MASTER

National Uranium Resource Evaluation

STATISTICAL TECHNIQUES APPLIED TO AERIAL RADIOMETRIC SURVEYS (STAARS):

PRINCIPAL COMPONENTS ANALYSIS USER'S MANUAL

**Field Engineering
Corporation**

Grand Junction Operations
Grand Junction, CO 81502

January 1981

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Resource Applications
Grand Junction Office, Colorado

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C. D. Koch
F. L. Pirkle
J. S. Schmidt

BENDIX FIELD ENGINEERING CORPORATION
Grand Junction Operations
P.O. Box 1569
Grand Junction, Colorado 81502

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PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
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ABSTRACT

A Principal Components Analysis (PCA) program has been written to aid in the interpretation of multivariate aerial radiometric data collected by the U.S. Department of Energy (DOE) under the National Uranium Resource Evaluation (NURE) program. The variations exhibited by these data have been reduced and classified into a number of linear combinations by using the PCA program. The PCA program then generates histograms and outlier maps of the individual variates. Black and white plots can be made on a Calcomp plotter by the application of follow-up programs. All programs referred to in this guide were written for a DEC-10.

From this analysis a geologist may begin to interpret the data structure. Insight into geological processes underlying the data may be obtained.

INTRODUCTION

The U.S. Department of Energy (DOE), under the National Uranium Resource Evaluation (NURE) program, has been conducting aerial radiometric surveys over various portions of the United States (Bendix Field Engineering Corporation, 1979). The data collected in these surveys include multichannel observations of gamma-ray emissions from which the uranium (from ^{214}Bi), thorium (from ^{208}Tl), and potassium (from ^{40}K) contributions to the total activity can be determined. The multivariate structure of the data suggests that statistical techniques of multivariate nature are appropriate.

Multivariate exploratory techniques can be used to suggest revealing projections and transformations of the data. Principal components analysis is one such technique. Its application is straightforward, providing a suitable starting point for such exploration.

Principal components analysis is a technique which provides insight into the structure of multivariate data. Many analysts consider it "strictly descriptive, (having) an interesting deterministic geometrical interpretation..." (Bargmann, 1969, p. 573). They view the principal components as possibly useful but strictly artificial constructs. However, it has been shown that when principal components analysis is applied to aerial radiometric data it may shed light on the geologic history of an area and may aid in the identification of areas favorable for uranium deposition (Pirkle et al., 1980).

Other workers have also found principal components analysis useful in analyzing aerial radiometric data. For instance, Los Alamos Scientific Laboratory (1975), as part of a DOE/Grand Junction sponsored study, applied principal components analysis to the three variables Bi, Tl, and K and the ratios $^{Bi}/K$, $^{Bi}/Tl$, and $^{Tl}/K$. This study indicated that 98 percent of the variation could be explained using only Bi, Tl, and K Data. Duval (1976, 1977) applied factor analysis, a technique similar to principal components analysis (see section on Principal Components Analysis Versus Factor Analysis), to aerial data and concluded that the technique was useful in mapping geology. Pirkle et al., (1980) used principal components analysis to develop an interpretation of aerial radiometric data suggestive of depositional processes.

In addition to the Bi, Tl, and K data, the flight-line number, record number, latitude, longitude, and geology for each observation are recorded. This information enables principal components to be calculated on subsets of the data or the total data set. Subset calculations may be accomplished as a function of the flight-line numbers or geologic labels, depending on the desires of the user. Maps of the locations of the desired component scores are made possible by using latitude and longitude information and a Mercator projection routine. The user may set these values so that the points plotted are outliers within the interpreter's context.

PRINCIPAL COMPONENTS ANALYSIS THEORY

The mathematical objective of principal components analysis is to determine N uncorrelated components that express linear combinations of the original data.

To illustrate the principal components analysis theory, a three variable data set comprised of potassium (K), bismuth (Bi), and thallium (Tl) counts will be used. The determination of uncorrelated components is accomplished by first calculating the means, variances, and covariances of these data and setting these values into matrix form. The standard covariance equation is:

$$CV_{ik} = (1/M) \sum_{j=1}^M [(X_{ij} - \bar{X}_i) (X_{kj} - \bar{X}_k)] \quad (1)$$

where M is the total number of data points and $\bar{X}$ is the mean of the respective variable. The integers i and k represent the K, Bi, or Tl values in the j th sample (Davis, 1973).

Equation (2) is derived from equation (1). This version was used initially within the program because the covariance calculation is accomplished with only one pass through the data. This equation proved to be slightly inaccurate as well as unstable. These two difficulties were overcome by implementing the West-Howell Algorithm (Chan and Lewis, 1979; Howell, 1980) which calculates the covariance by means of equation (3)

$$CV_{ik} = [(1/M) \sum_{j=1}^M X_{ij} X_{kj}] - [(1/M) \sum_{j=1}^M X_{ij} \sum_{j=1}^M X_{kj}] \quad (2)$$

$$CV_{ik} = [1/(M-1)] \sum_{j=2}^M (j-1) (A_i \cdot j) (A_k) \quad (3)$$

where the subscripts are the same as in equations (1) and (2) and the values for variable A are:

$$A_i = X_{i1}$$

and where the integer i represents the variate, K, Bi, or T1, and 1 is the first value for each. After A is initialized it then takes on the values given in equation (4):

$$A_i = \sum_{j=2}^M (1/j) [X_{ij} - (A_i - 1)] \quad (4)$$

The West-Howell Algorithm is an optimized version of the one-pass Hanson Algorithm (Hanson, 1975). Basically, the West-Howell Algorithm calculates the covariance matrix in a single pass through the data. The values of A tend to level out as the value of j approaches M which in turn forces CV to approach the respective variances and covariances of the data. This method is not as accurate as equation (1), but equation (1) requires two passes. Equation (2) requires only one pass through the data but is less accurate than is the West. The West Algorithm is a good blend of speed and accuracy (West, 1979).

The matrix CV is symmetrical and square with the respective variances on the diagonal. This satisfies the definition of a covariance matrix. (See Subroutine COVAR in Appendix A program listing.)

The next step in obtaining principal components is to calculate the eigenvalues and eigenvectors of the covariance matrix CV. Before the actual calculations of these values are discussed, the concept of eigenvalues and eigenvectors will be explored.

At this point variances and covariances of the K, Bi, and Tl data have been calculated and set into a matrix labeled CV. The elements of CV or any other $N \times N$ matrix may be thought of as defining coordinates in N -dimensional space. If the K and Bi variances and covariance are considered then these values may be expressed in two dimensional space on paper. If the K variance is plotted on the X axis, then the Bi variance may be plotted on the Y axis and the K, Bi covariance may be plotted as shown in Figure 1.

Figure 1. A Plot Illustrating a Two-Dimensional Representation of a Covariance Diagram.

Figure 1 also shows two additional lines or vectors, V_1 and V_2 . These two vectors show the structure or relationship of the K and Bi variances with respect to each other. The magnitudes of V_1 and V_2 define points in two dimensional space and may be regarded as lying on the boundary of an ellipse. To define this ellipse the principal axes must first be determined. This is accomplished by calculating the eigenvalues and eigenvectors. The eigenvectors are the direction cosines of the principal axes. The eigenvalues are the magnitudes of these axes. Figure 2 shows these axes superimposed over the covariance plot shown in Figure 1.

Figure 2. Eigenvector Plot.

Figure 2 shows the principal axes as being perpendicular or orthogonally positioned to each other. It may also be seen that one axis is of a greater magnitude than the other. Both effects are indicative of eigenvalues and eigenvectors.

The eigenvalues, λ , are defined as a set of values that when multiplied by the identity matrix, I , and subtracted from the covariance matrix CV leaves the determinant of the covariance matrix equal to zero.

Let CV^* be a new matrix which accounts for the original matrix CV and the eigenvalues, λ , and has a zero determinant. For example, in our three-parameter case of Bi , K , and Tl :

$$CV^* = CV - \lambda I$$

$$\begin{bmatrix} CV^*_{11} & CV^*_{12} & CV^*_{13} \\ CV^*_{21} & CV^*_{22} & CV^*_{23} \\ CV^*_{31} & CV^*_{32} & CV^*_{33} \end{bmatrix} = \begin{bmatrix} (CV_{11}-\lambda) & CV_{12} & CV_{13} \\ CV_{21} & (CV_{22}-\lambda) & CV_{23} \\ CV_{31} & CV_{32} & (CV_{33}-\lambda) \end{bmatrix} \quad (5)$$

Where:

λ is the unknown eigenvalue and I is the identity matrix. The identity matrix has ones on the diagonal elements and zeroes on all of the off-diagonal elements.

The next step is to calculate the determinant of the matrix CV^* . A determinant is a single number extracted from a square matrix by a series of operations of the form represented in equation (6). The determinant is represented symbolically by $\det CV^*$ or $|CV^*|$ and is defined as the sum of N terms of the form:

$$|CV^*| = \sum_{i=1}^k (-1)^k CV^*_{1i_1} \cdot CV^*_{2i_2} \dots CV^*_{ni_n} \quad (6)$$

where n is the number of rows (or columns), the subscripts $i_1, i_2, \dots, i_n$ taken in order, and k is the number of exchanges of two elements necessary to place the i th subscripts in the order of $1, 2, \dots, n$. Each term contains one and only one element from each row and each column. In the case of the matrix CV^* , the determinant may be calculated in the following way:

$$\text{TEMP1} = (-1)^k \cdot CV^*_{11} \cdot CV^*_{22} \cdot CV^*_{33} : \text{No exchanges are necessary so } k \text{ is even and the sign of TEMP1 remains unchanged.}$$

$$\text{TEMP2} = (-1)^k \cdot CV^*_{11} \cdot CV^*_{23} \cdot CV^*_{32} : \text{One exchange is necessary so } k \text{ is odd and the sign of TEMP2 is changed.}$$

$$\begin{aligned} \text{TEMP3} &= (-1)^k \cdot CV^*_{12} \cdot CV^*_{23} \cdot CV^*_{31} : \text{Two exchanges are necessary so } k \text{ is even and the sign of TEMP3 is unchanged.} \\ &= (-1)^k \cdot CV^*_{12} \cdot CV^*_{31} \cdot CV^*_{23} \\ &= (-1)^k \cdot CV^*_{31} \cdot CV^*_{12} \cdot CV^*_{23} \end{aligned}$$

where TEMP1, TEMP2, and TEMP3 are being used to demonstrate the sign changes necessary in calculating the determinant of CV^* .

There will be 3! (factorial) or 6 of these calculations for the matrix CV*. Once all the temporary values have been determined they must be summed, resulting in the determinant of CV*. But because CV* has the unknown value of λ included in the temporary variables, the determinant of CV* will take the form as shown in equation (7).

$$|CV^*| = a_1\lambda^3 + a_2\lambda^2 + a_3\lambda + a_4 \quad (7)$$

The values a_1 , a_2 , a_3 , and a_4 are known, leaving only the λ to be determined. The values of λ are equal to the roots of equation (7). This satisfies the condition that the determinant of CV* be equal to zero. Also, because equation (7) is a cubic, there may be three real solutions of λ . The roots extracted from equation (7) are:

$$\begin{aligned} (\lambda + b_1) \cdot (\lambda + b_2) \cdot (\lambda + b_3) &= 0 \\ \lambda_1 &= -b_1, \quad \lambda_2 = -b_2, \quad \lambda_3 = -b_3 \end{aligned} \quad (8)$$

The eigenvectors are the principal components of the data set and they are calculated next.

