHOICE  - LONG LOG IS STRETCHED*,F6.2,
      +*  TIMES*)
316    FORMAT(/,*  SECOND CHOICE - SHORT LOG IS STRETCHED*,F6.2,
      +*  TIMES*)
317    FORMAT(/,*  SECOND CHOICE - LONG LOG IS STRETCHED*,F6.2,
      +*  TIMES*)
318    FORMAT(///,*  FINAL RESULT SUGGESTS THAT SHORT LOG IS STRETCHED*,
      +F5.2,*  TIMES*,//,*  MAXIMUM CORRELATION IS*,F5.3,* AT A LAG OF*,
      +I5)
319    FORMAT(///,*  FINAL RESULT SUGGEST THAT LONG LOG IS STRETCHED*,
      +F5.2,*  TIMES*,//,*  MAXIMUM CORRELATION IS*,F5.3,* AT A LAG OF*,
      +I3)
       STOP
       END
       SUBROUTINE MEAN (A,N)
```

```
*-
*- REMOVE D.C. VALUE
*-
      DIMENSICN A(1)
      TOT=0.0
      DO 10 I=1,N
10    TOT=TOT+A(I)
      AMEAN=TCT/FLCAT(N)
      DO 20 I=1,N
20    A(I)=A(I)-AMEAN
      RETURN
      END
      SUBROUTINE CERIVAT (A,N)
*-
*- REPLACE LOG DATA BY THEIR FIRST DERIVATIVES
*-
      DIMENSICN A(1)
      N=N-1
      DO 10 I=1,N
10    A(I)=A(I+1)-A(I)
      RETURN
      END
      SUBROUTINE INTPOL3 (X,RLOG1,RLOG2,YIP1,YIP2,JSTART,JLAST,
     +NLAST,CELT)
*-
*- INTERPOLATE EQUALLY SPACEC SAMPLES USING LAGRANGE'S 3RD
*- DEGREE POLYNOMIAL.
*-
      DIMENSION X(1),RLOG1(1),RLOG2(1),YIP1(1),YIP2(1)
      NSEQ=1
      DO 1 J=JSTART,JLAST
2     TXIP=FLOAT(NSEQ-1)*DELT+1.0
      IF(X(J).LE.TXIP.AND.X(J+1).GE.TXIP) GO TO 3
      GO TO 1
3     A1=X(J-1)-X(J)
      A2=X(J-1)-X(J+1)
      A3=X(J-1)-X(J+2)
      A4=-A1
      A5=X(J)-X(J+1)
      A6=X(J)-X(J+2)
      A7=-A2
      A8=-A5
      A9=X(J+1)-X(J+2)
      A10=-A3
      A11=-A6
      A12=-A9
      C1=1.0/(A1*A2*A3)
      C2=1.0/(A4*A5*A6)
      C3=1.0/(A7*A8*A9)
      C4=1.0/(A10*A11*A12)
      B1=TXIF-X(J-1)
      B2=TXIP-X(J)
      B3=TXIP-X(J+1)
      B4=TXIF-X(J+2)
      P1=B2*B3*B4
      P2=B1*B3*B4
      P3=B1*B2*B4
      P4=B1*B2*B3
      YIP1(NSEQ)=(C1*P1*RLOG1(J-1))+(C2*P2*RLOG1(J))+
     +(C3*P3*RLOG1(J+1))+(C4*P4*RLOG1(J+2))
      YIP2(NSEQ)=(C1*P1*RLOG2(J-1))+(C2*P2*RLOG2(J))+
     +(C3*P3*RLOG2(J+1))+(C4*P4*RLOG2(J+2))
      IF (YIP1(NSEQ).LT.0.) YIP1(NSEQ)=0.0
      IF (YIP2(NSEQ).LT.0.) YIP2(NSEQ)=C.0
      NSEQ=NSEQ+1
      GO TO 2
1     CONTINUE
```

```
      NLAST=NSEQ-1
      RETURN
      END
      SUBROUTINE CROSS1 (A,B,C,L,ML)
*-
*- NORMALIZED CROSS-CORRELATION WITH A VARIABLE WINDOW SIZE
*-
      DIMENSION A(1),B(1),C(1)
      ATOT=BTOT=ASQ=BSQ=0.0
      DO 1 I=1,L
      ATOT=ATOT+A(I)
      BTOT=BTOT+B(I)
      ASQ=ASQ+A(I)**2
1     BSQ=BSQ+B(I)**2
      DO 2 J=1,ML
      AB=0.0
      N=L-J+1
      DO 3 K=1,N
3     AB=AB+(A(K+J-1)*B(K))
      CNUM=AB-(ATOT*BTOT/FLOAT(N))
      CDEN=SQRT((ASQ-(ATOT**2/FLOAT(N)))*(BSQ-(BTOT**2/FLOAT(N))))
      IF(CDEN.EQ.0.0) CDEN=100000000.
      C(J)=CNUM/CDEN
      ATOT=ATOT-A(J)
      BTOT=BTOT-B(L-J+1)
      ASQ=ASQ-A(J)**2
      BSQ=BSQ-B(L-J+1)**2
2     CONTINUE
      RETURN
      END
      SUBROUTINE CROSS2 (A,B,C,L1,L2,ML)
*-
*- NORMALIZED CROSS-CORRELATION WITH A FIXED WINDOW SIZE
*-
      DIMENSION A(1),B(1),C(1)
      ATOT=BTOT=ASQ=BSQ=0.0
      DO 1 I=1,L1
      ATOT=ATOT+A(I)
      BTOT=BTOT+B(I)
      ASQ=ASQ+A(I)**2
1     BSQ=BSQ+B(I)**2
      ML=L2-L1+1
      DO 2 J=1,ML
      AB=0.0
      DO 3 K=1,L1
3     AB=AB+(A(K)*B(K+J-1))
      CNUM=AB-(ATOT*BTOT/FLOAT(L1))
      CDEN=SQRT((ASQ-(ATOT**2/FLOAT(L1)))*(BSQ-(BTOT**2/FLOAT(L1))))
      IF(CDEN.EQ.0.0) CDEN=100000000.
      C(J)=CNUM/CDEN
      BTOT=BTOT-B(J)+B(L1+J)
      BSQ=BSQ-B(J)**2+B(L1+J)**2
2     CONTINUE
      RETURN
      END
      SUBROUTINE MAX (A,M,N,ID,AMAX)
```

```
*-
*- FIND THE MAXIMUM (AMAX) AND ITS POSITION (ID)
*-
      DIMENSION A(1)
      AMAX=0.0
      DO 1 I=M,N
      IF(A(I).GT.AMAX) GO TO 2
      GO TO 1
2     AMAX=A(I)
      ID=I
1     CONTINUE
      RETURN
      END
      SUBROUTINE SCAN (A,ID,LAGMAX)
*-
*- SCAN CORRELATION COEFFICIENTS TO DETERMINE SECOND BEST
*- STRETCH FACTOR
*-
      DIMENSION A(1)
      ID1=ID+1
      LMAX=LAGMAX-1
      IF (ID1.GE.LAGMAX) GO TO 3
      DO 1 I=ID1,LMAX
      IF ((A(I+1)-A(I)).LT.0.0) GO TO 2
      GO TO 4
2     A(I)=-1.0
      IF(I.EQ.LMAX) A(LAGMAX)=-1.0
1     CONTINUE
3     A(ID1)=-1.0
4     LAST=ID-2
      IF (LAST.LT.1) GO TO 7
      DO 5 J=1,LAST
      K=ID-J
      IF((A(K-1)-A(K)).LT.0.0) GO TO 6
      GO TO 8
6     A(K)=-1.0
      IF (K.EQ.2) A(1)=-1.0
5     CONTINUE
7     A(ID-1)=-1.0
8     A(ID)=0.0
      RETURN
      END
      SUBROUTINE STXCO1 (RLOG1,RLOG2,CLOG1,WORK,XCOR,LS,LL,ST,ML1,
     +ID1,CMAX1,IDER,ICRG)
*-
*- STRETCH THE SHORT LOG (LOG1) BY FFT INTERPOLATION METHOD
*- AND CROSS-CORRELATE WITH THE LONG LOG (LOG2).
*- FIND THE MAXIMUM CORRELATION COEFFICIENT.
*-
      DIMENSION RLOG1(1),RLOG2(1),CLOG1(1),WORK(1),XCOR(1)
      COMPLEX CLOG1
      REWIND 3
      READ(3) (RLOG1(I),I=1,LS)
      READ(3) (RLOG2(I),I=1,LL)
      IF (IDER.EQ.0.OR.ICRG.NE.0.) GO TO 1
      READ(3) (RLOG1(I),I=1,LS)
      READ(3) (RLOG2(I),I=1,LL)
1     M=FLOAT(LS)*ST+0.5
      CALL STRETCH (RLOG1,CLOG1,WORK,LS,M)
      CALL CROSS2 (RLOG1,RLOG2,XCOR,M,LL,ML1)
      CALL MAX (XCOR,1,ML1,ID1,CMAX1)
      RETURN
      END
      SUBROUTINE STXCO2 (RLOG1,RLOG2,CLOG2,WORK,XCOR,LS,LL,ST,ML2,
     +ID2,CMAX2,IDER,ICRG)
```

```
*-
*- STRETCH THE LONG LOG (LOG2) BY FFT INTERPOLATION METHOD
*- AND CROSS-CORRELATE WITH THE SHORT LOG (LOG1).
*-  FIND THE MAXIMUM CORRELATION COEFFICIENT.
*-
      DIMENSION RLOG1(1),RLOG2(1),CLOG2(1),WORK(1),XCOR(1)
      COMPLEX CLOG2
      REWIND 3
      READ(3) (RLOG1(I),I=1,LS)
      READ(3) (RLOG2(I),I=1,LL)
      IF (IDER.EQ.0.OR.IORG.NE.0.) GO TO 1
      READ(3) (RLOG1(I),I=1,LS)
      READ(3) (RLOG2(I),I=1,LL)
1     M=FLOAT(LL)*ST+0.5
      CALL STRETCH (RLOG2,CLOG2,WORK,LL,M)
      CALL CROSS2 (RLOG1,RLOG2,XCOR,LS,M,ML2)
      CALL MAX (XCOR,1,ML2,ID2,CMAX2)
      RETURN
      END
      SUBROUTINE STRETCH (RA,A,WORK,N,M)
*-
*- INTERPOLATE TIME SERIES DATA WITH N VALUES TO A SERIES WITH
*- M VALUES IN THE FREQUENCY DOMAIN.
*-
      DIMENSION WORK(1),RA(1),A(1)
      COMPLEX A
      DO 5 I=1,N
5     A(I)=CMPLX(RA(I),0.0)
      CALL FOURT (A,N,1,-1,1,WORK)
      IF(N.EQ.M) GO TO 50
*-
*- SEARCH FOR THE NYQUIST
*-
      K=FLOAT(N)/2.+1.5
      MN=M-N
      KZ=K+MN-1
*-
*- TRANSFER THE CONJUGATE PARTS
*-
      DO 10 I=K,N
10    A(M-I+K)=A(N-I+K)
*-
*- CHECK IF INPUT DATA TOTAL IS EVEN OR ODD
*-
      IF((N/2*2).EQ.N) GO TO 20
      GO TO 30
*-
*- DIVIDE THE AMPLITUDE OF NYQUIST FREQUENCY BY 2
*- FOR THE CASE OF EVEN N
*-
20    A(K)=A(K+MN)=A(K)/2.
      K=K+1
      IF(M.EQ.(N+1)) GO TO 50
30    CONTINUE
*-
*- ADD (M-N)ZEROS FOR ODD CASE ,(M-N-1) FOR EVEN CASE
*-
      DO 40 I=K,KZ
40    A(I)=0.0
*-
*- INVERSE F.T.
*-
50    CALL FOURT (A,M,1,1,1,WORK)
```