The eigenvectors are defined as a set of values that form a matrix μ such that when the matrix CV* is multiplied by μ the result is zero. In matrix form:

$$CV^* \cdot \mu = 0 \text{ or } \{CV - \lambda I\} \mu = 0 \quad (9)$$

The determination of μ must be done in columns. To calculate the first column of μ , substitute the first value of λ into equation (9). Then using a temporary vector, $\underline{T}$, equation (9) becomes:

$$\begin{bmatrix} CV_{11} - \lambda_1 & CV_{12} & CV_{13} \\ CV_{21} & CV_{22} - \lambda_1 & CV_{23} \\ CV_{31} & CV_{32} & CV_{33} - \lambda_1 \end{bmatrix} \cdot \begin{bmatrix} T_1 \\ T_2 \\ T_3 \end{bmatrix} = 0 \quad (10)$$

Multiplying equation (10) gives:

$$T_1 (CV_{11} - \lambda_1) + T_2 CV_{12} + T_3 CV_{13} = 0 \quad (11)$$

$$T_1 CV_{21} + T_2 (CV_{22} - \lambda_1) + T_3 CV_{23} = 0 \quad (12)$$

$$T_1 CV_{31} + T_2 CV_{32} + T_3 (CV_{33} - \lambda_1) = 0 \quad (13)$$

Solving for T_1 in equations (11) and (12) gives:

$$T_1 = \frac{-T_2 CV_{12} - T_3 CV_{13}}{(CV_{11} - \lambda_1)} \quad (14)$$

$$T_1 = \frac{-T_2 (CV_{22} - \lambda_1) - T_3 CV_{23}}{CV_{21}} \quad (15)$$

Because equations (14) and (15) are both equal to T_1 it follows that they are equal to each other. Using this equality and solving for T_2 gives:

$$T_2 = \frac{T_3 [CV_{13}CV_{21} - CV_{23}(CV_{11} - \lambda_1)]}{(CV_{11} - \lambda_1)(CV_{12} - \lambda_1) - CV_{12}CV_{21}} \quad (16)$$

Looking at equation (16) all values are known except T_2 and T_3 .

Substituting a constant "A" for the known values, equation (16) becomes:

$$T_2 = T_3 A \quad (17)$$

If the value "1" is assumed for T_2 then T_3 becomes:

$$T_3 = 1/A \quad (18)$$

Substituting the values of T_2 and T_3 into equation (14) gives:

$$T_1 = \frac{-CV_{22} + \lambda_1 - CV_{23}/A}{CV_{21}} \quad (19)$$

All values are known so T_1 is also known. At this point the first column of μ may be calculated by:

$$\mu_{11} = T_1 / (T_1^2 + T_2^2 + T_3^2)^{1/2} \quad (20)$$

$$\mu_{21} = T_2 / (T_1^2 + T_2^2 + T_3^2)^{1/2} \quad (21)$$

$$\mu_{31} = T_3 / (T_1^2 + T_2^2 + T_3^2)^{1/2} \quad (22)$$

The calculations of the second and third columns of μ are accomplished in the same manner with the exception that λ_2 is substituted into equation (10) when solving for the second column of μ and λ_3 is substituted into equation (10) when solving for the third column of μ .

The eigenvectors and principal components are the same and will now be referred to as PC.

At this point a new, orthonormalized data set will be generated from the original data using equation (23). The normalization permits each of the three resulting orthogonalized distributions to be compared on a uniform basis. The orthonormalization is given by:

$$Y_{ij} = \sum_{j=1}^3 PC_{jk} \cdot (X_{ji} - \bar{X}_j) / \lambda_k^{1/2} \quad (23)$$

Where: i is the i -th sample, j represents the K , Bi , or Tl data values, and k represents the principal component associated with K , Bi , and Tl respectively. This new data set represents the variation of the variate explained by each principal component. The j -th variable of the new data will be uncorrelated, orthogonally positioned, to the other variables of the data set.

The reader should understand that there are several methods in existence that calculate the eigenvalue and eigenvectors from the covariance matrix. This paper has dealt with one of the more basic methods in an effort to make clear the concepts of eigenvalue and eigenvector calculations. The PCA program, on the other hand, utilizes the Jacobi Method of eigenvalue and eigenvector extraction. This method is much more efficient from a standpoint of program size and speed of execution than would be a program designed to rigidly follow the method put forth in this paper. The Jacobi Method (Van Nostrands, 1967 and Carnahan et al., 1973) begins with the premise that eigenvectors are orthogonally positioned with respect to one another and, therefore, may be calculated using combinations of sine and cosine functions. It also assumes that the eigenvalues be considered when calculating the eigenvectors (equation 9). These assumptions enable the program to calculate the eigenvalues and eigenvectors simultaneously. This accounts for a significant savings in computer time and reduces the program size.

At the start of the program the identity matrix is initialized, the object matrix is input (the matrix upon which the eigenvalues and eigenvectors are to be calculated), and a threshold value is determined. This threshold value (determined by the degree of accuracy desired, usually 10^{-9}) is used to decide which elements in the object matrix are to be used in the next set of calculations and which are not. Should an element value be less than this threshold value it is bypassed and the next element is considered. This decision is made at the beginning of a series of iterations which, if the element value is greater than the threshold, normalize that element and calculate the sine and cosine of it with respect to another factor. This factor is created from its neighboring diagonal elements. The sine and cosine values are then used to calculate a replacement value for that element in the object matrix as well

as a new value for the parallel element in the identity matrix. Once this iterative process is complete, all the elements of both matrices have been replaced. The matrix that had initially been the identity matrix contains the eigenvectors and the matrix that originally had been the object matrix now has the eigenvalues as its diagonal elements. The program then ranks the eigenvalues in descending order and ends execution.

PRINCIPAL COMPONENTS ANALYSIS VERSUS FACTOR ANALYSIS

Principal components analysis and factor analysis are often misunderstood in that the differences between them are not fully appreciated. The following discussion leans heavily on the work of K. Campbell (written communication) and Jöreskog et al. (1976). The fundamental differences between principal components analysis and factor analysis are (1) which factors are defined, and (2) the assumptions made in regards to the residuals. (Residuals are defined as the differences between actual structure of the data and the structure predicted by the calculated factors.)

The principal components analysis determines factors that account for all the variance of all the observed variables. The factors determined in factor analysis account maximally for the intercorrelation of all the variables. Hence, it can be said principal components analysis is variance oriented whereas factor analysis is correlation oriented.

The residual terms are assumed to be small in principal components analysis, however, the converse is true in factor analysis. This implies that a large part of the total variance in a variable is important in the principal components analysis. On the other hand, factor analysis uses only that part of a

variable that correlates with the other variables. In both methods the residuals are assumed to be uncorrelated with the factors that are determined.

In the principal components analysis there are no assumptions made about the residuals with respect to themselves, whereas in factor analysis the residuals are assumed to be uncorrelated among themselves.

Finally, the goal of principal components analysis is to reproduce, or fit both the diagonal and off-diagonal elements of the covariance matrix. The goal of factor analysis is to fit the off-diagonal elements only, that is, the covariance elements and not the variance elements.

PROGRAM OPERATION

The PCA program is comprised of three sections. The first is named PCOMP and is the executive section where data file names are input, the covariance or correlation matrix is calculated, and where eigenvalues and eigenvectors are determined. The second section, HISPC, is the histogram routine that normalizes the original data (equation 23), determines the histograms to be printed and/or plotted, and creates the outlier data files. The third section called PIC3 creates the outlier maps.

Outlier data selection is one function of the histogram routine, HISPC. Selection has been accomplished in two ways: 1) by stripping out the normalized data values that are equal to or exceed a user determined sensitivity, and, 2) by sorting out normalized data values that fall in a user defined window. The window method proved to be more desirable because of its nature. The user is able to map a specific range of data. For example, if the histogram of a

data set shows it to be bimodal, the user could map only one of the modes without having to consider the data that fell above the upper bound of the mode.

Another option of the PCA program takes the square roots of the data before any other calculations are performed. This method minimized the tendency of the variances to increase in proportion to the means of the data. The principal components experienced small changes but tended to better represent inhomogeneities in ground concentrations.

AN EXAMPLE FROM AERIAL RADIOMETRIC DATA

An example of a principal components analysis is presented using the three radiometric observations (Bi, Tl, and K) obtained from 20,051 data points. The data for this example were collected over a portion of the Texas Coastal Plain by Geodata International, Inc. in 1974 (Geodata International, Inc., 1975). In the Geodata report the area under investigation is referred to as Detail Area C. Figure 3 illustrates the flow of processing data with the principal components program presented in this user's guide.

The first analytical decision facing the user is whether to use the covariance matrix or correlation matrix. As a general rule, a covariance matrix should be used when all variables are expressed in the same physical unit, for example, concentrations in parts per million (ppm). However, when the input variables are of different units, e.g., ppm and percentage, then the analyst is advised to use the correlation matrix. This choice of calculation techniques is required whether or not aerial radiometric data is under consideration. In the present example all of the variables are expressed in terms of counts per second; thus, the covariance matrix is utilized.

Figure 3. Processing Flow Chart for Principal Components Analysis Program.

Figure 3. (con't.)

Figure 3. (con't.)

The user next decides whether or not to take the square root of each individual observation. If the variance of observations of an element has a tendency to increase in proportion to the mean, a phenomenon characteristic of true count data, the square root of each observation should be taken to reduce the artificial trend. Since aerial radiometric data, even after considerable reduction, exhibit this characteristic of count rate data, the square root of each observation was taken prior to the principal components analysis.

The remaining options depend on the end product desired by the user. One can analyze all available data, or in the case of the aerial data, only that data on certain flight lines. All geologies can be analyzed together or an individual geology may be analyzed. In this example all available data points were analyzed without considering individual formations.

There are four output sections to each analysis. The output sections for this example are listed at the end of this section. Output 1 (Figure 5) lists pertinent statistics needed by the geologist performing the analysis. The mean vector, with the values in the order of parameter input, is listed. The covariance matrix appears next. The diagonal of this matrix equals the variance of the parameter. Examination of Output 1 reveals that the variance does not increase in proportion to the mean; thus, the square root transformation has aided in correcting the count rate statistics problem.

The eigenvalues are used to determine the amount of variation explained by each principal component. The percent of variation explained is obtained by dividing each eigenvalue by the sum of the eigenvalues.

Next are the principal components. The columnar loadings are in the same order as the parameters were input. These loadings are used to help the geologist interpret the structure of the data and are used in creating the histograms in Output 2 (Figure 6) and Output 3 (Figure 7). They are also instrumental in creating the displays of Output 4 (Figure 8).

Finally the correlations between the principal components and the original variables are listed.

With the given information the geologist may begin to interpret the data structure. There may be times when only the structure of a data set may be obtained. If geologic significance cannot be assigned to the analysis, the interpreter may always take the results obtained and compare them to results from similar analyses. Geometrics, Inc. uses this approach in their principal components analysis of aerial data. (For an example see Geometrics, Inc., 1978.) In their approach they perform a principal components analysis on a favorable formation for uranium resources in a quadrangle and then do the same for other formations and look for results that are similar to the results obtained from favorable formation analysis.