```
*-
*- NORMALIZATION - DIVIDE BY INPUT SIGNAL LENGTH (N)
*-
      DO 60 I=1,M
      A(I)=A(I)/FLOAT(N)
      RA(I)=REAL(A(I))
60    CONTINUE
      RETURN
      END
      SUBROUTINE NORMAL (X,Y,N,M)
*-
*- NORMALIZE LOG DATA TO FIT THE SCALE OF PLOT
*-
      DIMENSION X(1),Y(1)
      IMAX=IMIN=JMAX=JMIN=1
      DO 1 I=1,N
      IF ( X(I).GT. X(IMAX)) IMAX=I
      IF ( X(I).LT. X(IMIN)) IMIN=I
1     CONTINUE
      DO 2 J=1,M
      IF ( Y(J).GT. Y(JMAX)) JMAX=J
      IF ( Y(J).LT. Y(JMIN)) JMIN=J
2     CONTINUE
      ZMAX=AMAX1( X(IMAX), Y(JMAX))
      ZMIN=AMIN1( X(IMIN), Y(JMIN))
      DIFF=ZMAX-ZMIN
      DO 3 I=1,N
3     X(I)=(X(I)-ZMIN)/DIFF
      DO 4 J=1,M
4     Y(J)=(Y(J)-ZMIN)/DIFF
      RETURN
      END
      SUBROUTINE PLOTALL (RLOG1,RLOG2,YIP1,YIP2,WORK,LL,LS,NN,
     +NLAST,IDER,LAGTOT)
*-
*- PLOT ALL THE RESULTS INVOLVED IN THE PROCESSES TO OBTAIN
*- THE CROSS-CORRELATION FUNCTION OF POWER SPECTRA
*-
      DIMENSION RLOG1(1),RLOG2(1),YIP1(1),YIP2(1),WORK(1)
      CALL IDENT (10)
      CALL FACTOR (0.6)
*-
*- PLOT INITIAL LOG DATA
*-
      DO 1 I=1,800
1     WORK(I)=FLOAT(I-1)
      REWIND 3
      READ(3) (RLOG1(I),I=1,LS)
      READ(3) (RLOG2(I),I=1,LL)
      CALL AXISCL (WORK,0.0,LL,1,10HINPUT DATA,-10,
     +0.5,8.5,5.0,0,0,.08)
      CALL AXISCL (RLOG1,90.,LS,1,4HLOG1,4,0.5,8.5,1.5,0,2,.08)
      WORK(LS+1)=WORK(LL+1)
      WORK(LS+2)=WORK(LL+2)
      WORK(LS+3)=WORK(LL+3)
      CALL IULINE (WORK,RLOG1,LS,1,0.5,8.5,0)
      WORK(LS+1)=FLOAT(LS)
      WORK(LS+2)=FLOAT(LS+1)
      WORK(LS+3)=FLOAT(LS+2)
      CALL AXISCL (WORK,0.0,LL,1,10HINPUT DATA,-10,
     +0.5,6.0,5.0,0,0,.08)
      CALL AXISCL (RLOG2,90.,LL,1,4HLOG2,4,0.5,6.0,1.5,0,2,.08)
      CALL IULINE (WORK,RLOG2,LL,1,0.5,6.0,0)
      IF (IDER.EQ.0) GO TO 3
```

```
*-
*- PLOT DERIVATIVES OF THE LOG CATA
*-
      READ(3) (RLOG1(I),I=1,LL)
      READ(3) (RLOG2(I),I=1,LL)
      CALL IUAXIS (0.0,WORK(LL+1),WORK(LL+2),WORK(LL+3),
     +15HDERIVATIVE DATA,-15,0.5,3.5,5.0,0,0,.08)
      CALL AXISCL (RLOG1,90.,LL,1,4HLOG1,4,0.5,3.5,1.5,0,2,.08)
      CALL IULINE (WORK,RLOG1,LL,1,0.5,3.5,0)
      CALL IUAXIS (0.0,WORK(LL+1),WORK(LL+2),WORK(LL+3),
     +15HDERIVATIVE DATA,-15,0.5,1.0,5.0,0,0,.08)
      CALL AXISCL (RLOG2,90.,LL,1,4HLOG2,4,0.5,1.0,1.5,0,2,.08)
      CALL IULINE (WORK,RLOG2,LL,1,0.5,1.0,0)
3     CONTINUE
*-
*- PLOT POWER SPECTRA
*-
      READ(3) (RLOG1(I),I=1,NN)
      READ(3) (RLOG2(I),I=1,NN)
      CALL AXISCL (WORK,0.0,NN,1,17HFREQUENCY  (LOG1),-17,
     +6.5,8.5,4.0,0,0,.08)
      CALL AXISCL (RLOG1,90.,NN,1,8HPOWER SP,8,6.5,8.5,1.5,0,2,.08)
      CALL IULINE (WORK,RLOG1,NN,1,6.5,8.5,0)
      CALL IUAXIS (0.0,WORK(NN+1),WORK(NN+2),WORK(NN+3),
     +17HFREQUENCY  (LOG2),-17,6.5,6.0,4.0,0,0,.08)
      CALL AXISCL (RLOG2,90.,NN,1,8HPOWER SP,8,6.5,6.0,1.5,0,2,.08)
      CALL IULINE (WORK,RLOG2,NN,1,6.5,6.0,0)
*-
*- PLOT POWER SPECTRA ON THE LOGARITHMICALLY SCALED
*- FREQUENCY AXIS
*-
      READ(3) (WORK(I),I=1,NN)
      CALL AXISCL (WORK,0.0,NN,1,17HLOG10 FREQ (LOG1),-17,
     +6.5,3.5,4.0,0,2,.08)
      CALL AXISCL (RLOG1,90.,NN,1,8HPOWER SP,8,6.5,3.5,1.5,0,2,.08)
      CALL IULINE (WORK,RLOG1,NN,1,6.5,3.5,0)
      CALL IUAXIS (0.0,WORK(NN+1),WORK(NN+2),WORK(NN+3),
     +17HLOG10 FREQ (LOG2),-17,6.5,1.0,4.0,0,2,.08)
      CALL AXISCL (RLOG2,90.,NN,1,8HPOWER SP,8,6.5,1.0,1.5,0,2,.08)
      CALL IULINE (WORK,RLOG2,NN,1,6.5,1.0,0)
*-
*- PLOT THE INTERPOLATED POWER SPECTRA
*-
      DO 2 I=1,NLAST
2     WORK(I)=FLOAT(I-1)
      READ(3) (YIP1(I),I=1,NLAST)
      READ(3) (YIP2(I),I=1,NLAST)
      CALL AXISCL (WORK,0.0,NLAST,1,24HINTERPOLATED FREQ (LOG1),-24,
     +12.0,8.5,4.0,0,0,.08)
      CALL AXISCL (YIP1,90.,NLAST,1,8HPOWER SP,8,12.0,8.5,1.5,0,2,.08)
      CALL IULINE (WORK,YIP1,NLAST,1,12.0,8.5,0)
      CALL IUAXIS (0.0,WORK(NLAST+1),WORK(NLAST+2),WORK(NLAST+3),
     +24HINTERPOLATED FREQ (LOG2),-24,12.0,6.0,4.0,0,0,.08)
      CALL AXISCL (YIP2,90.,NLAST,1,8HPOWER SP,8,12.0,6.0,1.5,0,2,.08)
      CALL IULINE (WORK,YIP2,NLAST,1,12.0,6.0,0)
```

```
*-
*- PLOT THE NORMALIZED CROSS-CORRELATION FUNCTION OF
*- INTERPOLATED POWER SPECTRA
*-
      READ(3) (WORK(I),I=1,LAGTOT)
      READ(3) (RLOG1(I),I=1,LAGTOT)
      CALL AXISCL (WORK,0.0,LAGTOT,1,17HLAG (FOR STRETCH),-17,
     +12.0,3.5,4.0,0,0,.08)
      CALL AXISCL (RLOG1,90.,LAGTOT,1,5HX-COR,5,12.0,3.5,1.5,0,1,.08)
      CALL IULINE (WORK,RLOG1,LAGTOT,1,12.0,3.5,0)
      CALL CLOSEPF
      RETURN
      END
      SUBROUTINE PLOTRES (RLOG1,RLOG2,X,XCOR,LS,LL,SINT,ST,ID,
     +IDEND,CMAX,ML,ITITLE,CHOICE,DEPTH1,DEPTH2)
*-
*- PLOT ORIGINAL LOG DATA, TIE LINES CONNECTING EQUIVALENT
*- PARTS OF THE LOGS AND THE CROSS-CORRELATION FUNCTION OF
*- STRETCHED LOGS WITH THE OPTIMUM STRETCH
*-
      DIMENSION RLOG1(1),RLOG2(1),X(1),XCOR(1)
*-
*- RETRIEVE ORIGINAL DATA AND NORMALIZE TO PLOT
*-
      REWIND 3
      READ(3) (RLOG1(I),I=1,LS)
      READ(3) (RLOG2(I),I=1,LL)
      REWIND 4
      READ(4) (XCOR(I),I=1,ML)
      CALL NORMAL (RLOG1,RLOG2,LS,LL)
      CALL IDENT (10)
      CALL FACTOR(0.7)
*-
*- SET SCALE VALUES AND PLOT AXIS AND LOG DATA
*-
      DO 10 I=1,LL
10    X(I)=FLOAT(I-1)*SINT+DEPTH2
      RLOG2(LL+1)=0.0
      RLOG2(LL+2)=FACT=1./1.5
      RLOG2(LL+3)=.25
      CALL IUAXIS (90.,0.,FACT,.25,5HLOG 2,5,1.0,6.0,1.5,0,1,.10)
      FACTX=(X(LL)-X(1))/6.0
      CALL IUAXIS (0.0,X(1),FACTX,10.0,1H ,-1,1.0,6.0,6.0,
     +0,1,.10)
      X(LL+1)=X(1)
      X(LL+2)=FACTX
      X(LL+3)=10.0
      CALL IULINE (X,RLOG2,LL,1,1.0,6.0,0)
      X2S=(X(ID)-X(LL+1))/X(LL+2)+1.0
      X2L=(X(IDEND)-X(LL+1))/X(LL+2)+1.0
      DO 20 I=1,LS
20    X(I)=FLOAT(I-1)*SINT+DEPTH1
      SLENTH=6.0*FLOAT(LS-1)/FLOAT(LL-1)
      RLOG1(LS+1)=0.0
      RLOG1(LS+2)=FACT=1./1.5
      RLOG1(LS+3)=.25
      CALL IUAXIS (90.,0.0,FACT,.25,5HLOG 1,5,1.0,8.5,1.5,0,1,.10)
      CALL IUAXIS (0.0,X(1),FACTX,10.0,1H ,-1,1.0,8.5,SLENTH,
     +0,1,.10)
      X(LS+1)=X(1)
      X(LS+2)=FACTX
      X(LS+3)=10.0
      CALL IULINE (X,RLOG1,LS,1,1.0,8.5,0)
```

```
*-
*- WRITE TITLE (NAME OF LOG) AND CORRELATION RESULTS
*-
      X1S=(X(1)-X(LS+1))/X(LS+2)+1.0
      X1L=(X(LS)-X(LS+1))/X(LS+2)+1.0
      CALL SYMBOL (6.5,5.5,.12,4HFEET,0.0,4)
      XLOC=SLENTH+1.5
      CALL SYMBOL (XLOC,8.0,.15,ITITLE,0.0,10)
      XSYM=2.5
      CALL SYMBOL (XSYM,5.,.15,22HMAXIMUM CORRELATION IS,0.,22)
      XNUM=XSYM+3.25
      CMAX=CMAX+0.005
      CALL NUMBER (XNUM,5.,.15,CMAX,0.,2)
      CALL SYMBOL (XSYM,4.7,.15,24HAT A LAG OF         UNITS,0.,24)
      XNUM=XSYM+1.75
      XLAG=FLOAT(ID)
      CALL NUMBER (XNUM,4.7,.15,XLAG,0.,-1)
      CALL SYMBOL (XSYM,4.4,.15,38HWHEN        LOG IS STRETCHED       TIME
     +S,0.0,38)
      XCHO=XSYM+0.6
      XST=XSYM+3.6
      CALL SYMBOL (XCHO,4.4,.15,CHOICE,0.0,5)
      ST=ST+0.005
      CALL NUMBER (XST,4.4,.15,ST,0.,2)
*-
*- DRAW TIE LINES TO SHOW EQUIVALENT PORTIONS
*-
      Y1S=1.5*RLOG1(1)+8.5
      CALL SYMBOL (X1S,Y1S,.06,26,0.0,-1)
      Y2S=1.5*RLOG2(ID)+6.0
      CALL SYMBOL (X2S,Y2S,.06,26,0.0,-2)
      Y1L=1.5*RLOG1(LS)+8.5
      CALL SYMBOL (X1L,Y1L,.06,26,0.0,-1)
      Y2L=1.5*RLOG2(IDEND)+6.0
      CALL SYMBOL (X2L,Y2L,.06,26,0.0,-2)
*-
*- PLOT THE NORMALIZED CROSS-CORRELATION FUNCTION OF
*- STRETCHED LOG WITH THE OPTIMUM STRETCH
*-
      DO 30 I=1,ML
30    X(I)=FLOAT(I-1)
      XCOR(ML+1)=-1.0
      XCOR(ML+2)=FACT=2./1.5
      XCOR(ML+3)=.5
      CALL IUAXIS (90.,-1.,FACT,.5,5HX-COR,5,1.0,2.5,1.5,0,1,.10)
      CALL AXISCL (X,0.,ML,1,22HLAG (FOR DISPLACEMENT),-22,1.0,2.5,4.,
     +0,0,.10)
      CALL IULINE (X,XCOR,ML,1,1.0,2.5,0)
      CALL CLOSEPF
      RETURN
      END
```

```
      SUBROUTINE FOURT(DATA,NN,NDIM,ISIGN,IFORM,WORK)
      DIMENSION DATA(1),NN(1),IFACT(32),WORK(1)
      TWOPI=6.283185307
      IF(NDIM-1)920,1,1
1     NTOT=2
      DO 2 IDIM=1,NDIM
      IF(NN(IDIM))920,920,2
2     NTOT=NTOT*NN(IDIM)
C
C     MAIN LOOP FOR EACH DIMENSION
C
      NP1=2
      DO 910 IDIM=1,NDIM
      N=NN(IDIM)
      NP2=NP1*N
      IF(N-1)920,900,5
C
C     FACTOR N
C
5     M=N
      NTWO=NP1
      IF=1
      IDIV=2
10    IQUOT=M/IDIV
      IREM=M-IDIV*IQUOT
      IF(IQUOT-IDIV)50,11,11
11    IF(IREM)20,12,20
12    NTWO=NTWO+NTWO
      M=IQUOT
      GO TO 10
20    IDIV=3
30    IQUOT=M/IDIV
      IREM=M-IDIV*IQUOT
      IF(IQUOT-IDIV)60,31,31
31    IF(IREM)40,32,40
32    IFACT(IF)=IDIV
      IF=IF+1
      M=IQUOT
      GO TO 30
40    IDIV=IDIV+2
      GO TO 30
50    IF(IREM)60,51,60
51    NTWO=NTWO+NTWO
      GO TO 70
60    IFACT(IF)=M
C
C     SEPARATE FOUR CASES--
C        1. COMPLEX TRANSFORM OR REAL TRANSFORM FOR THE 4TH, 5TH,ETC.
C           DIMENSIONS.
C        2. REAL TRANSFORM FOR THE 2ND OR 3RD DIMENSION.  METHOD--
C           TRANSFORM HALF THE DATA, SUPPLYING THE OTHER HALF BY CON-
C           JUGATE SYMMETRY.
C        3. REAL TRANSFORM FOR THE 1ST DIMENSION, N ODD.  METHOD--
C           TRANSFORM HALF THE DATA AT EACH STAGE, SUPPLYING THE OTHER
C           HALF BY CONJUGATE SYMMETRY.
C        4. REAL TRANSFORM FOR THE 1ST DIMENSION, N EVEN.  METHOD--
C           TRANSFORM A COMPLEX ARRAY OF LENGTH N/2 WHOSE REAL PARTS
C           ARE THE EVEN NUMBERED REAL VALUES AND WHOSE IMAGINARY PARTS
C           ARE THE ODD NUMBERED REAL VALUES.  SEPARATE AND SUPPLY
C           THE SECOND HALF BY CONJUGATE SYMMETRY.
C
```

```
70      NON2=NP1*(NP2/NTWO)                                               FFTT1370
        ICASE=1                                                           FFTT1380
        IF(IDIM-4)71,90,90                                                FFTT1390
71      IF(IFORM)72,72,90                                                 FFTT1400
72      ICASE=2                                                           FFTT1410
        IF(IDIM-1)73,73,90                                                FFTT1420
73      ICASE=3                                                           FFTT1430
        IF(NTWO-NP1)90,90,74                                              FFTT1440
74      ICASE=4                                                           FFTT1450
        NTWO=NTWO/2                                                       FFTT1460
        N=N/2                                                             FFTT1470
        NP2=NP2/2                                                         FFTT1480
        NTOT=NTOT/2                                                       FFTT1490
        I=3                                                               FFTT1500
        DO 80 J=2,NTOT                                                    FFTT1510
        DATA(J)=DATA(I)                                                   FFTT1520
80      I=I+2                                                             FFTT1530
90      I1RNG=NP1                                                         FFTT1540
        IF(ICASE-2)100,95,100                                             FFTT1550
95      I1RNG=NP0*(1+NPREV/2)                                             FFTT1560
C                                                                         FFTT1570
C       SHUFFLE ON THE FACTORS OF TWO IN N.  AS THE SHUFFLING             FFTT1580
C       CAN BE DONE BY SIMPLE INTERCHANGE, NO WORKING ARRAY IS NEEDED     FFTT1590
C                                                                         FFTT1600
100     IF(NTWO-NP1)600,600,110                                           FFTT1610
110     NP2HF=NP2/2                                                       FFTT1620
        J=1                                                               FFTT1630
        DO 150 I2=1,NP2,NON2                                              FFTT1640
        IF(J-I2)120,130,130                                               FFTT1650
120     I1MAX=I2+NON2-2                                                   FFTT1660
        DO 125 I1=I2,I1MAX,2                                              FFTT1670
        DO 125 I3=I1,NTOT,NP2                                             FFTT1680
        J3=J+I3-I2                                                        FFTT1690
        TEMPR=DATA(I3)                                                    FFTT1700
        TEMPI=DATA(I3+1)                                                  FFTT1710
        DATA(I3)=DATA(J3)                                                 FFTT1720
        DATA(I3+1)=DATA(J3+1)                                             FFTT1730
        DATA(J3)=TEMPR                                                    FFTT1740
125     DATA(J3+1)=TEMPI                                                  FFTT1750
130     M=NP2HF                                                           FFTT1760
140     IF(J-M)150,150,145                                                FFTT1770
145     J=J-M                                                             FFTT1780
        M=M/2                                                             FFTT1790
        IF(M-NON2)150,140,140                                             FFTT1800
150     J=J+M                                                             FFTT1810
C                                                                         FFTT1820
C       MAIN LOOP FOR FACTORS OF TWO.  PERFORM FOURIER TRANSFORMS OF      FFTT1830
C       LENGTH FOUR, WITH ONE OF LENGTH TWO IF NEEDED.  THE TWIDDLE FACTORFFTT1840
C       W=EXP(ISIGN*2*PI*SQRT(-1)*M/(4*MMAX)).  CHECK FOR W=ISIGN*SQRT(-1)FFTT1850
C       AND REPEAT FOR W=ISIGN*SQRT(-1)*CONJUGATE(W).                     FFTT1860
C                                                                         FFTT1870
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```
      NON2T=NON2+NON2                                                   FFTT1880
      IPAR=NTWO/NP1                                                     FFTT1890
310   IF(IPAR-2)350,330,320                                             FFTT1900
320   IPAR=IPAR/4                                                       FFTT1910
      GO TO 310                                                         FFTT1920
330   DO 340 I1=1,I1RNG,2                                               FFTT1930
      DO 340 J3=I1,NON2,NP1                                             FFTT1940
      DO 340 K1=J3,NTOT,NON2T                                           FFTT1950
      K2=K1+NON2                                                        FFTT1960
      TEMPR=DATA(K2)                                                    FFTT1970
      TEMPI=DATA(K2+1)                                                  FFTT1980
      DATA(K2)=DATA(K1)-TEMPR                                           FFTT1990
      DATA(K2+1)=DATA(K1+1)-TEMPI                                       FFTT2000
      DATA(K1)=DATA(K1)+TEMPR                                           FFTT2010
340   DATA(K1+1)=DATA(K1+1)+TEMPI                                       FFTT2020
350   MMAX=NON2                                                         FFTT2030
360   IF(MMAX-NP2HF)370,600,600                                         FFTT2040
370   LMAX=MAX0(NON2T,MMAX/2)                                           FFTT2050
      IF(MMAX-NON2)405,405,380                                          FFTT2060
380   THETA=-TWOPI*FLOAT(NON2)/FLOAT(4*MMAX)                            FFTT2070
      IF(ISIGN)400,390,390                                              FFTT2080
390   THETA=-THETA                                                      FFTT2090
400   WR=COS(THETA)                                                     FFTT2100
      WI=SIN(THETA)                                                     FFTT2110
      WSTPR=-2.*WI*WI                                                   FFTT2120
      WSTPI=2.*WR*WI                                                    FFTT2130
405   DO 570 L=NON2,LMAX,NON2T                                          FFTT2140
      M=L                                                               FFTT2150
      IF(MMAX-NON2)420,420,410                                          FFTT2160
410   W2R=WR*WR-WI*WI                                                   FFTT2170
      W2I=2.*WR*WI                                                      FFTT2180
      W3R=W2R*WR-W2I*WI                                                 FFTT2190
      W3I=W2R*WI+W2I*WR                                                 FFTT2200
420   DO 530 I1=1,I1RNG,2                                               FFTT2210
      DO 530 J3=I1,NON2,NP1                                             FFTT2220
      KMIN=J3+IPAR*M                                                    FFTT2230
      IF(MMAX-NON2)430,430,440                                          FFTT2240
430   KMIN=J3                                                           FFTT2250
440   KDIF=IPAR*MMAX                                                    FFTT2260
450   KSTEP=4*KDIF                                                      FFTT2270
      DO 520 K1=KMIN,NTOT,KSTEP                                         FFTT2280
      K2=K1+KDIF                                                        FFTT2290
      K3=K2+KDIF                                                        FFTT2300
      K4=K3+KDIF                                                        FFTT2310
      IF(MMAX-NON2)460,460,480                                          FFTT2320
460   U1R=DATA(K1)+DATA(K2)                                             FFTT2330
      U1I=DATA(K1+1)+DATA(K2+1)                                         FFTT2340
      U2R=DATA(K3)+DATA(K4)                                             FFTT2350
      U2I=DATA(K3+1)+DATA(K4+1)                                         FFTT2360
      U3R=DATA(K1)-DATA(K2)                                             FFTT2370
      U3I=DATA(K1+1)-DATA(K2+1)                                         FFTT2380
      IF(ISIGN)470,475,475                                              FFTT2390
470   U4R=DATA(K3+1)-DATA(K4+1)                                         FFTT2400
      U4I=DATA(K4)-DATA(K3)                                             FFTT2410
      GO TO 510                                                         FFTT2420
475   U4R=DATA(K4+1)-DATA(K3+1)                                         FFTT2430
      U4I=DATA(K3)-DATA(K4)                                             FFTT2440
      GO TO 510                                                         FFTT2450
```

```
480   T2R=W2R*DATA(K2)-W2I*DATA(K2+1)                                      FFTT2460
      T2I=W2R*DATA(K2+1)+W2I*DATA(K2)                                      FFTT2470
      T3R=WR*DATA(K3)-WI*DATA(K3+1)                                        FFTT2480
      T3I=WR*DATA(K3+1)+WI*DATA(K3)                                        FFTT2490
      T4R=W3R*DATA(K4)-W3I*DATA(K4+1)                                      FFTT2500
      T4I=W3R*DATA(K4+1)+W3I*DATA(K4)                                      FFTT2510
      U1R=DATA(K1)+T2R                                                     FFTT2520
      U1I=DATA(K1+1)+T2I                                                   FFTT2530
      U2R=T3R+T4R                                                          FFTT2540
      U2I=T3I+T4I                                                          FFTT2550
      U3R=DATA(K1)-T2R                                                     FFTT2560
      U3I=DATA(K1+1)-T2I                                                   FFTT2570
      IF(ISIGN)490,500,500                                                 FFTT2580
490   U4R=T3I-T4I                                                          FFTT2590
      U4I=T4R-T3R                                                          FFTT2600
      GO TO 510                                                            FFTT2610
500   U4R=T4I-T3I                                                          FFTT2620
      U4I=T3R-T4R                                                          FFTT2630
510   DATA(K1)=U1R+U2R                                                     FFTT2640
      DATA(K1+1)=U1I+U2I                                                   FFTT2650
      DATA(K2)=U3R+U4R                                                     FFTT2660
      DATA(K2+1)=U3I+U4I                                                   FFTT2670
      DATA(K3)=U1R-U2R                                                     FFTT2680
      DATA(K3+1)=U1I-U2I                                                   FFTT2690
      DATA(K4)=U3R-U4R                                                     FFTT2700
520   DATA(K4+1)=U3I-U4I                                                   FFTT2710
      KMIN=4*(KMIN-J3)+J3                                                  FFTT2720
      KDIF=KSTEP                                                           FFTT2730
      IF(KDIF-NP2)450,530,530                                              FFTT2740
530   CONTINUE                                                             FFTT2750
      M=MMAX-M                                                             FFTT2760
      IF(ISIGN)540,550,550                                                 FFTT2770
540   TEMPR=WR                                                             FFTT2780
      WR=-WI                                                               FFTT2790
      WI=-TEMPR                                                            FFTT2800
      GO TO 560                                                            FFTT2810
550   TEMPR=WR                                                             FFTT2820
      WR=WI                                                                FFTT2830
      WI=TEMPR                                                             FFTT2840
560   IF(M-LMAX)565,565,410                                                FFTT2850
565   TEMPR=WR                                                             FFTT2860
      WR=WR*WSTPR-WI*WSTPI+WR                                              FFTT2870
570   WI=WI*WSTPR+TEMPR*WSTPI+WI                                           FFTT2880
      IPAR=3-IPAR                                                          FFTT2890
      MMAX=MMAX+MMAX                                                       FFTT2900
      GO TO 360                                                            FFTT2910
C                                                                          FFTT2920
C     MAIN LOOP FOR FACTORS NOT EQUAL TO TWO.  APPLY THE TWIDDLE FACTOR FFTT2930
C     W=EXP(ISIGN*2*PI*SQRT(-1)*(J2-1)*(J1-J2)/(NP2*IFP1)), THEN          FFTT2940
C     PERFORM A FOURIER TRANSFORM OF LENGTH IFACT(IF), MAKING USE OF       FFTT2950
C     CONJUGATE SYMMETRIES.                                                FFTT2960
C                                                                          FFTT2970
```