The histograms provided in Output 2 allow the interpreter to see the frequency of observations represented in class intervals of Output 3. Output 2 and Output 3 are generated for each of the components, and as a program option either output can be displayed without the other. The histograms aid in revealing a data structure that may have geologic significance. For example, a bimodal histogram as seen in Figure 6 for principal component 1 may be indicating the mixing of geologies when an analysis is performed without regard to separating formations or it may reflect facies of mineralogical differences

when a single formation is being analyzed. A bimodal second principal component histogram may be representing various degrees of radioelement mobility while the third principal component histogram may be depicting non-mobilized radioelement distributions (Pirkle et al., 1980; Pirkle in preparation). Depending on the loadings of elements on the principal components other interpretations may be considered for the histograms.

Output 4 (Figure 7) allows a spatial viewing of points comprising portions of the histograms that are of interest to the interpreter. All points greater than or less than some critical value (sensitivity parameters) may be plotted to give an outlier map (Figure 7), or all points between two values may be plotted to help determine if a significant spatial clustering is observed. If significant clusterings occur then the investigator has a clue as to where additional data may be needed and the type of data needed to verify an interpretation.

The following will illustrate how one may use Output 3 (Figure 6) and Output 4 (Figure 7). Looking at the histogram PC-1 in Figure 6 an investigator may be interested in the interval 2-3. There appears to be a slight increase in the number of observations found in this interval. A plot of the geographic position of the points in this region (Figure 7, Principal Component 1) reveals two distinct groupings of data. If a generalized geologic map (Figure 8) is overlain, it appears that these points occur in the alluvium and part of the undivided Jackson. Thus, it seems geology has influenced this histogram. Pirkle (in preparation) provides more details as to how the geologist may develop an interpretation of aerial radiometric data from a principal components analysis.

```

MEAN VECTOR
      7.238      8.202      5.848

COVARIANCE MATRIX
      4.019      1.916      1.075
      1.916      2.415      0.995
      1.075      0.995      1.045

EIGENVALUES
      5.740      1.220      0.519

PRINCIPAL COMPONENTS
      FIRST      SECOND      THIRD
      0.78709    -0.61553    -0.04001
      0.54173      0.72082    -0.43238
      0.29499      0.31865      0.90080

CORRELATION WITH ORIGINAL ELEMENTS
      0.94065    -0.33906    -0.01438
      0.83514      0.51220    -0.20050
      0.69145      0.34427      0.63512

```

Figure 4. Output 1. Statistics Derived from a Principal Components Analysis.*

*Order of variable output is the same as the order of the variable input. In this analysis the order is K, Bi, Ti.

```

HISTOGRAM FOR COMPONENT 1
CELL WIDTH = 0.100
J START      H(J),...H(J+9)
NUMBER OF CELLS 101
THE TOTAL NUMBER OF POINTS 20051
1 -5.00      0.      0.      0.      0.      0.      0.      0.      0.      0.
11 -4.00      0.      0.      0.      0.      0.      1.      2.      1.      0.
21 -3.00      1.      0.      1.      1.      0.      8.      15.      9.      30.
31 -2.00      46.      92.      146.      175.      256.      395.      507.      611.      682.
41 -1.00      728.      615.      674.      609.      537.      559.      540.      623.      583.
51 0.00      743.      821.      826.      810.      846.      785.      769.      649.      546.
61 1.00      407.      379.      321.      276.      174.      187.      166.      125.      95.
71 2.00      82.      61.      55.      39.      47.      46.      48.      50.      57.
81 3.00      45.      23.      17.      14.      3.      5.      0.      0.      0.
91 4.00      0.      0.      0.      0.      0.      0.      0.      0.      0.
101 5.00      0.

```

```

HISTOGRAM FOR COMPONENT 2
CELL WIDTH = 0.100
J START      H(J),...H(J+9)
NUMBER OF CELLS 101
THE TOTAL NUMBER OF POINTS 20051
1 -5.00      0.      0.      3.      0.      3.      0.      1.      3.      1.
11 -4.00      1.      0.      0.      1.      0.      2.      3.      2.      7.
21 -3.00      6.      11.      14.      36.      35.      55.      62.      67.      96.
31 -2.00      142.      186.      163.      197.      214.      272.      356.      362.      410.
41 -1.00      469.      521.      559.      634.      643.      658.      731.      749.      801.
51 0.00      776.      826.      824.      764.      781.      774.      740.      649.      591.
61 1.00      460.      400.      326.      313.      248.      219.      183.      177.      131.
71 2.00      111.      73.      50.      50.      39.      34.      20.      11.      11.
81 3.00      6.      4.      3.      2.      2.      0.      1.      0.      0.
91 4.00      0.      0.      0.      0.      0.      0.      0.      0.      0.
101 5.00      0.

```

```

HISTOGRAM FOR COMPONENT 3
CELL WIDTH = 0.100
J START      H(J),...H(J+9)
NUMBER OF CELLS 101
THE TOTAL NUMBER OF POINTS 20051
1 -5.00      0.      0.      0.      0.      0.      0.      0.      0.      2.
11 -4.00      1.      5.      2.      3.      1.      4.      4.      5.      9.
21 -3.00      12.      7.      17.      10.      27.      31.      45.      47.      71.
31 -2.00      89.      122.      141.      194.      236.      287.      309.      360.      452.
41 -1.00      553.      592.      645.      692.      705.      747.      804.      800.      814.
51 0.00      878.      817.      785.      739.      722.      669.      609.      566.      496.
61 1.00      403.      413.      298.      202.      264.      183.      191.      144.      145.
71 2.00      100.      84.      68.      71.      50.      38.      35.      33.      28.
81 3.00      15.      15.      5.      8.      5.      1.      2.      0.      1.
91 4.00      0.      0.      0.      2.      5.      2.      0.      0.      1.
101 5.00      0.

```

Figure 5. Output 2. Frequency Distribution for the Principal Components.

Figure 6a. Output 3. Histograms of the Principal Component 1.*

*Horizontal axis is standard deviation. Vertical axis is frequency.

Figure 6b. Output 3. Histograms of the Principal Component 2.*

*Horizontal axis is standard deviation. Vertical axis is frequency.

Figure 6c. Output 4. Histograms of the Principal Component 3.*

***Horizontal axis is standard deviation. Vertical axis is frequency.**

TEXAS GULF COAST DATA
 PRINC COMP 1 SENSITIVITY 2.00 - 3.00 NUM PNTS PLOTTED 554

Figure 7. Output 4. Plot of Points of Interest to Interpreter for All Three Components.*

*These plots show points that fall between 2.00-3.00 standard deviations. Figures 7a, 7b, and 7c show the region begin plotted.

(A geology overlay of Figure 8 may be found in the jacket at the end of this report.)

TEXAS GULF COAST DATA
PRINC COMP 2 SENSITIVITY 2.00 - 3.00 NUM PNTS PLOTTED 413

Figure 7. (con't.)

TEXAS GULF COAST DATA
PRINC COMP 3 SENSITIVITY 2.00 - 3.00 NUM PNTS PLOTTED 528

Figure 7. (con't.)

EXPLANATION

1. Alluvium
2. Fluvatile terrace deposits
(higher gravels)
3. Beaumont and Lissie Fms
4. Willis Fm
5. Fleming Fm
6. Oakville Fm
7. Catahoula Fm
8. Jackson Group (undivided)
9. Yegua Fm

Figure 8. Generalized Geology of Detail Area C.*

*A clear film of this figure that may be overlain onto Figure 7 may be found in the jacket at the end of this report.

APPENDIX A

Program Listing

APPENDIX A

Program Listing

<u>Program Name</u>	<u>Function</u>
NEWPC	Receives input and output data file names Calculates data means, variances, and covariances Prints output of calculated values Calls other subroutines
INST	Prints program execution instructions
HEAD	Receives outlier map information
READIT	Inputs data from input data file
EIGEN	Calculates eigenvalues and eigenvectors
HISPC1	Calculates histogram printouts and bar graphs utilizing AG II (Advanced Graphics 2) plot functions
PIC3	Plots outlier data location on a Mercator projection Outputs map title information
BASG	Determines map dimensions in latitude and longitude Initializes Mercator projection subroutine
MRCMAP	Plots outside border Calls NMERC, NMERCP, NMERCC, and ANOTE, all utilizing Plot 10 functions
NMERC	Receives initialization information for Mercator pro- jection Selects calculation constants for Mercator projection
NMERCP	Initializes the north-south and east-west physical scale factors
NMERCC	Receives latitude and longitude information and returns X-Y information (Mercator projection subroutine)
TAN	A function which returns the tangent of an argument in radians
SGNF	A function which returns a plus, minus, or zero deter- mined for a cotangent calculation in the Mercator projection subroutine
ANOTE	Plots annotation of map border

COVAR

West Algorithm for covariance
calculation

Program NEWPC

Array

Contents

CORR

Correlation with original data

NSAVE

Number of outliers for PC1-PC3

TSXY

Weighted mean values

CVARA

Working array for the subroutine
EIGEN containing covariance initially
and eigenvalues finally

S

Standard deviations for the three
variates

ITITL

Passes to the subroutine HEAD and
returns with the title printed across
the top of each outlier map

IFMT

The input data format

IFILE

Device numbers for the outlier map
data

Labeled Common

BLK1 XBAR

Variate mean values

CVAR

Variate covariance values

XLAM

Eigenvalues

PC

Eigenvectors or principal components

BLK2 XLONG

Data longitude values

XLAT

Data latitude values

X

Data Values

CRPA ICRT

Plot 10 internal flag for outputting
to a tektronix terminal

IPAPER

Plot 10 internal flag for outputting
to a Calcomp plotter

Subroutine Eigen

Array

A

Contents

Initially covariance values and eigenvalues at completion

B

Initially zeroes and eigenvectors or principal components at completion

Subroutine HISPC1

Array

TH1

Contents

The histogram for PC1

TH2

The histogram for PC2

TH3

The histogram for PC3

Z

The base or X axis values for TH1, TH2, and TH3 or Y axis values

ITL1 }
ITL2 }
ITL3 }

Contains the ADE characters for the PC1, PC2, and PC3 titles at the top of each histogram

All other arrays were previously described.

Subroutine PIC3

Array

MTIT

Contents

Title printed across each outlier map

ITIT

Heading containing encoded information as to which PC was mapped, the sensitivity used, and the number of normalized data points exceeding the sensitivity

Labeled Common

MPORG XO

X value in inches of the longitude from the central meridian

YO

Y value in inches of the latitude from the central meridian

XORG

X value in inches of the origin (lower left corner of map)

YORG

Y value in inches of the origin (lower left corner of map)

Subroutine BASG

Array

XEW

YEW

XNS

YNS

Contents

X measurements in inches of the actual east-west map dimension

Y measurements in inches of the actual east-west map dimension (usually zero)

X measurements in inches of the actual north-south map dimension (usually zero)

Y measurements in inches of the actual north-south map dimension

Labeled Common

DATA CMERID

CLAT

CLON

SPA

SCAL

PSCEW

PSCNS

DEGEW

DEGNS

TICSZ

Central meridian longitude in decimal degrees

Latitude of the southwest corner of the map

Longitude of the southwest corner of the map

Spheroid constants selection flag

Map scale inch/inches

Physical scale factor for the theoretical east-west distance produced by the mapping equation (actual distance/theoretical distance)

Physical scale factor for the theoretical north-south distance produced by the mapping equation (actual distance/theoretical distance)

Map size east-west in decimal degrees

Map size north-south in decimal degrees

North-south annotation interval in decimal degrees

TICWZ	East-west annotation interval in decimal degrees
MTITL	The second map title
MAP	Not used
JDMA	Not used
JDELS	Not used
JOVO	Not used
DOEV	Not used

Subroutine MRCMAP

All labeled common blocks have previously been described.