```
600    IF(NTWO-NP2)605,700,700                           FFTT2980
605    IFP1=NON2                                         FFTT2990
       IF=1                                              FFTT3000
       NP1HF=NP1/2                                       FFTT3010
610    IFP2=IFP1/IFACT(IF)                               FFTT3020
       J1RNG=NP2                                         FFTT3030
       IF(ICASE-3)612,611,612                            FFTT3040
611    J1RNG=(NP2+IFP1)/2                                FFTT3050
       J2STP=NP2/IFACT(IF)                               FFTT3060
       J1RG2=(J2STP+IFP2)/2                              FFTT3070
612    J2MIN=1+IFP2                                      FFTT3080
       IF(IFP1-NP2)615,640,640                           FFTT3090
615    DO 635 J2=J2MIN,IFP1,IFP2                         FFTT3100
       THETA=-TWOPI*FLOAT(J2-1)/FLOAT(NP2)               FFTT3110
       IF(ISIGN)625,620,620                              FFTT3120
620    THETA=-THETA                                      FFTT3130
625    SINTH=SIN(THETA/2.)                               FFTT3140
       WSTPR=-2.*SINTH*SINTH                             FFTT3150
       WSTPI=SIN(THETA)                                  FFTT3160
       WR=WSTPR+1.                                       FFTT3170
       WI=WSTPI                                          FFTT3180
       J1MIN=J2+IFP1                                     FFTT3190
       DO 635 J1=J1MIN,J1RNG,IFP1                        FFTT3200
       I1MAX=J1+I1RNG-2                                  FFTT3210
       DO 630 I1=J1,I1MAX,2                              FFTT3220
       DO 630 I3=I1,NTOT,NP2                             FFTT3230
       J3MAX=I3+IFP2-NP1                                 FFTT3240
       DO 630 J3=I3,J3MAX,NP1                            FFTT3250
       TEMPR=DATA(J3)                                    FFTT3260
       DATA(J3)=DATA(J3)*WR-DATA(J3+1)*WI                FFTT3270
630    DATA(J3+1)=TEMPR*WI+DATA(J3+1)*WR                 FFTT3280
       TEMPR=WR                                          FFTT3290
       WR=WR*WSTPR-WI*WSTPI+WR                           FFTT3300
635    WI=TEMPR*WSTPI+WI*WSTPR+WI                        FFTT3310
640    THETA=-TWOPI/FLOAT(IFACT(IF))                     FFTT3320
       IF(ISIGN)650,645,645                              FFTT3330
   645 THETA=-THETA
   650 SINTH=SIN(THETA/2.)
       WSTPR=-2.*SINTH*SINTH
       WSTPI=SIN(THETA)
       KSTEP=2*N/IFACT(IF)
       KRANG=KSTEP*(IFACT(IF)/2)+1
       DO 698 I1=1,I1RNG,2
       DO 698 I3=I1,NTOT,NP2
       DO 690 KMIN=1,KRANG,KSTEP                         FFTT3420
       J1MAX=I3+J1RNG-IFP1                               FFTT3430
       DO 680 J1=I3,J1MAX,IFP1                           FFTT3440
       J3MAX=J1+IFP2-NP1                                 FFTT3450
       DO 680 J3=J1,J3MAX,NP1                            FFTT3460
       J2MAX=J3+IFP1-IFP2                                FFTT3470
       K=KMIN+(J3-J1+(J1-I3)/IFACT(IF))/NP1HF            FFTT3480
       IF(KMIN-1)655,655,665                             FFTT3490
655    SUMR=0.                                           FFTT3500
       SUMI=0.                                           FFTT3510
       DO 660 J2=J3,J2MAX,IFP2                           FFTT3520
       SUMR=SUMR+DATA(J2)                                FFTT3530
660    SUMI=SUMI+DATA(J2+1)                              FFTT3540
       WORK(K)=SUMR                                      FFTT3550
       WORK(K+1)=SUMI                                    FFTT3560
       GO TO 680                                         FFTT3570
```

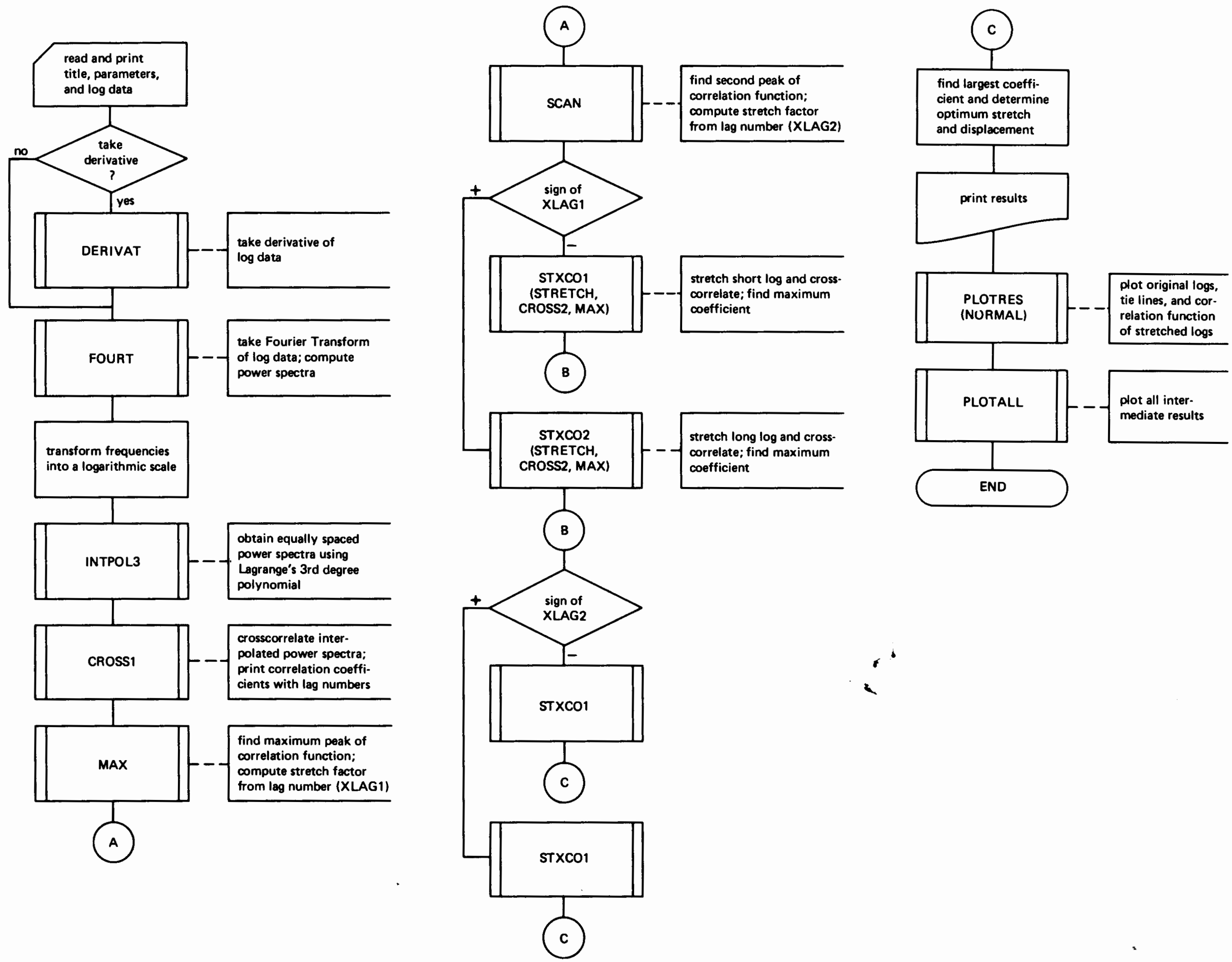
```
665   KCONJ=K+2*(N-KMIN+1)
      J2=J2MAX
      SUMR=DATA(J2)
      SUMI=DATA(J2+1)
      OLDSR=0.
      OLDSI=0.
      J2=J2-IFP2
670   TEMPR=SUMR
      TEMPI=SUMI
      SUMR=TWOWR*SUMR-OLDSR+DATA(J2)
      SUMI=TWOWR*SUMI-OLDSI+DATA(J2+1)
      OLDSR=TEMPR
      OLDSI=TEMPI
      J2=J2-IFP2
      IF(J2-J3)675,675,670
675   TEMPR=WR*SUMR-OLDSR+DATA(J2)
      TEMPI=WI*SUMI
      WORK(K)=TEMPR-TEMPI
      WORK(KCONJ)=TEMPR+TEMPI
      TEMPR=WR*SUMI-OLDSI+DATA(J2+1)
      TEMPI=WI*SUMR
      WORK(K+1)=TEMPR+TEMPI
      WORK(KCONJ+1)=TEMPR-TEMPI
680   CONTINUE
      IF(KMIN-1)685,685,686
685   WR=WSTPR+1.
      WI=WSTPI
      GO TO 690
686   TEMPR=WR
      WR=WR*WSTPR-WI*WSTPI+WR
      WI=TEMPR*WSTPI+WI*WSTPR+WI
690   TWOWR=WR+WR
      IF(ICASE-3)692,691,692
691   IF(IFP1-NP2)695,692,692
692   K=1
      I2MAX=I3+NP2-NP1
      DO 693 I2=I3,I2MAX,NP1
      DATA(I2)=WORK(K)
      DATA(I2+1)=WORK(K+1)
693   K=K+2
      GO TO 698
C
C     COMPLETE A REAL TRANSFORM IN THE 1ST DIMENSION, N ODD, BY CON-
C     JUGATE SYMMETRIES AT EACH STAGE.
C
695   J3MAX=I3+IFP2-NP1
      DO 697 J3=I3,J3MAX,NP1
      J2MAX=J3+NP2-J2STP
      DO 697 J2=J3,J2MAX,J2STP
      J1MAX=J2+J1RG2-IFP2
      J1CNJ=J3+J2MAX+J2STP-J2
      DO 697 J1=J2,J1MAX,IFP2
      K=1+J1-I3
      DATA(J1)=WORK(K)
      DATA(J1+1)=WORK(K+1)
      IF(J1-J2)697,697,696
696   DATA(J1CNJ)=WORK(K)
      DATA(J1CNJ+1)=-WORK(K+1)
697   J1CNJ=J1CNJ-IFP2
698   CONTINUE
      IF=IF+1
      IFP1=IFP2
      IF(IFP1-NP1)700,700,610
```

```
C
C     COMPLETE A REAL TRANSFORM IN THE 1ST DIMENSION, N EVEN, BY CON-
C     JUGATE SYMMETRIES.
C
700   GO TO (900,800,900,701),ICASE
701   NHALF=N
      N=N+N
      THETA=-TWOPI/FLOAT(N)
      IF(ISIGN)703,702,702
702   THETA=-THETA
703   SINTH=SIN(THETA/2.)
      WSTPR=-2.*SINTH*SINTH
      WSTPI=SIN(THETA)
      WR=WSTPR+1.
      WI=WSTPI
      IMIN=3
      JMIN=2*NHALF-1
      GO TO 725
710   J=JMIN
      DO 720 I=IMIN,NTOT,NP2
      SUMR=(DATA(I)+DATA(J))/2.
      SUMI=(DATA(I+1)+DATA(J+1))/2.
      DIFR=(DATA(I)-DATA(J))/2.
      DIFI=(DATA(I+1)-DATA(J+1))/2.
      TEMPR=WR*SUMI+WI*DIFR
      TEMPI=WI*SUMI-WR*DIFR
      DATA(I)=SUMR+TEMPR
      DATA(I+1)=DIFI+TEMPI
      DATA(J)=SUMR-TEMPR
      DATA(J+1)=-DIFI+TEMPI
720   J=J+NP2
      IMIN=IMIN+2
      JMIN=JMIN-2
      TEMPR=WR
      WR=WR*WSTPR-WI*WSTPI+WR
      WI=TEMPR*WSTPI+WI*WSTPR+WI
725   IF(IMIN-JMIN)710,730,740
730   IF(ISIGN)731,740,740
731   DO 735 I=IMIN,NTOT,NP2
735   DATA(I+1)=-DATA(I+1)
740   NP2=NP2+NP2
      NTOT=NTOT+NTOT
      J=NTOT+1
      IMAX=NTOT/2+1
745   IMIN=IMAX-2*NHALF
      I=IMIN
      GO TO 755
750   DATA(J)=DATA(I)
      DATA(J+1)=-DATA(I+1)
755   I=I+2
      J=J-2
      IF(I-IMAX)750,760,760
760   DATA(J)=DATA(IMIN)-DATA(IMIN+1)
      DATA(J+1)=0.
      IF(I-J)770,780,780
765   DATA(J)=DATA(I)
      DATA(J+1)=DATA(I+1)
770   I=I-2
      J=J-2
      IF(I-IMIN)775,775,765
775   DATA(J)=DATA(IMIN)+DATA(IMIN+1)
      DATA(J+1)=0.
      IMAX=IMIN
      GO TO 745
780   DATA(1)=DATA(1)+DATA(2)
      DATA(2)=0.
      GO TO 900
```

```
C
C     COMPLETE A REAL TRANSFORM FOR THE 2ND OR 3RD DIMENSION BY
C     CONJUGATE SYMMETRIES.
C
800   IF(I1RNG-NP1)805,900,900
805   DO 860 I3=1,NTOT,NP2
      I2MAX=I3+NP2-NP1
      DO 860 I2=I3,I2MAX,NP1
      IMIN=I2+I1RNG
      IMAX=I2+NP1-2
      JMAX=2*I3+NP1-IMIN
      IF(I2-I3)820,820,810
810   JMAX=JMAX+NP2
820   IF(IDIM-2)850,850,830
830   J=JMAX+NP0
      DO 840 I=IMIN,IMAX,2
      DATA(I)=DATA(J)
      DATA(I+1)=-DATA(J+1)
840   J=J-2
850   J=JMAX
      DO 860 I=IMIN,IMAX,NP0
      DATA(I)=DATA(J)
      DATA(I+1)=-DATA(J+1)
860   J=J-NP0
C
C     END OF LOOP ON EACH DIMENSION
C
900   NP0=NP1
      NP1=NP2
910   NPREV=N
920   RETURN
      END
```

# Appendix 2. Generalized Flow Diagram of Program SPECOR

Subroutines used by the main calling program are identified at the sides of the diagram. Subroutines called subroutines are enclosed in parentheses.



## Appendix 3. Input Cards for Test Case

The source of the data for this test case is a density log digitized from a report of the Deep Sea Drilling Project of 1969 (Kennedy and others, p. 321-324). The log is stretched 1.35 times, and a part of the stretched log is chosen for the short log (Log 1). The long log (Log 2) is the first 350 points of the initial log data.

*Card 1.* Number of sets to be correlated. In this test case one set of the model density log is correlated. (NSET = 1). Format (I5).

*Card 2.* Description of input data. (MODEL DENSITY LOGS: SHORT LOG (LOG 1) IS STRETCHED 1.35 TIMES). Format (8A10).

*Card 3.* Name of logs. (DENSITY). Format (A10).

*Card 4.* Input parameters. Described in detail in the program comment card. (See appendix 1.) A short log of 130 points is correlating with a long log of 350 points (LS = 130, LL = 350). Derivatives of data are used to compute power spectra and also for stretching and correlation (IDER = 1, IORG = 0). Maximum anticipated stretch is set to 2.0 (SMAX = 2.0). Sampling interval is 2.0 feet (SINT = 2.0). Depths of both logs are set to 0 feet (DEPTH1 = 0.0, DEPTH2 = 0.0). Plots and all intermediate results are requested (PLRES = 1.0, PLALL = 1.0, PRALL = 1.0). Format (4I5, 7F5.0).

*Cards 5-134.* Data values for the short log. Format (F10.3).

*Cards 135-484.* Data values for the long log. Format (F10.3).

```
card 1      1
card 2  MODEL DENSITY LOGS: SHORT LOG (LOG 1) IS STRETCHED 1.35 TIMES
card 3 DENSITY
card 4    130  350    1    0  2.0  2.0  0.0  0.0  1.0  1.0  1.0
card 5       1.184  \
  .           .723  |
  .           .481  |
  .           .681  |
                .    >  130 data cards for Log 1
                .   |
                .   |
                .   |
                .   |
  .           .909  |
  .          1.138  |
  .          1.003  |
card 134      .755  /
card 135     1.230  \
  .          1.260  |
  .          1.250  |
  .          1.300   >  350 data cards for Log 2
                .   |
                .   |
                .   |
                .   |
                .   |
  .          1.120  |
  .          1.130  |
  .          1.160  |
card 484      .870  /
```

## Appendix 4. Test Case Output

The output of the test case consists of (1) a line printer listing of the original log data, derivative of the data, power spectra, interpolated power spectra, and coefficients of the crosscorrelation function of power spectra and (2) two Calcomp plots summarizing these same results. (See figs. 4 and 5.)

```
1 DEEP SEA DENSITY LOG& SHORT LOG STRETCHED 1.35 TIMES

   DENSITY
   LS=  130    LL=  350    IDER= 1    IORG= 0    SMAX=  2.0    SINT=  2.0
   DEPTH OF LOG 1 =     .0 FEET
   DEPTH CF LCG 2 =     .C FEET