Subroutine NMERC

Array

TANPHI

COTPHI

A and B

AZ

BZ

Contents

Stores intermediate values for each point plotted

Reciprocal of TANPHI

Stores intermediate values used in the calculations of TANPHI

Stores the first of two UTM constants

Stores the second UTM constant

Subroutine READIT

All arrays have been previously described.

Subroutine HEAD

Array

JTITL

ITITL

Contents

Used in subroutine BASG under the name of MTITL

Described previously

Subroutine INST

Array

IT

Subroutine COVAR

Array

X

CVAR

AM and AM1

Contents

Receives documentation file instructions

Contents

Described previously

Described previously

Stores intermediate values for covariance calculations

```

PROGRAM PCOMP
C*****
C
C PROGRAM PCOMP
C
C MODEL NUMBER: 3.0
C
C
C PURPOSE: TO CALCULATE THE PRINCIPAL COMPONENTS OR EIGENVALUES
C          AND EIGENVECTORS FROM A MULTIVARIATE DATA SET
C
C PROGRAMMER: CHUCK KOCH
C
C*****
C          REVISION LIST
C  REV  DATE      SRO # BY REASON FOR CHANGE
C  ---  ---      ---  -
C  01   3/1/79    0000  CK TO INCLUDE HISTOGRAMS AND OUTLIER MAPS
C  02   5/1/79    0000  CK TO USE PLOT10 AND AGII INSTEAD OF DISTEK
C  03   7/1/79    0000  CK DELETED THE SUBROUTINES:
C                               SMHTR
C                               SMEVEU
C                               PRODHH
C                               DOTPRO
C                               AND REPLACED THEM WITH THE SUBROUTINE
C                               EIGEN TO INCREASE THE SPEED AND EFFICIENCY
C                               OF THE PCA PROGRAM
C*****
C
C          DIMENSION CORR(3,3),NSAVE(3),CVARA(3,3),SENSE(2)
C          DIMENSION S(3),ITITL(10),IFMT(16)
C          DIMENSION XLONG(1000),XLAT(1000),X(3,1000),IFILE(3)
C          COMMON /BLK1/XBAR(3),CVAR(3,3),XLAM(3),PC(3,3)
C          COMMON /CRPA/ICRT,IPAPER
C
C          INITIALIZE IFILE TO DEVICE NUMBERS 23,24 AND 25 WHICH
C          WILL CONTAIN THE OUTLIER MAP INFORMATION.
C
C          DATA IFILE/23,24,25/
C
C          INITIALIZE IFILE1 TO DEVICE 20 WHICH CONTAINS THE
C          DATA TO BEUSED FOR THE CALCULATIONS.
C
C          DATA IFILE1/20/
C
C          INITIALIZE IFILE2 TO DEVICE 21 WHICH WILL CONTAIN
C          THE CALCULATED VALUES. (XBAR,CVAR,ETC)
C
C          DATA IFILE2/21/
C
C          INITIALIZE IFILE3 TO DEVICE 22 WHICH WILL CONTAIN
C          THE HEADER INFORMATION FOR THE HISTOGRAMS AND OUTLIER MAPS.
C
C          DATA IFILE3/22/
C
C          INITIALIZE ICRT TO 1 AND IPAPER TO 0 WHICH TELLS PLOT10
C          THAT IT WILL ADDRESS A TEKTRONIX TERMINAL INSTEAD OF A
C          CALCOMP PLOTTER.
C
C          DATA ICRT/1/
C          DATA IPAPER/0/
C
C          INITIALIZE ITE TO 5 WHICH IS THE DEVICE NUMBER OF THE
C          TERMINAL.
C
C          ITE = 5

```

```

C
C      INITIALIZE THE GRAPHICS LIBRARY PLOT-10
C
      CALL INITT(120)
      WRITE(ITE,981)
      READ(ITE,982) IANS
      IF (IANS.EQ.'NO') GOTO 983
C
C      THE SUBROUTINE INST PRINTS TO THE TERMINAL
C      A DOCUMENTAION FILE STATING THE NECESSARY INPUTS
C      TO SUCCESSFULLY RUN THIS PROGRAM.
C
      CALL INST
      CALL ERASE
983    CONTINUE
      KOUNT = 0
      NPTS=0
      DO 5 K=1,3
      XBAR(K)=0.
      DO 5 J=1,3
5      CVAR(J,K)=0.
      WRITE(ITE,1001)
      OPEN(UNIT=IFILE1,DIALOG)
      WRITE(ITE,1002)
      OPEN(UNIT=IFILE2,DIALOG)
      WRITE(ITE,1013)
      READ(ITE,982) IFLG
      WRITE(ITE,2011)
      READ(ITE,2012) IFMT
      DO 1112 JT=1,3
      WRITE(ITE,1020) JT
      OPEN(UNIT=IFILE(JT),DIALOG)
1112    CONTINUE
      CALL ERASE
C
C      THE HEAD SUBROUTINE ENABLES THE INPUTS OF
C      ALL THE INFORMATION NEEDED TO GENERATE THE
C      HISTOGRAMS AND OUTLIER MAPS.
C
      CALL HEAD(IFILE3,NCELLS,HMIN,HMAX,KPLOT,ITITL)
C
C      INPUT THE SENSE VALUE. THIS VALUE IS USED IN THE HISPC
C      SUBROUTINE AS THE DECIDING FACTOR AS TO WHICH DATA
C      POINTS ARE TO BE USED IN THE OUTLIER MAPS.
C
1118    CONTINUE
      WRITE(ITE,1113)
      READ(ITE,1114) SENSE(1)
      WRITE(ITE,1115)
      READ(ITE,1114) SENSE(2)
C
C      CHECK TO MAKE SURE THAT THE MAX SENSE IS
C      GREATER THAN THE MIN SENSE
C
      IF(SENSE(1).LT.SENSE(2)) GOTO 1117
      WRITE(ITE,1116)
      GOTO 1118
1117    CONTINUE
C
C      READ THE FLAG TO CALCULATE COVARIANCE OR CORRELATION
C
118    CONTINUE
      WRITE(ITE,2006)
      READ(ITE,2007) ICORR
      IF((ICORR.EQ.5HCORRE).OR.(ICORR.EQ.5HCOVAR)) GOTO 117
      WRITE(ITE,2008)
      GOTO 118
117    CONTINUE
C
C      READ LINE NUMBER,LAT,LON,GEO,K,U AND TH DATA
C
10    CALL READIT(XLAT,XLONG,X,NPTS,IFILE1,IFMT)

```

```

C
C IF PRINCIPAL COMPONENTS HAVE ALREADY BEEN CALCULATED
C DO NOT REREAD NOR RECALCULATE THEM. HOWEVER ONE
C CALL TO READIT MUST BE MADE IN ORDER TO SET THE
C OPTIONS.
C
C IF(IFLG.NE.2HNO) GOTO 1021
C IF(NPTS.EQ.0)GOTO 100
C
C COUNT THE TOTAL NUMBER OF POINTS READ AND STORE
C IN KOUNT.
C
C KOUNT=KOUNT+NPTS
C
C SUM THE K,U AND T DATA AND STORE IN XBAR.
C CALCULATE THE COVARIANCES OF THE K,U AND T DATA
C AND STORE IN THE MATRIX CUAR. ALSO LOAD THE WORKING
C ARRAY CUARA FROM CUAR.
C
C DO 50 I=1,NPTS
C DO 40 K=1,3
C XBAR(K)=XBAR(K)+X(K,I)
40 CONTINUE
50 CONTINUE
C CALL COVAR(X,NPTS,CUAR)
C GO TO 10
100 XN=FLOAT(KOUNT)
C
C XBAR CONTAINS CALCULATED DATA MEANS
C
C DO 120 K=1,3
C XBAR(K)=XBAR(K)/XN
C DO 115 J=K,3
C CUAR(K,J)=CUAR(K,J)/(XN-1.)
115 CUAR(J,K)=CUAR(K,J)
120 S(K)=SQRT(CUAR(K,K))
C
C IF COVARIANCE MATRIX IS TO BE USED GO TO 116
C
C IF(ICORR.EQ.5HCOVAR) GOTO 116
C DO 211 I=1,3
C DO 211 J=I,3
C CUAR(I,J)=CUAR(I,J)/(S(I)*S(J))
211 CUAR(J,I)=CUAR(I,J)
116 CONTINUE
C DO 110 I=1,3
C DO 110 J=1,3
110 CUARA(I,J)=CUAR(I,J)
C
C STORE THE K,U AND T STANDARD DEVIATIONS IN THE VECTOR S
C
C M = 3
C
C INITIALIZE M TO 3
C CALL EIGEN SUBROUTINE TO EXTRACT THE
C EIGENVALUES AND EIGENVECTORS FROM THE WORKING
C ARRAY CUARA. CUARA AND PC ARE 3X3 MATRICES
C SO PASS M,M TO EIGEN.
C
C CALL EIGEN(CUARA,PC,M,M)
C
C LOAD THE VECTOR XLAM FROM THE DIAGONALS OF CUARA
C WHICH CONTAINS THE EIGENVALUES.
C
C DO 1331 L=1,3
C PRINT *,CUARA(L,L)
1331 XLAM(L)=CUARA(L,L)
C
C WRITE THE MEAN VECTOR, COVARIANCE ARRAY, EIGENVALUE
C VECTOR, PRINCIPAL COMPONENT ARRAY AND K,U AND
C T STANDARD DEVIATIONS TO A FILE THROUGH UNIT IFILE2.
C