0           INPUT  DATA

            LOG 1      LOG 2
```

| | LOG 1 | LOG 2 | | LOG 1 | LOG 2 |
|---|---|---|---|---|---|
| 1 | 1.184 | 1.230 | 41 | 1.337 | 1.220 |
| 2 | .723 | 1.260 | 42 | 1.241 | 1.300 |
| 3 | .481 | 1.250 | 43 | 1.134 | 1.310 |
| 4 | .681 | 1.300 | 44 | 1.329 | 1.340 |
| 5 | 1.C86 | 1.410 | 45 | 1.472 | 1.350 |
| 6 | 1.233 | 1.350 | 46 | 1.357 | 1.400 |
| 7 | 1.C26 | 1.120 | 47 | 1.260 | 1.390 |
| 8 | 1.001 | 1.110 | 48 | 1.331 | 1.280 |
| 9 | 1.090 | 1.05C | 49 | 1.325 | 1.310 |
| 10 | 1.072 | 1.140 | 50 | 1.210 | 1.330 |
| 11 | 1.123 | 1.200 | 51 | 1.277 | 1.150 |
| 12 | 1.C67 | 1.290 | 52 | 1.392 | 1.170 |
| 13 | .954 | 1.070 | 53 | 1.316 | 1.190 |
| 14 | .961 | 1.080 | 54 | 1.311 | .890 |
| 15 | .939 | .830 | 55 | 1.427 | .940 |
| 16 | 1.C53 | 1.050 | 56 | 1.334 | .780 |
| 17 | 1.171 | 1.200 | 57 | 1.062 | .680 |
| 18 | .973 | 1.280 | 58 | .963 | .730 |
| 19 | .699 | 1.27C | 59 | 1.059 | .690 |
| 20 | .472 | 1.310 | 60 | 1.098 | .520 |
| 21 | .745 | 1.35C | 61 | 1.164 | .020 |
| 22 | 1.527 | 1.330 | 62 | 1.348 | .440 |
| 23 | 1.225 | 1.250 | 63 | 1.382 | .150 |
| 24 | .C10 | 1.410 | 64 | 1.354 | .130 |
| 25 | .000 | 1.420 | 65 | 1.472 | .060 |
| 26 | .492 | 1.400 | 66 | 1.439 | .180 |
| 27 | .495 | 1.360 | 67 | 1.132 | .640 |
| 28 | .625 | 1.420 | 68 | .841 | .360 |
| 29 | .884 | 1.440 | 69 | .823 | .160 |
| 30 | .657 | 1.260 | 70 | 1.057 | .330 |
| 31 | .567 | 1.320 | 71 | 1.257 | .99C |
| 32 | .804 | 1.380 | 72 | 1.341 | .260 |
| 33 | .839 | 1.340 | 73 | 1.309 | .110 |
| 34 | .876 | 1.320 | 74 | 1.159 | .150 |
| 35 | .986 | 1.330 | 75 | 1.153 | .060 |
| 36 | .848 | 1.010 | 76 | 1.186 | .550 |
| 37 | .774 | 1.150 | 77 | 1.053 | .560 |
| 38 | .914 | 1.350 | 78 | .927 | .320 |
| 39 | .976 | 1.350 | 79 | .674 | .110 |
| 40 | 1.127 | 1.150 | 80 | .566 | .050 |

| | | |
|---|---|---|
| 81 | 1.017 | .280 |
| 82 | 1.317 | .180 |
| 83 | 1.331 | .640 |
| 84 | 1.438 | .540 |
| 85 | 1.103 | .460 |
| 86 | .709 | .660 |
| 87 | .972 | .820 |
| 88 | 1.264 | 1.020 |
| 89 | 1.325 | .670 |
| 90 | 1.297 | .890 |
| 91 | 1.163 | 1.600 |
| 92 | 1.156 | 1.460 |
| 93 | .959 | 1.570 |
| 94 | .754 | 1.280 |
| 95 | 1.119 | 1.040 |
| 96 | .971 | 1.160 |
| 97 | .065 | 1.700 |
| 98 | .027 | .990 |
| 99 | .781 | 1.550 |
| 100 | 1.108 | 1.050 |
| 101 | 1.080 | .980 |
| 102 | 1.211 | .770 |
| 103 | 1.348 | .850 |
| 104 | 1.057 | .940 |
| 105 | .695 | 1.040 |
| 106 | .925 | 1.120 |
| 107 | 1.297 | .980 |
| 108 | 1.223 | 1.050 |
| 109 | 1.059 | 1.480 |
| 110 | 1.200 | 1.640 |
| 111 | 1.333 | .950 |
| 112 | 1.139 | 1.450 |
| 113 | 1.103 | 1.460 |
| 114 | 1.246 | 1.320 |
| 115 | .768 | 1.590 |
| 116 | .152 | 1.160 |
| 117 | .237 | 1.510 |
| 118 | .590 | 1.690 |
| 119 | .955 | 1.580 |
| 120 | 1.170 | 1.020 |
| 121 | 1.019 | 1.130 |
| 122 | 1.065 | 1.330 |
| 123 | 1.145 | 1.130 |
| 124 | .697 | 1.330 |
| 125 | .361 | .630 |
| 126 | .548 | .870 |
| 127 | .909 | .640 |
| 128 | 1.138 | .660 |
| 129 | 1.003 | .950 |
| 130 | .755 | .880 |
| 131 | | 1.080 |
| 132 | | 1.180 |
| 133 | | 1.070 |
| 134 | | 1.300 |
| 135 | | .700 |
| 136 | | .750 |
| 137 | | .950 |
| 138 | | .980 |
| 139 | | 1.060 |
| 140 | | .960 |
| 141 | | 1.200 |
| 142 | | 1.150 |
| 143 | | 1.040 |
| 144 | | .950 |
| 145 | | 1.220 |
| 146 | | 1.080 |
| 147 | | 1.230 |
| 148 | | 1.370 |
| 149 | | 1.480 |
| 150 | | 1.390 |
| 151 | | 1.480 |
| 152 | | 1.460 |
| 153 | | 1.420 |
| 154 | | 1.080 |
| 155 | | 1.160 |
| 156 | | 1.190 |
| 157 | | 1.220 |
| 158 | | 1.360 |
| 159 | | 1.330 |
| 160 | | 1.180 |
| 161 | | 1.230 |
| 162 | | 1.260 |
| 163 | | 1.260 |
| 164 | | 1.290 |
| 165 | | 1.400 |
| 166 | | 1.340 |
| 167 | | 1.160 |
| 168 | | 1.340 |
| 169 | | 1.300 |
| 170 | | 1.230 |
| 171 | | 1.310 |
| 172 | | 1.290 |
| 173 | | 1.140 |
| 174 | | .980 |
| 175 | | 1.180 |
| 176 | | 1.260 |
| 177 | | 1.160 |
| 178 | | .790 |
| 179 | | 1.240 |
| 180 | | .990 |
| 181 | | .780 |
| 182 | | .830 |
| 183 | | 1.060 |
| 184 | | 1.160 |
| 185 | | 1.120 |
| 186 | | 1.180 |
| 187 | | .580 |
| 188 | | .590 |
| 189 | | 1.110 |
| 190 | | 1.160 |

| | | | |
|---|---|---|---|
| 191 | .980 | 246 | 1.320 |
| 192 | 1.090 | 247 | 1.390 |
| 193 | 1.090 | 248 | 1.210 |
| 194 | 1.090 | 249 | .710 |
| 195 | .950 | 250 | 1.160 |
| 196 | .950 | 251 | 1.320 |
| 197 | 1.030 | 252 | 1.270 |
| 198 | 1.150 | 253 | 1.150 |
| 199 | .810 | 254 | .990 |
| 200 | .480 | 255 | .810 |
| 201 | .970 | 256 | 1.170 |
| 202 | 1.530 | 257 | .090 |
| 203 | .020 | 258 | .250 |
| 204 | .140 | 259 | 1.070 |
| 205 | .530 | 260 | 1.080 |
| 206 | .640 | 261 | 1.290 |
| 207 | .840 | 262 | 1.180 |
| 208 | .540 | 263 | .690 |
| 209 | .820 | 264 | 1.120 |
| 210 | .830 | 265 | 1.270 |
| 211 | .980 | 266 | 1.060 |
| 212 | .820 | 267 | 1.300 |
| 213 | .840 | 268 | 1.180 |
| 214 | .970 | 269 | 1.140 |
| 215 | 1.180 | 270 | 1.080 |
| 216 | 1.320 | 271 | .190 |
| 217 | 1.130 | 272 | .320 |
| 218 | 1.390 | 273 | .800 |
| 219 | 1.420 | 274 | 1.170 |
| 220 | 1.260 | 275 | .990 |
| 221 | 1.350 | 276 | 1.170 |
| 222 | 1.240 | 277 | .700 |
| 223 | 1.280 | 278 | .380 |
| 224 | 1.380 | 279 | .800 |
| 225 | 1.290 | 280 | 1.140 |
| 226 | 1.430 | 281 | .890 |
| 227 | 1.220 | 282 | .700 |
| 228 | .960 | 283 | .830 |
| 229 | 1.070 | 284 | 1.140 |
| 230 | 1.110 | 285 | 1.190 |
| 231 | 1.320 | 286 | 1.290 |
| 232 | 1.370 | 287 | 1.210 |
| 233 | 1.410 | 288 | 1.350 |
| 234 | 1.460 | 289 | 1.370 |
| 235 | 1.050 | 290 | 1.470 |
| 236 | .790 | 291 | 1.450 |
| 237 | 1.040 | 292 | 1.340 |
| 238 | 1.290 | 293 | 1.160 |
| 239 | 1.340 | 294 | 1.250 |
| 240 | 1.160 | 295 | 1.070 |
| 241 | 1.180 | 296 | 1.270 |
| 242 | 1.100 | 297 | 1.340 |
| 243 | .920 | 298 | 1.200 |
| 244 | .570 | 299 | 1.340 |
| 245 | .880 | 300 | 1.400 |

| | |
|---|---|
| 301 | 1.300 |
| 302 | 1.190 |
| 303 | 1.290 |
| 304 | 1.320 |
| 305 | 1.300 |
| 306 | 1.270 |
| 307 | 1.190 |
| 308 | 1.200 |
| 309 | 1.360 |
| 310 | 1.260 |
| 311 | 1.210 |
| 312 | 1.360 |
| 313 | 1.260 |
| 314 | 1.380 |
| 315 | 1.180 |
| 316 | .970 |
| 317 | 1.070 |
| 318 | 1.210 |
| 319 | 1.290 |
| 320 | 1.450 |
| 321 | 1.460 |
| 322 | 1.430 |
| 323 | 1.380 |
| 324 | 1.310 |
| 325 | 1.450 |
| 326 | 1.110 |
| 327 | 1.180 |
| 328 | 1.320 |
| 329 | 1.230 |
| 330 | 1.200 |
| 331 | 1.260 |
| 332 | 1.370 |
| 333 | 1.340 |
| 334 | 1.220 |
| 335 | 1.050 |
| 336 | .860 |
| 337 | 1.100 |
| 338 | 1.160 |
| 339 | 1.020 |
| 340 | .980 |
| 341 | 1.020 |
| 342 | 1.030 |
| 343 | 1.180 |
| 344 | 1.020 |
| 345 | 1.120 |
| 346 | 1.170 |
| 347 | 1.120 |
| 348 | 1.130 |
| 349 | 1.160 |
| 350 | .870 |

DERIVATIVEC DATA

| | LOG 1 | LOG 2 |
|---|---|---|
| 1 | -.461 | .030 |
| 2 | -.242 | -.010 |
| 3 | .200 | .050 |
| 4 | .405 | .110 |
| 5 | .147 | -.060 |
| 6 | -.207 | -.230 |
| 7 | -.025 | -.010 |
| 8 | .089 | -.060 |
| 9 | -.018 | .090 |
| 10 | .051 | .060 |
| 11 | -.056 | .090 |
| 12 | -.113 | -.220 |
| 13 | .007 | .010 |
| 14 | -.022 | -.250 |
| 15 | .114 | .220 |
| 16 | .118 | .150 |
| 17 | -.198 | .080 |
| 18 | -.274 | -.010 |
| 19 | -.227 | .040 |
| 20 | .273 | .040 |
| 21 | .782 | -.020 |
| 22 | -.302 | -.080 |
| 23 | -1.215 | .160 |
| 24 | -.010 | .010 |
| 25 | .492 | -.020 |
| 26 | .003 | -.040 |
| 27 | .130 | .060 |
| 28 | .259 | .020 |
| 29 | -.227 | -.180 |
| 30 | -.090 | .060 |
| 31 | .237 | .060 |
| 32 | .035 | -.040 |
| 33 | .037 | -.020 |
| 34 | .110 | .010 |
| 35 | -.138 | -.320 |
| 36 | -.074 | .140 |
| 37 | .140 | .200 |
| 38 | .062 | .000 |
| 39 | .151 | -.200 |
| 40 | .210 | .070 |
| 41 | -.096 | .080 |
| 42 | -.107 | .010 |
| 43 | .195 | .030 |
| 44 | .143 | .010 |
| 45 | -.115 | .050 |
| 46 | -.097 | -.010 |
| 47 | .071 | -.110 |
| 48 | -.006 | .030 |
| 49 | -.115 | .020 |
| 50 | .067 | -.180 |
| 51 | .115 | .020 |
| 52 | -.076 | .020 |
| 53 | -.005 | -.300 |
| 54 | .116 | .050 |
| 55 | -.093 | -.160 |
| 56 | -.272 | -.100 |
| 57 | -.099 | .050 |
| 58 | .096 | -.040 |
| 59 | .039 | -.170 |
| 60 | .066 | -.500 |
| 61 | .184 | .420 |
| 62 | .034 | -.290 |
| 63 | -.028 | -.020 |
| 64 | .118 | -.070 |
| 65 | -.033 | .120 |
| 66 | -.307 | .460 |
| 67 | -.291 | -.280 |
| 68 | -.018 | -.200 |
| 69 | .234 | .170 |
| 70 | .200 | .660 |
| 71 | .084 | -.730 |
| 72 | -.032 | -.150 |
| 73 | -.150 | .040 |
| 74 | -.006 | -.090 |
| 75 | .033 | .490 |
| 76 | -.133 | .010 |
| 77 | -.126 | -.240 |
| 78 | -.253 | -.210 |
| 79 | -.108 | -.060 |
| 80 | .451 | .230 |
| 81 | .300 | -.100 |
| 82 | .014 | .460 |
| 83 | .107 | -.100 |
| 84 | -.335 | -.080 |
| 85 | -.394 | .200 |
| 86 | .263 | .160 |
| 87 | .292 | .200 |
| 88 | .061 | -.350 |
| 89 | -.028 | .220 |
| 90 | -.134 | .710 |
| 91 | -.007 | -.140 |
| 92 | -.197 | .110 |
| 93 | -.205 | -.290 |
| 94 | .365 | -.240 |
| 95 | -.148 | .120 |
| 96 | -.906 | .540 |
| 97 | -.038 | -.710 |
| 98 | .754 | .560 |
| 99 | .327 | -.500 |
| 100 | -.028 | -.070 |

| | | |
|---|---|---|
| 101 | .131 | -.210 |
| 102 | .137 | .080 |
| 103 | -.291 | .090 |
| 104 | -.362 | .100 |
| 105 | .230 | .080 |
| 106 | .372 | -.140 |
| 107 | -.074 | .070 |
| 108 | -.164 | .430 |
| 109 | .141 | .160 |
| 110 | .133 | -.690 |
| 111 | -.194 | .500 |
| 112 | -.036 | .010 |
| 113 | .143 | -.140 |
| 114 | -.478 | .270 |
| 115 | -.616 | -.430 |
| 116 | .085 | .350 |
| 117 | .353 | .180 |
| 118 | .365 | -.110 |
| 119 | .215 | -.560 |
| 120 | -.151 | .110 |
| 121 | .046 | .200 |
| 122 | .080 | -.200 |
| 123 | -.448 | .200 |