```

```

        WRITE(IFILE2,1000) XBAR
        WRITE(IFILE2,1000) CUAR
        WRITE(IFILE2,1000) XLAM
        WRITE(IFILE2,1000) PC
        WRITE(IFILE2,1000) S
        GOTO 1031
C
C   IF THE PRINCIPAL COMPONENTS ETC. WERE PREVIOUSLY
C   CALCULATED THEN READ THEM FROM A FILE THROUGH UNIT
C   IFILE2.
C
1021   CALL ERASE
        READ(IFILE2,1000) XBAR
        READ(IFILE2,1000) CUAR
        READ(IFILE2,1000) XLAM
        READ(IFILE2,1000) PC
        READ(IFILE2,1000) S
1031   CONTINUE
C
C   PRINT OUT TO THE TERMINAL ALL CALCULATED VALUES
C   AND MAKE A HARD COPY OF THEM.
C
        WRITE(ITE,2000) XBAR
        IF(ICORR.EQ.5HCORRE) GOTO 1090
        WRITE(ITE,2001) CUAR
        GOTO 1091
1090   WRITE(ITE,2009) CUAR
1091   CONTINUE
        WRITE(ITE,2002) XLAM
        WRITE(ITE,2003)((PC(J,K),K=1,3),J=1,3)
C
C   COMPUTE CORRELATION OF EACH PRINCIPAL COMPONENT
C   WITH EACH ORIGINAL VARIATE.
C
        DO 160 K=1,3
        DO 160 J=1,3
160    CORR(J,K)=PC(J,K)*SQRT(XLAM(K))/S(J)
        WRITE(ITE,2004)((CORR(J,K),K=1,3),J=1,3)
        CALL HDCOPY
C
C   HISPC IS THE SUBROUTINE WHICH GENERATES THE
C   HISTOGRAMS OF PC1,PC2 AND PC3 AND IS RESPONSIBLE FOR
C   CREATING THE 3 FILES WHICH CONTAIN THE OUTLIER
C   MAP INFORMATION.
C
        CALL HISPC(NCELLS,IFILE1,SENSE,NSAVE,IFMT
1,HMIN,HMAX,KPLOT,IFILE)
        DO 1111 KAT=1,3
        IPRINC=KAT
        JFILE=IFILE(KAT)
        MSAVE=NSAVE(KAT)
C
C   PIC3 IS THE SUBROUTINE WHICH CREATES THE OUTLIER MAPS
C   BY USING A MERCADOR PROJECTION CALCULATION.
C
        CALL PIC3(JFILE,IFILE3,IPRINC,SENSE,MSAVE,ITITL)
1111   CONTINUE
        CLOSE(UNIT=IFILE1)
        CLOSE(UNIT=IFILE2)
        CLOSE(UNIT=IFILE3)
        CLOSE(UNIT=IFILE(1))
        CLOSE(UNIT=IFILE(2))
        CLOSE(UNIT=IFILE(3))
981    FORMAT(42H DOES THE USER REQUIRE INSTRUCTIONS TO RUN
1 28H THIS PROGRAM (YES OR NO) ? ,%)
982    FORMAT(A2)
1000   FORMAT(3E15.8)
1001   FORMAT(34H INPUT DATA FILE TO BE READ FROM ?)
1002   FORMAT(34H INPUT DATA FILE TO HOLD PRINCIPAL
1 14H COMPONENTS ? )
1013   FORMAT(40H HAVE PC S BEEN CALCULATED FOR THIS DATA
1 23H SET BEFORE (YES,NO) ? ,%)

```

```

1020  FORMAT(24H INPUT DATA FILE FOR PC ,I2,
1 28H OUTLIERS USED IN THE MAP ? )
1113  FORMAT(34H INPUT THE LOWER LIMIT SENSITIVITY,/,
1 24H FOR THE OUTLIER MAPS ? ,S)
1114  FORMAT(F4.2)
1115  FORMAT(34H INPUT THE UPPER LIMIT SENSITIVITY,/,
1 24H FOR THE OUTLIER MAPS ? ,S)
1116  FORMAT(37H THE MAX SENSITIVITY IS LESS THAN THE
1 41H MINIMUM SENSITIVITY RELOAD THESE VALUES )
2000  FORMAT(/12H MEAN VECTOR//3F12.3)
2001  FORMAT(/18H COVARIANCE MATRIX//3F12.3))
2002  FORMAT(/12H EIGENVALUES//3F12.3)
2003  FORMAT(/21H PRINCIPAL COMPONENTS//7X,5HFIRST,6X,6HSECOND,
1 7X,5HTHIRD/(3F12.5))
2004  FORMAT(/35H CORRELATION WITH ORIGINAL ELEMENTS//3F12.5))
2006  FORMAT(36H DOES THE USER WISH TO CALCULATE THE ,/,
1 53H CORRELATION OR COVARIANCE MATRIX (CORRE OR COVAR) ? ,S)
2007  FORMAT(A5)
2008  FORMAT(16H INCORRECT INPUT )
2009  FORMAT(/19H CORRELATION MATRIX//3F12.3))
2011  FORMAT(43H INPUT THE FORMAT OF THE DATA (80 CHARS) ? )
2012  FORMAT(16A5)
      STOP
      END

```

SUBROUTINE INST

```

C
C THIS SUBROUTINE PRINTS THE DOCUMENTAION
C FILE CALLED PCOMP.DOC DURING PROGRAM EXECUTION
C TO PRECLUDE HAVING TO STOP EXECUTION TO READ THE
C DOCUMENTATION. IT ALSO MAKES A HARD COPY AS IT PRINTS.
C

```

```

      DIMENSION IT(16)

```

```

C
C SET DEVICE 10 TO FILENAME PCOMP.DOC
C

```

```

      OPEN (UNIT=10,FILE='PCOMP.DOC')
      CALL ERASE
      DO 1 I=1,60
      READ(10,2,END=3) IT
1      WRITE(5,2) IT
      CALL HDCOPY
      CALL ERASE
      GOTO 4
3      CALL HDCOPY
      CLOSE(UNIT=10)
2      FORMAT(1X,16A5)
      RETURN
      END

```

```

      SUBROUTINE READIT (XLAT,XLONG,X,NPTS,IFILE1,IFMT)
      DIMENSION XLAT(1000),XLONG(1000),X(3,1000),IFMT(16)
      DATA IFLAG/0/,ITE/5/

```

```

C
C THIS ROUTINE READS DATA FROM THE FILE ASSIGNED TO UNIT
C IFILE1. IFMT IS THE FORMAT OF THE DATA TO BE READ.
C THE DATA MUST BE ORDERED AS FOLLOWS:

```

```

C 1) FLIGHT LINE NUMBER - LINE
C 2) LATITUDE - XLATT
C 3) LONGITUDE - XLONGG
C 4) GEOLOGY - NGE0
C 5) DATA VALUE 1 - X1
C 6) DATA VALUE 2 - X2
C 7) DATA VALUE 3 - X3
C

```

```

C THIS ROUTINE ALSO HAS PROVISIONS TO SORT THE DATA ON A
C FLIGHT LINE AND/OR GEOLOGIC LABEL BASIS AND MAY OR MAY NOT
C TAKE THE SQUARE ROOTS OF THE DATA. ANY COMBINATION OF THESE
C PROVISIONS MAY BE USED.
C

```

```

C INITIALIZE THE POINT COUNTER

```



```

C      NPTS=0
C
C      IFLAG ALLOWS ONLY ONE READING OF OPTIONS
C
C      IF(IFLAG.NE.0) GOTO 10
C      WRITE(ITE,100)
C
C      READ THE FLAG FOR FLIGHT LINE SORT
C
C      READ(ITE,1000) IFL
C      IF(IFL.NE.2HYE) GOTO 200
C      WRITE(ITE,101)
C
C      READ THE BEGINING FLIGHT LINE NUMBER
C
C      READ(ITE,1001) IFL1
C      WRITE(ITE,102)
C
C      READ THE ENDING FLIGHT LINE NUMBER
C
C      READ(ITE,1001) IFL2
C      WRITE(ITE,103)
200
C
C      READ THE FLAG FOR GEOLOGICAL SORT
C
C      READ(ITE,1000) IGL
C      IF(IGL.NE.2HYE) GOTO 300
C      WRITE(ITE,104)
C
C      READ THE DESIRED GEOLOGIC CODE
C
C      READ(ITE,1002) IGSRT
C      WRITE(ITE,105)
300
C
C      READ THE FLAG TO TAKE SQUARE ROOTS
C
C      READ(ITE,1000) ISQR
C      IFLAG=1
C      CALL ERASE
C      CONTINUE
10
C
C      READ INPUT FILE AND TEST FOR END OF FILE.
C
C      READ(IFILE1,IFMT,END=965) LINE,XLATT,XLONGG,NGEO,X1,X2,X3
C      IF(IFL.NE.2HYE) GOTO 400
C
C      ASSIGN INPUT FILE DATA TO APPROPRIATE MATRICES
C      RETURN DATA TO CALLING ROUTINE WHEN MARICES ARE FULL
C
C      IF(LINE.LT.IFL1) GOTO 10
C      IF(LINE.GT.IFL2) GOTO 965
400
C      IF(IGL.NE.2HYE) GOTO 410
C      IF(NGEO.NE.IGSRT) GOTO 10
410
C      IF(ISQR.NE.2HYE) GOTO 420
C
C      CHECK TO SEE IF X1,X2 OR X3 ARE NEGATIVE. IF SO ZERO
C      IT BEFORE TAKING THE SQUARE ROOT
C
C      IF(X1.LT..0) X1=0.
C      IF(X2.LT..0) X2=0.
C      IF(X3.LT..0) X3=0.
C      X1=SQRT(X1)
C      X2=SQRT(X2)
C      X3=SQRT(X3)
420
C      CONTINUE
C      NPTS=NPTS+1
C      XLAT(NPTS)=XLATT
C      XLONG(NPTS)=XLONGG
C      X(1,NPTS)=X1
C      X(2,NPTS)=X2
C      X(3,NPTS)=X3

```

```

C
C   LIMIT THE NUMBER OF DATA POINTS READ AT ONE TIME TO 1000
C
      IF(NPTS.EQ.1000) GO TO 965
      GO TO 10
C
965   CONTINUE
100   FORMAT(36H DOES THE USER WISH TO SORT THE DATA,/,
1     1 38H ON A FLIGHT LINE BASIS (YES OR NO) ? ,%)
101   FORMAT(37H INPUT BEGINING FLIGHT LINE NUMBER ? ,%)
102   FORMAT(35H INPUT ENDING FLIGHT LINE NUMBER ? ,%)
103   FORMAT(43H DOES THE USER WISH TO SORT ON A GEOLOGICAL
1     1 21H BASIS (YES OR NO) ? ,%)
104   FORMAT(32H INPUT THE GEOLOGY TO BE USED ? ,%)
105   FORMAT(39H DOES THE USER WISH TO WISH TO TAKE THE
1     1 28H SQUARE ROOTS OF THE DATA ? ,%)
1000  FORMAT(A2)
1001  FORMAT(I5)
1002  FORMAT(A5)
      RETURN
      END

      SUBROUTINE EIGEN(A,B,N,N1)
C
C   THIS ROUTINE CALCULATES THE EIGENVALUES AND
C   EIGENVECTORS OF THE OBJECT MATRIX 'A' WHICH
C   IS AN N X N1 SYMMETRIC MATRIX.
C
C   UPON COMPLETION THE EIGENVALUES ARE STORED IN THE
C   DIAGONAL ELEMENTS OF A AND THE EIGENVECTORS ARE
C   STORED IN THE MATRIX B BY COLUMNS.
C
      DIMENSION A(N1,N1),B(N1,N1)
      TS=1.E-09
      AN=0.
C
C   CALCULATE THE INITIAL AND FINAL NORMS
C   AND SET MATRIX B TO THE IDENTITY MATRIX.
C
      DO 10 I=1,N
      DO 10 J=1,N
      IF(I-J) 2,1,2
1     B(I,J)=1.
      GOTO 10
2     B(I,J)=0.
      AN=AN+A(I,J)**2
10    CONTINUE
C
C   INITIALIZE THE INDICATORS AND COMPUTE THE THRESHOLD.
C
      AN=SQRT(AN)
C
C   CALCULATE THE THRESHOLD VALUE
C
      FN=(AN*TS)/FLOAT(N)
      THR=AN
23    THR=THR/FLOAT(N)
3     IND=0
C
C   BEGIN THE ITERATIVE PROCESS TO FIND THE EIGENVALUES
C   AND EIGENVECTORS
C
      DO 20 I=2,N
      I1=I-1
      DO 30 J=1,I1
C
C   IF THE DATA VALUE IS GREATER THAN THE THRESHOLD
C   VALUE THEN DO THE CALCULATIONS IF NOT CHECK THE
C   NEXT VALUE
C
      IF(ABS(A(J,I1))-THR) 30,4,4

```

```

C
C COMPUTE THE SINES AND THE COSINES AND SQUARES
C EACH WHICH WILL SET THE OFF-DIAGONALS AT
C 90 DEGREES TO EACH OTHER.
C
C IND=1
C
C NORMALIZE THE DATA VALUE
C
C AL=A(J,I)
C AM=(A(J,J)-A(I,I))/2.
C AO=AL/SQRT(AL**2+AM**2)
C IF(AM) 5,6,6
C AO=-AO
C TM=SQRT(1.-AO**2)
C
C CALCULATE THE SINE AND ITS SQUARE
C
C SINX=AO/SQRT(2.*(1.+TM))
C SINX2=SINX**2
C
C CALCULATE THE COSINE AND ITS SQUARE
C
C COSX=SQRT(1.-SINX2)
C COSX2=COSX**2
C
C ROTATE COLUMNS I AND J
C
C DO 40 K=1,N
C IF(K-J) 7,8,7
C IF(K-I) 11,8,11
C ATT=A(K,J)
C
C CALCULATE NEW DATA VALUES IN THE OBJECT MATRIX USING THE
C SINES AND COSINES COMPUTED BEFORE
C
C A(K,J)=ATT*COSX-A(K,I)*SINX
C A(K,I)=ATT*SINX+A(K,I)*COSX
C BTT=B(K,J)
C
C CALCULATE NEW VALUES IN THE IDENTITY MATRIX USING THE
C SINES AND COSINES COMPUTED BEFORE
C
C B(K,J)=BTT*COSX-B(K,I)*SINX
C B(K,I)=BTT*SINX+B(K,I)*COSX
C CONTINUE
C
C CALCULATE THE EIGENVALUES AND SET INTO THE DIAGONAL
C ELEMENTS OF THE OBJECT MATRIX
C
C XTT=2.*A(J,I)*SINX*COSX
C ATT=A(J,J)
C BTT=A(I,I)
C A(J,J)=ATT*COSX2+BTT*SINX2-XTT
C A(I,I)=ATT*SINX2+BTT*COSX2+XTT
C A(J,I)=(ATT-BTT)*SINX*COSX+A(J,I)*(COSX2-SINX2)
C A(I,J)=A(J,I)
C
C SET OPPOSIT OFFDIAGONAL ELEMENTS EQUAL (SQUARE MATRIX)
C
C DO 50 K=1,N
C A(J,K)=A(K,J)
C A(I,K)=A(K,I)
C CONTINUE
C CONTINUE
C IF(IND) 60,60,3
C IF(THR-FN) 70,70,23
C
C SORT THE EIGENVALUES AND EIGENVECTORS
C
C DO 80 I=2,N
C J=I

```

```

29      IF(A(J-1,J-1)-A(J,J)) 90,80,80
90      ATT=A(J-1,J-1)
        A(J-1,J-1)=A(J,J)
        A(J,J)=ATT
        DO 100 K=1,N
        ATT=B(K,J-1)
        B(K,J-1)=B(K,J)
100     B(K,J)=ATT
        J=J-1
        IF(J-1) 80,80,29
80      CONTINUE
        RETURN
        END

```

```

      SUBROUTINE HEAD(IFILE3,NCELLS,HMIN,HMAX,KPLOT,ITITL)

```

```

C
C THIS SUBROUTINE GENERATES THE INFORMATION NECESSARY
C FOR THE HISTOGRAMS AND OUTLIER MAPS
C

```

```

      DIMENSION JTITL(16),ITITL(10)

```

```

C
C ITE IS THE DEVICE NUMBER OF THE TERMINAL
C

```

```

      DATA ITE/5/
      WRITE(ITE,21)

```

```

C
C ASSIGN A FILENAME TO UNIT IFILE3
C

```

```

      OPEN(UNIT=IFILE3,DIALOG)

```

```

C
C DECIDE WHAT HISTOGRAM OUTPUTS WILL BE DONE
C

```

```

      WRITE(ITE,25)
      READ(ITE,126) KPLOT
      WRITE(ITE,23)

```

```

C
C INPUT THE MINIMUM VALUE FOR THE HISTOGRAMS TO
C BE GENERATED FROM
C

```

```

      READ(ITE,3) HMIN
      WRITE(ITE,41)

```

```

C
C INPUT THE MAXIMUM VALUE FOR THE HISTOGRAMS TO
C BE GENERATED FROM
C

```

```

      READ(ITE,3) HMAX

```

```

C
C CALCULATE THE NUMBER OF CELLS TO BE USED IN THE
C HISTOGRAMS BUT LIMIT TO A MAXIMUM OF 401
C

```

```

      NCELLS=(HMAX-HMIN)*10.
      NCELLS=NCELLS+1
      IF(NCELLS.GT.401) NCELLS=401

```

```

C
C OUTPUT THE NUMBER OF CELLS
C

```

```

      WRITE(ITE,31) NCELLS
      WRITE(ITE,30)

```

```

C
C INPUT INFORMATION ABOUT THE MAPS
C

```

```

      READ(ITE,32) ITITL
      WRITE(ITE,42)
      READ(ITE,43) ITL

```

```

C
C IF OUTLIER MAP INFORMATION HAS BEEN STORED IN
C IFILE3 PREVIOUSLY DO NOT REENTER IT
C

```

```

      IF(ITL.NE.2HNO) GOTO 24

```

```

C
C INPUT NECESSARY MAP INFORMATION

```

```

C      WRITE(ITE,10)
C      READ(ITE,61) XLAT
C      WRITE(ITE,12)
C      READ(ITE,62) XLONG
C
C      WRITE(ITE,26)
C      READ(ITE,63) CMER
C
C      MAKE SURE CENTRAL MERIDIAN IS NEGATIVE FOR
C      THE U.S.
C
C      CMER=-ABS(CMER)
C
C      WRITE(ITE,13)
C      READ(ITE,64) EUSZ
C      WRITE(ITE,66)
C      READ(ITE,64) NSSZ
C
C      WRITE(ITE,14)
C      READ(ITE,65) EUTC
C      WRITE(ITE,15)
C      READ(ITE,65) NSTC
C      WRITE(ITE,16)
C      READ(ITE,18) JTITL
C
C      WRITE ALL INFORMATION PLUS 17.46 AND 28.94 TO IFILE3.
C      THE 17.46 AND 28.94 ARE THE MAP SIZE IN INCHES NECESSARY
C      FOR THE ROUTINE PIC3
C
C      WRITE(IFILE3,22)XLAT,XLONG,NSSZ,EUSZ,CMER,EUTC,
1      NSTC,JTITL
21      FORMAT(40H FILE NAME HOLDING HEADER INFORMATION ? )
25      FORMAT(42H SELECT HISTOGRAM PLOTS, PRINTOUT, OR BOTH,/,
1      43H PLOTS ONLY--1, BOTH=0, PRINTOUT ONLY--1 ? ,%)
126     FORMAT(I2)
23     FORMAT(49H INPUT THE LOWER LIMIT TO BE USED IN THE PLOTS ? ,%)
3      FORMAT(F5.2)
41     FORMAT(49H INPUT THE UPPER LIMIT TO BE USED IN THE PLOTS ? ,%)
31     FORMAT(/,51H THE NUMBER OF CELLS TO BE USED IN THE HISTOGRAMS -
1      ,I4,/)
30     FORMAT(35H GIVE SPECIAL DATA TITLE FOR MAP ? )
32     FORMAT(10A5)
42     FORMAT(42H HAS HEADER FILE BEEN WRITTEN (YES,NO) ? ,%)
43     FORMAT(A2)
10     FORMAT(39H ENTER THE NORTHWEST CORNER LATITUDE ? ,%)
61     FORMAT(F12.5)
12     FORMAT(30H NORTHWEST CORNER LONGITUDE ? ,%)
62     FORMAT(F9.3)
26     FORMAT(20H CENTRAL MERIDIAN ? ,%)
63     FORMAT(F7.2)
13     FORMAT(32H E-U MAP SIZE (DECIMAL DEGS) ? ,%)
64     FORMAT(F7.2)
66     FORMAT(31H N-S MAP SIZE (DECIMAL DEGS) ? ,%)
14     FORMAT(26H E-U TIC MARK INCREMENT ? ,%)
65     FORMAT(F6.3)
15     FORMAT(26H N-S TIC MARK INCREMENT ? ,%)
16     FORMAT(29H MAP TITLE (80 CHARACTERS) ? )
18     FORMAT(16A5)
22     FORMAT(F12.3,F9.3,/,3F7.2,2F6.3,/,16A5,/,
1      10H 17.46,/,10H 28.94)
24     RETURN
      END

```

```

C      SUBROUTINE COVAR(X,NPTS,CVAR)
C      DIMENSION X(3,1000),CVAR(3,3),TEM(3),TEM1(3)
C      DATA IFLAG/0/
C
C      THIS IS THE BEST ALGORITHM FOR CALCULATING THE
C      COVARIANCE MATRIX
C

```

```

C   IFLAG IS USED TO INITIALIZE THE TEMPORARY VARIABLES
C
C       IF(IFLAG.NE.0) GOTO 100
C       IFLAG=1
C
C   ZERO THE COVARIANCE MATRIX
C
C       DO 50 I=1,3
C       DO 50 J=1,3
50    CUAR(I,J)=0.
C
C   INITIALIZE THE TEMPORARY STORAGE VECTOR
C
C       TEM1(1)=X(1,1)
C       TEM1(2)=X(2,1)
C       TEM1(3)=X(3,1)
C       L=2
C       LT=0
C       GOTO 200
100    L=1
200    CONTINUE
C
C   BEGIN THE CALCULATIONS
C
C       DO 10 I=1,3
C       DO 20 J=1,3
C
C   IF I AND J ARE THE SAME VALUE THEN A VARIANCE
C   CALCULATION IS UNDERWAY OTHERWISE ITS A COVARIANCE
C   CALCULATION
C
C       TX=TEM1(I)
C       TY=TEM1(J)
C       DO 30 K=L,NPTS
C
C   CALCULATE THE TOTAL NUMBER OF POINTS UNTIL NOW
C
C       A=FLOAT(K+LT)
C
C   CALCULATE THE DIFFERENCE BETWEEN THE DATA VALUE AND
C   THE AVERAGE SUMMED DIFFERENCE
C
C       QX=X(I,K)-TX
C
C   AVERAGE THE DIFFERENCE
C
C       RX=QX/A
C
C   SUMMATE THE AVERAGE DIFFERENCE
C
C       TX=TX+RX
C
C   DO THE SAME CALCULATIONS ON THE SECOND DATA VALUE
C
C       QY=X(J,K)-TY
C       RY=QY/A
C       TY=TY+RY
C
C   CALCULATE THE VARIANCE -- COVARIANCE MATRIX
C
C       CUAR(I,J)=CUAR(I,J)+(A-1.)*QX*RY
30    CONTINUE
20    CONTINUE
C
C   STORE TEMPORARY VALUES
C
C       TEM(I)=TX
10    CONTINUE
C       DO 40 I=1,3
40    TEM1(I)=TEM(I)
C
C   SUM TOTAL NUMBER OF POINTS UNIT NOW