| 124 | -.336 | -.700 |
| 125 | .187 | .240 |
| 126 | .361 | -.230 |
| 127 | .229 | .020 |
| 128 | -.135 | .290 |
| 129 | -.248 | -.070 |
| 130 | | .200 |
| 131 | | .100 |
| 132 | | -.110 |
| 133 | | .230 |
| 134 | | -.600 |
| 135 | | .050 |
| 136 | | .200 |
| 137 | | .030 |
| 138 | | .080 |
| 139 | | -.100 |
| 140 | | .240 |
| 141 | | -.050 |
| 142 | | -.110 |
| 143 | | -.090 |
| 144 | | .270 |
| 145 | | -.140 |
| 146 | | .150 |
| 147 | | .140 |
| 148 | | .110 |
| 149 | | -.090 |
| 150 | | .090 |
| 151 | | -.020 |
| 152 | | -.040 |
| 153 | | -.340 |
| 154 | | .080 |
| 155 | | .030 |

| | |
|---|---|
| 156 | .030 |
| 157 | .140 |
| 158 | -.030 |
| 159 | -.150 |
| 160 | .050 |
| 161 | .030 |
| 162 | .000 |
| 163 | .030 |
| 164 | .110 |
| 165 | -.060 |
| 166 | -.180 |
| 167 | .180 |
| 168 | -.040 |
| 169 | -.070 |
| 170 | .080 |
| 171 | -.020 |
| 172 | -.150 |
| 173 | -.160 |
| 174 | .200 |
| 175 | .080 |
| 176 | -.100 |
| 177 | -.370 |
| 178 | .450 |
| 179 | -.250 |
| 180 | -.210 |
| 181 | .050 |
| 182 | .230 |
| 183 | .100 |
| 184 | -.040 |
| 185 | .060 |
| 186 | -.600 |
| 187 | .010 |
| 188 | .520 |
| 189 | .050 |
| 190 | -.180 |
| 191 | .110 |
| 192 | .000 |
| 193 | .000 |
| 194 | -.140 |
| 195 | .000 |
| 196 | .080 |
| 197 | .120 |
| 198 | -.340 |
| 199 | -.330 |
| 200 | .490 |
| 201 | .560 |
| 202 | -1.510 |
| 203 | .120 |
| 204 | .390 |
| 205 | .110 |
| 206 | .200 |
| 207 | -.300 |
| 208 | .280 |
| 209 | .010 |
| 210 | .150 |

| | | | |
|---|---|---|---|
| 211 | -.160 | 266 | .240 |
| 212 | .020 | 267 | -.120 |
| 213 | .130 | 268 | -.040 |
| 214 | .210 | 269 | -.060 |
| 215 | .140 | 270 | -.890 |
| 216 | -.190 | 271 | .130 |
| 217 | .260 | 272 | .480 |
| 218 | .030 | 273 | .370 |
| 219 | -.160 | 274 | -.180 |
| 220 | .090 | 275 | .180 |
| 221 | -.110 | 276 | -.470 |
| 222 | .040 | 277 | -.320 |
| 223 | .100 | 278 | .420 |
| 224 | -.090 | 279 | .340 |
| 225 | .140 | 280 | -.250 |
| 226 | -.210 | 281 | -.190 |
| 227 | -.260 | 282 | .130 |
| 228 | .110 | 283 | .310 |
| 229 | .040 | 284 | .050 |
| 230 | .210 | 285 | .100 |
| 231 | .050 | 286 | -.080 |
| 232 | .040 | 287 | .140 |
| 233 | .050 | 288 | .020 |
| 234 | -.410 | 289 | .100 |
| 235 | -.260 | 290 | -.020 |
| 236 | .250 | 291 | -.110 |
| 237 | .250 | 292 | -.180 |
| 238 | .050 | 293 | .090 |
| 239 | -.180 | 294 | -.180 |
| 240 | .020 | 295 | .200 |
| 241 | -.080 | 296 | .070 |
| 242 | -.180 | 297 | -.140 |
| 243 | -.350 | 298 | .140 |
| 244 | .310 | 299 | .060 |
| 245 | .440 | 300 | -.100 |
| 246 | .070 | 301 | -.110 |
| 247 | -.180 | 302 | .100 |
| 248 | -.500 | 303 | .030 |
| 249 | .450 | 304 | -.020 |
| 250 | .160 | 305 | -.030 |
| 251 | -.050 | 306 | -.080 |
| 252 | -.120 | 307 | .010 |
| 253 | -.160 | 308 | .160 |
| 254 | -.180 | 309 | -.100 |
| 255 | .360 | 310 | -.050 |
| 256 | -1.080 | 311 | .150 |
| 257 | .160 | 312 | -.100 |
| 258 | .820 | 313 | .120 |
| 259 | .010 | 314 | -.200 |
| 260 | .210 | 315 | -.210 |
| 261 | -.110 | 316 | .100 |
| 262 | -.490 | 317 | .140 |
| 263 | .430 | 318 | .080 |
| 264 | .150 | 319 | .160 |
| 265 | -.210 | 320 | .010 |

| | |
|---|---|
| 321 | -.030 |
| 322 | -.050 |
| 323 | -.070 |
| 324 | .140 |
| 325 | -.340 |
| 326 | .070 |
| 327 | .140 |
| 328 | -.090 |
| 329 | -.030 |
| 330 | .060 |
| 331 | .110 |
| 332 | -.030 |
| 333 | -.120 |
| 334 | -.170 |
| 335 | -.190 |
| 336 | .240 |
| 337 | .060 |
| 338 | -.140 |
| 339 | -.040 |
| 340 | .040 |
| 341 | .010 |
| 342 | .150 |
| 343 | -.160 |
| 344 | .100 |
| 345 | .050 |
| 346 | -.050 |
| 347 | .010 |
| 348 | .030 |
| 349 | -.290 |

# FOURIER TRANSFORM

| | LOG 1 | | | LOG 2 | | |
|---|---|---|---|---|---|---|
| | REAL | IMAGINARY | POWER SPECTRUM | REAL | IMAGINARY | POWER SPECTRUM |
| 1 | .033 | .196 | .000 | -.592 | .095 | .001 |
| 2 | .039 | -.462 | .001 | -1.029 | .832 | .005 |
| 3 | -.607 | -.455 | .002 | .438 | .924 | .003 |
| 4 | -.747 | -.098 | .002 | .477 | -1.109 | .004 |
| 5 | -.905 | .189 | .002 | 1.206 | -2.885 | .028 |
| 6 | -.674 | .852 | .003 | -2.667 | .182 | .020 |
| 7 | .139 | .903 | .002 | -.923 | .979 | .005 |
| 8 | .414 | .458 | .001 | .317 | .697 | .002 |
| 9 | .582 | .362 | .001 | -.425 | .002 | .001 |
| 10 | 1.048 | -.147 | .003 | 1.564 | -1.963 | .018 |
| 11 | .686 | -1.105 | .005 | -.812 | .721 | .003 |
| 12 | -.294 | -1.018 | .003 | -.655 | 1.091 | .005 |
| 13 | -.071 | -.402 | .000 | .630 | .596 | .002 |
| 14 | .190 | -1.290 | .005 | -3.990 | -.239 | .046 |
| 15 | -1.525 | -1.395 | .012 | 1.151 | 2.205 | .018 |
| 16 | -1.471 | .908 | .009 | 2.472 | 2.714 | .039 |
| 17 | 1.080 | .451 | .004 | .911 | -1.709 | .011 |
| 18 | .014 | -2.100 | .013 | -3.288 | .118 | .031 |
| 19 | -2.322 | -.482 | .016 | -.457 | -.330 | .001 |
| 20 | -.409 | 1.372 | .006 | 2.108 | -.638 | .014 |
| 21 | .700 | -.574 | .002 | -.719 | 1.682 | .010 |
| 22 | -1.157 | -.839 | .006 | .067 | -1.283 | .005 |
| 23 | -.765 | .927 | .004 | -.188 | -.494 | .001 |
| 24 | .866 | .322 | .002 | .935 | 1.339 | .008 |
| 25 | .501 | -.945 | .003 | -2.502 | .060 | .018 |
| 26 | -.117 | -.994 | .003 | -.885 | -1.164 | .006 |
| 27 | -.473 | -1.031 | .004 | 3.056 | -.225 | .027 |
| 28 | -.744 | -.401 | .002 | -.895 | -.090 | .002 |
| 29 | .443 | -.413 | .001 | -2.904 | -.149 | .024 |
| 30 | -.022 | -2.452 | .017 | -1.640 | -1.875 | .018 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 31 | -2.617 | -1.727 | .C28 | 1.436 | -2.762 | .028 |
| 32 | -1.766 | .342 | .009 | .699 | 1.358 | .007 |
| 33 | -1.591 | -.831 | .009 | 1.767 | .024 | .009 |
| 34 | -3.357 | 1.801 | .042 | .172 | -1.859 | .010 |
| 35 | 2.142 | 4.C07 | .C59 | -.780 | 2.623 | .021 |
| 36 | 4.028 | -3.672 | .085 | .223 | .131 | .000 |
| 37 | -4.727 | -4.224 | .115 | -.255 | 1.419 | .006 |
| 38 | -3.337 | 4.365 | .C87 | .873 | 1.860 | .012 |
| 39 | 3.823 | 1.316 | .C47 | -1.335 | -1.163 | .009 |
| 40 | .187 | -3.233 | .030 | -1.668 | -.096 | .008 |
| 41 | -1.C03 | -.238 | .CC3 | 2.347 | -2.619 | .035 |
| 42 | .589 | -2.146 | .014 | -3.185 | 3.793 | .070 |
| 43 | -2.903 | -2.109 | .037 | 2.194 | -1.524 | .020 |
| 44 | -1.277 | .852 | .007 | 2.052 | -2.437 | .029 |
| 45 | -.331 | -2.065 | .013 | -2.095 | -3.443 | .047 |
| 46 | -3.619 | -.871 | .C40 | 5.078 | 2.414 | .091 |
| 47 | -1.160 | 1.249 | .CC8 | -1.047 | 4.122 | .052 |
| 48 | -1.489 | -1.449 | .012 | -2.736 | -4.327 | .075 |
| 49 | -3.586 | 1.249 | .041 | 1.883 | -7.163 | .157 |
| 50 | -.092 | 1.831 | .01C | 3.026 | 2.410 | .043 |
| 51 | -2.036 | -.5C9 | .013 | -3.638 | 2.993 | .064 |
| 52 | -2.202 | 4.339 | .C68 | 1.555 | -8.269 | .203 |
| 53 | 4.466 | 2.485 | .075 | -.188 | -4.508 | .058 |
| 54 | 1.030 | -3.697 | .042 | .209 | 4.476 | .058 |
| 55 | -2.684 | 1.416 | .C26 | -2.288 | .890 | .017 |
| 56 | 4.386 | 2.586 | .C74 | 1.239 | -.083 | .004 |
| 57 | 4.768 | -5.797 | .161 | -3.062 | -1.092 | .030 |
| 58 | -3.1C8 | -7.133 | .173 | 3.650 | -1.016 | .041 |
| 59 | -5.417 | -1.350 | .C89 | -1.922 | 1.163 | .014 |
| 60 | -1.415 | .593 | .C07 | -3.892 | 1.076 | .047 |
| 61 | -.609 | -3.557 | .C37 | -2.448 | 2.011 | .029 |
| 62 | -6.174 | -4.C08 | .155 | -.469 | -5.201 | .078 |
| 63 | -7.386 | 1.886 | .166 | 1.578 | -1.039 | .010 |
| 64 | -3.590 | 3.611 | .C74 | -4.757 | .242 | .065 |
| 65 | -2.706 | 3.165 | .050 | -.815 | 5.690 | .095 |
| 66 | -.777 | 3.647 | .040 | -1.685 | .761 | .010 |
| 67 | -.191 | 1.165 | .004 | 3.353 | -5.937 | .133 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 68 | -2.260 | 2.137 | .028 | -3.930 | -.093 | .044 |
| 69 | .327 | 3.641 | .038 | 2.086 | 3.753 | .053 |
| 70 | .765 | 1.144 | .005 | .773 | 3.015 | .028 |
| 71 | .093 | 2.812 | .023 | -5.082 | -6.461 | .194 |
| 72 | 4.169 | 1.336 | .055 | 3.573 | -6.623 | .162 |
| 73 | 1.328 | -3.633 | .043 | 1.563 | -1.536 | .014 |
| 74 | -1.926 | -.075 | .011 | -2.659 | 6.626 | .146 |
| 75 | 2.280 | -.241 | .015 | 2.415 | 2.033 | .029 |
| 76 | -.826 | -4.808 | .068 | 1.580 | -7.172 | .155 |
| 77 | -4.477 | -.753 | .059 | 5.932 | 4.295 | .154 |
| 78 | -1.169 | .294 | .004 | -5.428 | 5.612 | .175 |
| 79 | -3.196 | -1.898 | .040 | 1.572 | -9.177 | .248 |
| 80 | -4.606 | 1.575 | .068 | -.151 | 5.757 | .095 |
| 81 | -2.311 | 2.152 | .029 | 1.669 | 1.517 | .015 |
| 82 | -2.933 | 2.557 | .043 | 1.991 | -.802 | .013 |
| 83 | -.297 | 3.890 | .044 | -4.388 | -9.508 | .314 |
| 84 | -.030 | .404 | .000 | .480 | 7.760 | .173 |
| 85 | -3.503 | 2.989 | .061 | -7.290 | 5.827 | .250 |
| 86 | 2.061 | 6.110 | .119 | 2.514 | -3.672 | .057 |
| 87 | 4.030 | -.877 | .049 | -.620 | 2.759 | .023 |
| 88 | -2.739 | -.302 | .022 | .585 | -5.842 | .099 |
| 89 | 1.143 | 5.738 | .098 | -.767 | .533 | .003 |
| 90 | 6.597 | -.559 | .126 | -2.477 | 4.252 | .069 |
| 91 | -.213 | -5.022 | .072 | 2.471 | -.943 | .020 |
| 92 | -2.569 | 1.097 | .022 | -3.556 | -.461 | .037 |
| 93 | 3.243 | .630 | .031 | 5.668 | -1.587 | .099 |
| 94 | .632 | -6.014 | .105 | -2.684 | 2.589 | .040 |
| 95 | -7.197 | -2.956 | .173 | 1.134 | -.148 | .004 |
| 96 | -4.975 | 5.013 | .143 | -1.733 | 4.148 | .058 |
| 97 | 1.573 | 3.489 | .042 | -.380 | -4.121 | .049 |
| 98 | -.367 | -.903 | .003 | 6.961 | .715 | .140 |
| 99 | -3.046 | 2.145 | .040 | -2.257 | -3.646 | .053 |
| 100 | .606 | 3.802 | .042 | -5.187 | -.301 | .077 |
| 101 | 1.240 | .551 | .005 | -2.763 | -3.517 | .057 |
| 102 | -1.334 | 1.339 | .010 | .876 | -.483 | .003 |