```

```

C      LT=LT+NPTS
      RETURN
      END

      SUBROUTINE HISPC(NCELLS,IFILE1,SEN,NSAVE,IFMT
1,HMIN,HMAX,KPLOT,IFILE)
C
C      COMPUTE HISTOGRAMS FOR EACH OF THE THREE PRINCIPAL
C      COMPONENTS, AND PRINT THEM OUT AND/OR PLOT THEM
C      USING PLOT10 AND AGII.
C
C      VECTORS TH1,TH2 AND TH3 CONTAIN THE HISTOGRAMS
C      FOR THE THREE PRINCIPAL COMPONENTS. IFILE IS
C      A VECTOR CONTAINING THE UNIT NUMBERS OF THE FILES
C      WHICH WILL RECEIVE THE OUTLIER DATA.
C
      COMMON /BLK1/XBAR(3),CVAR(3,3),XLAM(3),PC(3,3)
      DIMENSION TH1(402),TH2(402),TH3(402),Z(402)
      DIMENSION IFILE(3),NSAVE(3),IFMT(16),SEN(2)
      DIMENSION XLONG(1000),XLAT(1000),X(3,1000)
      DIMENSION ITL1(4),ITL2(4),ITL3(4)
C
C      SET LABELS TO BE PLACED AT THE TOP OF EACH PLOT
C
      DATA ITL1/80,67,45,49/
      DATA ITL2/80,67,45,50/
      DATA ITL3/80,67,45,51/
C
C      REWIND THE FILES TO BE USED FOR THE OUTLIERS
C
      REWIND IFILE1
      REWIND IFILE(1)
      REWIND IFILE(2)
      REWIND IFILE(3)
C
C      INITIALIZE THE PLOT10 LIBRARY
C
      CALL RESET
      CALL TERM(3,4096)
      CALL CHR512(4)
10      CONTINUE
20      CONTINUE
C
C      SET THE CELL WIDTH
C
      DH=.1
C
C      TAKE THE SQUARE ROOTS OF THE EIGENVALUES IN
C      PREPARATION FOR DATA NORMALIZATION
C
      DO 30 K=1,3
30      XLAM(K)=1./SQRT(XLAM(K))
      Z(2)=HMIN
C
C      ZERO THE CELL COUNTERS TH1,TH2 AND TH3 ALSO LOAD
C      THE X AXIS VECTOR
C
      DO 31 J=2,NCELLS
      Z(J+1)=Z(J)+DH
      TH1(J)=0.
      TH2(J)=0.
      TH3(J)=0.
31
C
C      INITIALIZE THE TOTAL POINT COUNTER AND THE OUTLIER
C      COUNTERS
C
      NTOTAL=0
      DO 17 I=1,3
17      NSAVE(I)=0
C

```

```

C   SORT DATA INTO THREE HISTOGRAMS IN ONE PASS
C   THROUGH IFILE1.
C
50   CALL READIT(XLAT,XLONG,X,NPTS,IFILE1,IFMT)
      IF(NPTS.EQ.0) GOTO 100
C
C   CALCULATE THE TOTAL NUMBER OF POINTS
C
      NTOTAL=NTOTAL+NPTS
      DO 90 I=1,NPTS
      DO 80 K=1,3
      TEMP=0.
C
C   CALCULATE THE NORMALIZED PC VALUE AND STORE IT IN TEMP
C
      DO 60 J=1,3
60   TEMP=TEMP+PC(J,K)*(X(J,I)-XBAR(J))
      TEMP=TEMP*XLAM(K)
C
C   DETERMINE THE CELL THAT THE TEMP VALUE BELONGS IN
C   2 MUST BE ADDED TO THE CALCULATED BEN VALUE MAKING
C   THE SECOND ELEMENT OF EACH TH VECTOR EQUAL TO HMIN
C
      NH=IFIX((TEMP-HMIN)/DH)+2
      IF(NH.GT.NCELLS+1) NH=NCELLS+1
      IF(NH.LT.1) NH=1
      GOTO (76,77,78),K
C
C   ADD 1 TO THE NUMBER STORED IN THE CORRECT TH VECTOR
C
76   TH1(NH)=TH1(NH)+1.
      GOTO 79
77   TH2(NH)=TH2(NH)+1.
      GOTO 79
78   TH3(NH)=TH3(NH)+1.
79   CONTINUE
C
C   SUBTRACT THE SENSITIVITY FROM THE NORMLIZED VALUE
C   AND CHECK TO SEE IF IT IS GREATER THE ZERO, IF SO WRITE LAT
C   ,LONG AND NORMALIZED VALUE TO THE CORRECT FILE.
C
      IF((TEMP.LT.SEN(1)).OR.(TEMP.GT.SEN(2))) GOTO 80
C
C   INCREMENT THEHE OUTLIER COUNTER BY 1
C
      NSAVE(K)=NSAVE(K)+1.
C
C   OUTPUT TO THE APPROPRIATE FILE
C
      JFILE=IFILE(K)
      WRITE (JFILE,3000) XLAT(I),XLONG(I),TEMP
80   CONTINUE
90   CONTINUE
      GO TO 50
100  CONTINUE
      CALL ERASE
      Z(1)=NCELLS
      TH1(1)=NCELLS
      TH2(1)=NCELLS
      TH3(1)=NCELLS
C
C   IF PLOTS ONLY WERE SELECTED GO TO 200
C
      IF(KPLOT.GT.0) GOTO 200
C
C   PRINT OUT HISTOGRAMS
C
      NKOW=10
      DROW=10.*DH
      DO 150 K=1,3
      CALL ERASE
      WRITE(5,2001) K,DH,NCELLS,NTOTAL

```



```

      XP=HMIN
      I1=1
      I2=NROW
C
C   PRINT OUT THE COUNTS IN THE RESPECTIVE VECTORS
C
120    GOTO (117,118,119),K
117    WRITE(5,2002) I1,XP,(TH1(I),I-I1+1,I2+1)
      GOTO 116
118    WRITE(5,2002) I1,XP,(TH2(I),I-I1+1,I2+1)
      GOTO 116
119    WRITE(5,2002) I1,XP,(TH3(I),I-I1+1,I2+1)
116    CONTINUE
      I1=I2+1
      IF (I1.GT.NCELLS) GO TO 160
      I2=MIN0(I2+NROW,NCELLS)
      XP=XP+DROW
      GOTO 120
160    CONTINUE
      CALL HDCOPY
150    CONTINUE
C
C   DRAW THE PLOTS
C
200    IF (KPLOT.LT.0) GO TO 300
      DO 250 K=1,3
C
C   INITIALIZE THE ADVANCED GRAPHICS II LIBRARY
C
      CALL BINITT
      CALL ERASE
      CALL CHRSTZ(4)
      CALL PLACE(3HSTD)
      X1=600.
      X2=3600.
      SET=(X2-X1)/(NCELLS-1)
      ISET=SET
      IF((SET-ISET).GE..5) ISET=ISET+1
      CALL XDEN(9)
      CALL XFRM(2)
      CALL XLEN(40)
C
C   PLOT THE RESPECTIVE HISTOGRAM
C
      GOTO(12,13,14),K
12     CONTINUE
      CALL VBARST(0,ISET,0)
      CALL XFRM(1)
      CALL CHECK(2,TH1)
      CALL DSPLAY(2,TH1)
      CALL MOVABS(2020,3120)
      CALL HLABEL(4,ITL1)
      GOTO 15
13     CONTINUE
      CALL VBARST(0,ISET,0)
      CALL XFRM(1)
      CALL CHECK(2,TH2)
      CALL DSPLAY(2,TH2)
      CALL MOVABS(2020,3120)
      CALL HLABEL(4,ITL2)
      GOTO 15
14     CONTINUE
      CALL VBARST(0,ISET,0)
      CALL XFRM(1)
      CALL CHECK(2,TH3)
      CALL DSPLAY(2,TH3)
      CALL MOVABS(2020,3120)
      CALL HLABEL(4,ITL3)
15     CONTINUE
      IYT=450
      IXT=600-(IEST/2)
      ITT=ISET*10

```

```

        NT=(NCELLS-1)/10
        CALL MOVABS(600,450)
        DO 251 I=1,NT+1
        CALL DRUREL(0,50)
        IXT=IXT+ITT
        CALL MOVABS(IXT,IYT)
251      CONTINUE
        CALL HDCOPY
250      CONTINUE
C
300      CONTINUE
C
1000     FORMAT(3E15.8)
1001     FORMAT(20H HISTOGRAM FOR P.C. ,I2)
3000     FORMAT(3F10.4)
2001     FORMAT(/,/,25H HISTOGRAM FOR COMPONENT ,I2,/,14H CELL WIDTH =
1 F8.3,/,3X,10H J   START ,4X,16H H(J),...H(J+9) ,/,
2 17H NUMBER OF CELLS ,I4,/,28H THE TOTAL NUMBER OF POINTS ,I6)
2002     FORMAT(I4,F8.2,3X,10F6.0)
        RETURN
        END

```

```

        SUBROUTINE PIC3(JFILE,IFILE3,IPRINC,SENSE,
1 MSAVE,MTIT)

```

```

C
C   BENDIX FIELD ENGINEERING CORPORATION
C   UNDER U.S. DEPT. OF ENERGY CONTRACT
C   EY-76-C-13-1664
C
C*****
C
C   PROGRAM:  PIC3
C
C   MODEL NUMBER:  1.0
C
C   PURPOSE:  PLOT QUAD OUTLINE AND LOCATIONS OF OBSERVATIONS
C
C*****
C*****  REVISION LIST  *****
C
C   RU DATE      SRO  BY   REASON FOR CHANGE
C   -----
C
C
C*****
C*****
C

```

```

        DIMENSION MTIT(16),ITIT(13),SENSE(2)
        COMMON/MPORG/X0,Y0,XORG,YORG
        REWIND IFILE3
        REWIND JFILE
C   MAP INITIALIZATION ROUTINE
        CALL BASG(IFILE3)
C   READ THE THREE VALUES TO BE PLOTTED
50      READ(JFILE,10,END=99) RLAT,RLON,XVAL
C   GET THE X-Y COORDINATES OF THE POINT READ
C   AND PLOT IT
12      CALL NMERCC( RLAT,-ABS(RLON),X,Y)
        CALL MOVEA((X-X0)+XORG,(Y-Y0)+YORG)
        CALL ANCHO(43)
        GOTO 50
99      CONTINUE
C   SET THE PLOT TO ALPHA MODE
        CALL ANMODE
C   ENCODE PERTINENT INFO INTO ITIT
        ENCODE(65,30,ITIT) IPRINC,SENSE(1),SENSE(2),MSAVE
        CALL CHR5IZ(3)