| 103 | .528 | 3.821 | .043 | 6.723 | 1.221 | .134 |
| 104 | 3.230 | 2.310 | .045 | -4.137 | 2.425 | .066 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 105 | 3.396 | .208 | .033 | 1.615 | -2.553 | .026 |
| 106 | 3.119 | -1.512 | .034 | -2.900 | 3.277 | .055 |
| 107 | 1.260 | -3.177 | .033 | 6.758 | -1.257 | .135 |
| 108 | -.910 | -2.328 | .018 | 2.862 | 1.777 | .033 |
| 109 | -.818 | -1.403 | .008 | -4.913 | -4.431 | .125 |
| 110 | -1.641 | -1.865 | .018 | .413 | 7.323 | .154 |
| 111 | -2.969 | -.276 | .025 | -.622 | -.023 | .001 |
| 112 | -1.894 | 1.011 | .013 | 3.004 | -5.846 | .124 |
| 113 | -2.209 | .783 | .016 | -6.050 | .239 | .105 |
| 114 | -2.253 | 3.441 | .048 | 2.717 | .969 | .024 |
| 115 | 1.967 | 3.882 | .054 | -4.657 | -1.093 | .066 |
| 116 | 2.360 | -.320 | .016 | 1.088 | -2.869 | .027 |
| 117 | -.809 | .523 | .003 | 7.800 | 6.180 | .284 |
| 118 | 1.931 | 2.801 | .033 | 3.001 | -1.673 | .034 |
| 119 | 3.937 | -1.112 | .048 | -6.020 | -4.701 | .167 |
| 120 | .423 | -2.950 | .025 | -2.693 | -5.035 | .093 |
| 121 | -.792 | -.919 | .004 | 6.596 | -.663 | .126 |
| 122 | -.158 | -.473 | .001 | 1.900 | 4.898 | .079 |
| 123 | .226 | -.419 | .001 | -1.583 | -4.123 | .056 |
| 124 | .488 | -1.764 | .010 | 2.832 | -3.896 | .066 |
| 125 | -2.200 | -2.107 | .027 | -.195 | 1.588 | .007 |
| 126 | -2.388 | 1.420 | .022 | 3.387 | 6.520 | .155 |
| 127 | 1.197 | .978 | .007 | -2.963 | -3.730 | .065 |
| 128 | -.127 | -2.178 | .014 | -.300 | -7.930 | .180 |
| 129 | -2.634 | -.329 | .020 | 5.677 | 8.716 | .310 |
| 130 | -.955 | 1.301 | .007 | -2.216 | -3.923 | .058 |
| 131 | -.377 | .238 | .001 | -4.259 | -5.462 | .137 |
| 132 | -.852 | .529 | .003 | 3.885 | 3.901 | .087 |
| 133 | -.255 | .646 | .001 | 5.756 | -2.351 | .111 |
| 134 | -.359 | .288 | .001 | -.845 | .691 | .003 |
| 135 | -.322 | .548 | .001 | -2.323 | -3.392 | .048 |
| 136 | -.054 | .314 | .000 | .077 | 6.676 | .128 |
| 137 | -.242 | .232 | .000 | 1.036 | 2.940 | .028 |
| 138 | -.079 | .291 | .000 | -.740 | -.310 | .002 |
| 139 | -.115 | .030 | .000 | -6.109 | -1.259 | .111 |
| 140 | -.263 | .115 | .000 | 6.695 | 2.243 | .143 |
| 141 | -.161 | .060 | .000 | -1.549 | -.319 | .007 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 142 | -.346 | -.015 | .000 | -.733 | -1.505 | .008 |
| 143 | -.348 | .153 | .000 | 2.291 | 1.858 | .025 |
| 144 | -.308 | .069 | .000 | -5.721 | -3.878 | .137 |
| 145 | -.441 | .160 | .001 | 2.969 | 4.446 | .082 |
| 146 | -.308 | .263 | .000 | 5.971 | -.567 | .103 |
| 147 | -.317 | .194 | .000 | -1.180 | -5.543 | .092 |
| 148 | -.292 | .334 | .001 | -.792 | 1.484 | .008 |
| 149 | -.113 | .262 | .000 | -2.339 | -2.146 | .029 |
| 150 | -.186 | .191 | .000 | 1.740 | 3.380 | .041 |
| 151 | -.082 | .264 | .000 | 2.725 | 3.890 | .065 |
| 152 | -.012 | .073 | .000 | 4.419 | -7.459 | .215 |
| 153 | -.136 | .058 | .000 | -7.957 | .220 | .182 |
| 154 | -.043 | .044 | .000 | -.878 | -.565 | .003 |
| 155 | -.145 | -.123 | .000 | 3.631 | 3.951 | .083 |
| 156 | -.262 | -.020 | .000 | -5.139 | -1.395 | .081 |
| 157 | -.202 | -.053 | .000 | -1.370 | 1.943 | .016 |
| 158 | -.366 | -.075 | .000 | 4.349 | -3.723 | .094 |
| 159 | -.355 | .097 | .000 | .644 | -4.991 | .073 |
| 160 | -.300 | .043 | .000 | -4.485 | -3.000 | .083 |
| 161 | -.398 | .132 | .001 | .688 | 2.158 | .015 |
| 162 | -.248 | .234 | .000 | 4.672 | -2.694 | .083 |
| 163 | -.222 | .139 | .000 | -2.965 | 2.401 | .042 |
| 164 | -.214 | .241 | .000 | -1.741 | -2.754 | .030 |
| 165 | -.033 | .174 | .000 | -2.084 | 2.839 | .036 |
| 166 | -.100 | .052 | .000 | 2.464 | -.857 | .019 |
| 167 | -.054 | .109 | .000 | -2.529 | 1.185 | .022 |
| 168 | .011 | -.070 | .000 | .418 | 2.737 | .022 |
| 169 | -.159 | -.114 | .000 | 6.842 | .447 | .135 |
| 170 | -.118 | -.070 | .000 | -3.960 | -2.592 | .064 |
| 171 | -.192 | -.210 | .000 | .355 | .397 | .001 |
| 172 | -.344 | -.100 | .000 | 4.911 | .136 | .069 |
| 173 | -.268 | -.056 | .000 | 6.035 | .675 | .106 |
| 174 | -.373 | -.087 | .000 | -2.912 | -.173 | .024 |

INTERPOLATED POWER SPECRUM ( START FROM 10TH OF ORIGINAL )

| | LOG 1 | LOG 2 | | | |
|---|---|---|---|---|---|
| 1 | .003 | .018 | 51 | .017 | .015 |
| 2 | .004 | .015 | 52 | .006 | .006 |
| 3 | .004 | .012 | 53 | .012 | .009 |
| 4 | .005 | .008 | 54 | .038 | .010 |
| 5 | .005 | .004 | 55 | .054 | .019 |
| 6 | .005 | .003 | 56 | .071 | .011 |
| 7 | .004 | .003 | 57 | .097 | .000 |
| 8 | .004 | .004 | 58 | .113 | .007 |
| 9 | .003 | .004 | 59 | .086 | .012 |
| 10 | .002 | .002 | 60 | .050 | .009 |
| 11 | .001 | .000 | 61 | .033 | .007 |
| 12 | .001 | .001 | 62 | .008 | .027 |
| 13 | .001 | .011 | 63 | .008 | .064 |
| 14 | .002 | .026 | 64 | .032 | .038 |
| 15 | .004 | .040 | 65 | .017 | .023 |
| 16 | .006 | .043 | 66 | .008 | .039 |
| 17 | .009 | .034 | 67 | .034 | .082 |
| 18 | .011 | .023 | 68 | .016 | .060 |
| 19 | .012 | .020 | 69 | .010 | .068 |
| 20 | .011 | .029 | 70 | .041 | .157 |
| 21 | .009 | .037 | 71 | .008 | .039 |
| 22 | .007 | .033 | 72 | .028 | .110 |
| 23 | .005 | .021 | 73 | .077 | .141 |
| 24 | .004 | .011 | 74 | .053 | .054 |
| 25 | .007 | .019 | 75 | .026 | .019 |
| 26 | .011 | .028 | 76 | .096 | .009 |
| 27 | .014 | .026 | 77 | .179 | .040 |
| 28 | .016 | .012 | 78 | .101 | .016 |
| 29 | .016 | .001 | 79 | .005 | .042 |
| 30 | .011 | .006 | 80 | .118 | .066 |
| 31 | .006 | .013 | 81 | .159 | .013 |
| 32 | .004 | .013 | 82 | .056 | .091 |
| 33 | .002 | .010 | 83 | .037 | .017 |
| 34 | .004 | .008 | 84 | .016 | .084 |
| 35 | .005 | .005 | 85 | .033 | .044 |
| 36 | .005 | .002 | 86 | .017 | .163 |
| 37 | .004 | .001 | 87 | .054 | .086 |
| 38 | .003 | .003 | 88 | .009 | .134 |
| 39 | .002 | .008 | 89 | .062 | .136 |
| 40 | .003 | .015 | 90 | .021 | .162 |
| 41 | .003 | .017 | 91 | .056 | .192 |
| 42 | .003 | .008 | 92 | .030 | .000 |
| 43 | .003 | .013 | 93 | .035 | .302 |
| 44 | .004 | .026 | 94 | .070 | .233 |
| 45 | .003 | .013 | 95 | .043 | .030 |
| 46 | .001 | .005 | 96 | .105 | .008 |
| 47 | .000 | .021 | 97 | .060 | .019 |
| 48 | .009 | .021 | 98 | .052 | .086 |
| 49 | .021 | .020 | 99 | .169 | .029 |
| 50 | .028 | .027 | 100 | .007 | .121 |

| | | |
|---|---|---|
| 101 | .042 | .077 |
| 102 | .021 | .045 |
| 103 | .036 | .032 |
| 104 | .032 | .122 |
| 105 | .013 | .159 |
| 106 | .012 | .129 |
| 107 | .056 | .058 |
| 108 | .016 | .168 |
| 109 | .020 | .098 |
| 110 | .001 | .056 |
| 111 | .023 | .143 |
| 112 | .020 | .304 |
| 113 | .002 | .096 |
| 114 | .001 | .040 |
| 115 | .000 | .005 |
| 116 | .000 | .000 |
| 117 | .000 | .112 |
| 118 | .001 | .014 |
| 119 | .000 | .120 |
| 120 | .000 | .071 |
| 121 | .000 | .088 |
| 122 | .000 | .080 |
| 123 | .000 | .020 |
| 124 | .000 | .081 |

NORMALIZED CORRELATION COEFFICIENTS

| ( ASSUME LONG LOG IS STRETCHED ) | | ( ASSUME SHORT LOG IS STRETCHED ) | |
|---|---|---|---|
| G NUMBER | VALUE OF COEFFICIENT | LAG NUMBER | VALUE OF COEFFICIENT |
| 0 | .077 | 0 | .077 |
| -1 | .139 | 1 | .093 |
| -2 | .045 | 2 | .106 |
| -3 | .216 | 3 | .080 |
| -4 | .147 | 4 | .157 |
| -5 | .268 | 5 | .236 |
| -6 | .244 | 6 | .264 |
| -7 | .183 | 7 | .238 |
| -8 | .291 | 8 | .297 |
| -9 | .163 | 9 | .451 |
| -10 | .180 | 10 | .437 |
| -11 | .099 | 11 | .376 |
| -12 | -.002 | 12 | .552 |
| -13 | .090 | 13 | .768 |
| -14 | .057 | 14 | .457 |
| -15 | -.053 | 15 | .352 |
| -16 | -.123 | 16 | .454 |
| -17 | -.027 | 17 | .390 |
| -18 | -.098 | 18 | .261 |
| -19 | -.094 | 19 | .096 |
| -20 | -.185 | 20 | .202 |
| -21 | -.134 | 21 | .199 |
| -22 | -.142 | 22 | .092 |
| -23 | -.148 | 23 | .267 |
| -24 | -.140 | 24 | .203 |
| -25 | -.124 | 25 | .203 |
| -26 | -.054 | 26 | .186 |
| -27 | -.091 | 27 | .285 |
| -28 | -.164 | 28 | .374 |
| -29 | -.089 | 29 | .290 |
| -30 | -.174 | 30 | .418 |

STRETCH FACTOR FOUND FROM CORRELATION OF POWER SPECTRA

FIRST CHOICE - SHORT LOG IS STRETCHED 1.35 TIMES

SECOND CHOICE - SHORT LOG IS STRETCHED 1.45 TIMES

FINAL RESULT SUGGESTS THAT SHORT LOG IS STRETCHED 1.35 TIMES

MAXIMUM CORRELATION IS .849 AT A LAG OF 185
TOTAL COMPUTING TIME = 6.609SECONDS

## INDIANA GEOLOGICAL SURVEY
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No. 1 "Fortran Program for the Upward and Downward Continuation and Derivatives of Potential Fields" (Occasional Paper 10)

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No. 5 "Fortran Program for Reduction of Gravimeter Observations to Bouguer Anomaly" (Occasional Paper 23)

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## ERRATA

Geophysical Computer Program 1 (Occasional Paper 10)

Page 9, 19 lines from the bottom of the page:

Second line of R(M,N,4) now reads 1+P(I+1,J+1)+P(I+1,J-1)+ P(I-1,J+1)+P(I-1,J-1))/8.0

Second line of R(M,N,4) should read 1+P(I+1,J+2)+P(I+1,J-2)+ P(I-1,J+2)+P(I-1,J-2))/8.0

Page 9, 4 lines from the bottom of the page:

Second line of R(M,N,11) now reads 1P(I-20,J-15)+P(I-15,J-15)+ P(I+20,J+15)+P(I+15,J+20)

Second line of R(M,N,11) should read 1P(I-20,J-15)+P(I-15,J-20)+ P(I+20,J+15)+P(I+15,J+20)

Geophysical Computer Program 2 (Occasional Paper 13)

Page 11, line 18:

Now reads: (1,170)ITYPE,Z(I),XI(I)

Should read: (2,230)ITYPE,Z(I),XI(I)

Page 12, after line 18:

Insert: 230 FORMAT (I1,F4.0,F4.1)

Geophysical Computer Program 3 (Occasional Paper 14)

Page 12, line 11:

Now reads: 10 A(I+MN)=A(I)

Should read: 10 A(M+K-I)=A(N+K-I)