```

```

C MOVE TO LOWER LEFT CORNER
  CALL MOVABS(50,100)
C OUTPUT MAP TITLE
  CALL AOUTST(80,MTIT)
C MOVE UNDER THE MAP TITLE
  CALL MOVABS(10,10)
C OUTPUT PERTINENT INFO
  CALL AOUTST(65,ITIT)
  CALL HDCOPY
10  FORMAT(3F10.3)
30  FORMAT(11H PRINC COMP ,12,14H SENSITIVITY ,F5.2,3H -
    1,F5.2,18H NUM PNTS PLOTTED ,16,2H )
  RETURN
  END
C*****
C
C PROGRAM: BASG
C
C PURPOSE: TO PLOT A 1 BY 2 DEGREE QUADRANGLE OUTLINE
C
C*****
C
C BASG OVERVIEW
C
C BASE MAPS SHOWING THE GEOGRAPHIC GRATICULE OF SPECIFIED
C 1 TO 250,000 SCALE MAPS PUBLISHED BY THE US GEOLOGICAL
C SURVEY WERE REQUIRED BY BENDIX FIELD ENGINEERING GEOLOGY
C DIVISION. THE BASG PROGRAM WAS WRITTEN TO PLOT
C THOSE GRATICULES TO OVERLAY NEGATIVES OF THE USGS PLATES
C OF THE CULTURE AND HYDROGRAPHY FOR EACH QUADRANGLE.
C
C MAPS FOR AREAS NORTH OF 60 DEGREES LATITUDE WILL AUTOMATICALLY
C BE CHANGED TO 1 BY 3 DEGREES.
C
C SUBROUTINE BASG(IFILE3)
C
C PROGRAM TO GENERATE GEOGRAPHIC BASE MAP OVERLAYS FOR ENTIRE UNITED STATES
C
  COMMON /DATA/ CMERID,CLAT,CLON,SPH,SCAL,
  1 PSCEU,PSCHS,DEGEU,DEGNS,TICSZ,TICWZ,
  2 MTITL(16),MAP(6),JDMA(3)
  3 ,JDELS(6),JOUO(5),DOEU
  common /crpa/ icrt,ipaper
C
C
C----- INPUT DATA FORMAT 5-CARDS/QUAD
C
C 1 VERSION ( DOE OR GEOL )
C 2 LOCATION, MAPNAME CARD
C 3 SIZE, TICMARKS, CENTRAL MERIDIAN
C 4 TITLE (FOR UPPER LEFT OVER MAP)
C 5 LINE AB MEASUREMENTS
C 6 LINE CD MEASUREMENTS
C
C COMPUTE THE THEORETICAL CENTRAL MERIDIAN AND CENTER E-U
C DISTANCES OF THE NURE QUADRANGLES
C
C----- THIS INITIALIZES THE PLOT BLOCK COUNTER
  ipaper=0
  icrt=1
C OVERRIDE OPTION CARD 1
  DOEU=1.
C
C INPUT THE NORTHWEST LAT,LON NTMS IDENT AND MAP NAME
C DEGREES N-S AND E-U, CENTRAL MERIDIAN AND TIC MARK
C INTERVAL N-S AND E-U.
C
  READ(IFILE3,10,END=99)RNULA,RNULO,JDMA,MAP,
  1 DEGNS,DEGEU,CMERID,TICWZ,TICSZ
C
C----- BEGIN TO DETERMINE IF DEFAULT MAP SIZE AND TICK MARK
C INTERVALS WILL BE APPLIED OR IF THIS MAP IS ABOVE 60
C DEGREES NORTH LATITUDE.

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C
C
C----- READ TITLE CARD
      READ(IFILE3,14,END=99) MTITL
C
C SET DEFAULT TIC MARK INTERVAL AND MAP SIZE IF NOT
C DEFINED PREVIOUSLY.
C
      IF(DEGNS.EQ.0.)DEGNS=1.0
      IF(DEGEW.EQ.0.)DEGEW=2.0
C
      IF(DEGEW.EQ.0..AND.RNULA.GE.60.)DEGEW=3.0
C
      IF(TICSZ.EQ.0.)TICSZ=0.25
C
      IF(TICUZ.EQ.0..AND.RNULA.LT.60.)TICUZ=0.25
C
C SET PHYSICAL SCALE FACTORS TO 1.
      PSNS=1.
      PSEW=1.
C
C INITIALIZE THE PLOTTING ROUTINES
C
      CALL RESET
      CALL ERASE
C TELL PLOT ROUTINES THAT YOU ARE AN ENHANCED GRAPHICS TERMINAL
      CALL TERM(3,4096)
C SET CHARACTER SIZE TO THE SMALLEST
      CALL CHRSTZ(4)
C SET SCREEN WINDOW LIMITS
      CALL SUINDO(1,4000,1,3000)
C DETERMIN X AND Y MAX VALUES
      XNAN=(53.*DEGEW)/2.
      YNAN=31.*DEGNS
C SET X AND Y MINIMUM VALUES
      XMIN=-8.
      YMIN=1.
C SET DATA VALUE WINDOW
      CALL DUINDO(XMIN,XNAN,YMIN,YNAN)
C
C DRAW A BORDER AROUND THE AREA WHERE THE MAP WILL BE
      CALL MOVEA(XMIN,YNAN)
      CALL DRAWA(XNAN,YNAN)
      CALL DRAWA(XNAN,YMIN)
      CALL DRAWA(XMIN,YMIN)
      CALL DRAWA(XMIN,YNAN)
      CALL MOVEA(XMIN,YMIN)
C
C MOVE TO THE TOP OF THE BORDER AND PRINTOUT THE TITLE
C AND SET CHARACTER SIZE TO 3
C
      CALL CHRSTZ(3)
      CALL MOVABS(800,2900)
      CALL AOUTST(80,MTITL)
C
C RETURN CHARACTER SIZE TO 4
C
      CALL CHRSTZ(4)
C SET MAP SCALE TO 250000.
C
      SCAL=250000.
      RCAL=SCAL/39.37008
C SPHEROID NUMBER 2 (CLARK 1866)
      SPH=2.
C BE SURE LONGITUDES ARE NEGATIVE FOR U.S.
      RNULO=-ABS(RNULO)
      CLAT=RNULA-DEGNS
      CLON=RNULO
C FIND CENTRAL MERIDIAN
      AQ=RNULO+(DEGEW/2.)

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C----- USE GEOGRAPHICAL CENTER OF MAP AREA FOR CENTRAL MERIDIAN
C----- UNLESS IT WAS SPECIFICALLY REPORTED IN THE INPUT DATA SET
          IF(CMERID.EQ.0.)CMERID=A0
C
C      INITIALIZE MERCATOR PROJECTION TO GO THROUGH THE CENTER OF
C      EACH MAP.
          CALL NMERCI(CMERID,RCAL,SPH,Z)
          CALL NMERCP(0.,0.,PSNS,PSEU)
          CALL CHRISZ(4)
C
          CALL MRCMAP(XRAN,YRAN)
C
99      CONTINUE
C
10      FORMAT(6X,F6.3,F9.3,1X,2A5,A2,1X,5A5,A4,/,
1F7.2,F7.2,F7.2,1X,F5.3,1X,F5.3)
14      FORMAT(16A5)
12      FORMAT(2F10.0)
          RETURN
          END
          SUBROUTINE MRCMAP(XRAN,YRAN)
C
C
C..... M R C M A P
C
          COMMON/MPORG/X0,Y0,XORG,YORG
          COMMON/DATA/CMERID,CLAT,CLON,SPH,SCAL,
1 PSCEU,PSNS,DEGEU,DEGNS,TICSZ,TICUZ,
2 MTITL(16),MAP(6),JDMA(3)
3 ,JDELS(6),JOUO(5),DOEU
C
C---- ANNOTATION FLAG (NOTAT)  0=YES, ANNOTATE  1=NO ANNOTATION
          NOTAT=0
C  SET ANNOTATION FLAG TO YES
          CNULA=CLAT+DEGNS
          CNULO=CLON
C
C
C..... BEGIN TO FIND ORIGIN OFFSET TO CENTER OF NEW MAP FROM
C      THE TRIM LINE ORIGIN. DO THIS BY FINDING SEPARATION
C      OF NORTHWEST CORNER FROM CENTRAL MERIDIAN
C
          CALL NMERCC(CLAT,CMERID,X0,Y0)
          CALL NMERCC(CNULA,CNULO,XNU,YNU)
C..... FIND INCHES FROM NW CORNER TO CM
          YNS=ABS(YNU-Y0)
          XEU=ABS(XNU-X0)
C..... THE OFFSET TO CENTER OF MAP
          XORG=(XRAN-8.)/2.
          YORG=.2*YRAN
          NTCNS=DEGNS/TICSZ
          NTCEU=DEGEU/TICUZ
C----- XTIC IS THE SIZE OF THE EDGE TIC MARKS
          XTIC=.5
C
C..... WE START PLOTTING AT THE SOUTHWEST CORNER OF THE MAP
          BLAT=CLAT
          BLON=CLON
          CALL NMERCC(CLAT,CLON,X,Y)
          XXO=X-X0+XORG
          YYO=Y-Y0+YORG
          CALL MOVEA(XXO,YYO)
C
          XYU=XORG*.02
          HGT=XYU*2.
          IF(NOTAT.EQ.0)CALL ANOTE(CLON,XXO,YYO,8)
C
C..... LOWER EDGE OF MAP
C
          DO 10 J=1,NTCEU
          BLRJ=BLON+FLOAT(J)*TICUZ
          CALL NMERCC(BLAT,BLRJ,X,Y)

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      XXO=X-XO+XORG
      VYO=Y-YO+YORG
      CALL DRAWA(XXO,VYO)
      YZ=YYO+XTIC
      CALL DRAWA(XXO,YZ)
      CALL MOVEA(XXO,VYO)
C-----ANNOTATE THE LOW EDGE OF MAP
      IF(NOTAT.EQ.0)CALL ANOTE(BLRJ,XXO,VYO,1)
10    CONTINUE
C
C.....RIGHT SIDE OF MAP
C
      IF(NOTAT.EQ.0)CALL ANOTE(CLAT,XXO,VYO,5)
      BLON=BLON+DEGEU
      DO 20 J=1,NTCNS
      BLRJ=BLAT+FLOAT(J)*TICSZ
      CALL NMERCC(BLRJ,BLON,X,Y)
      XXO=X-XO+XORG
      VYO=Y-YO+YORG
      CALL DRAWA(XXO,VYO)
      XZ=XXO+XTIC
      CALL DRAWA(XZ,VYO)
      CALL MOVEA(XXO,VYO)
      IF(NOTAT.EQ.0)CALL ANOTE(BLRJ,XXO,VYO,2)
20    CONTINUE
C
C.....TOP OF MAP
C
      IF(NOTAT.EQ.0)CALL ANOTE(BLON,XXO,VYO,6)
      BLAT=BLAT+DEGNS
      DO 30 J=1,NTCEU
      BLRJ=BLON-FLOAT(J)*TICUZ
      CALL NMERCC(BLAT,BLRJ,X,Y)
      XXO=X-XO+XORG
      VYO=Y-YO+YORG
      CALL DRAWA(XXO,VYO)
      YZ=YYO+XTIC
      CALL DRAWA(XXO,YZ)
      CALL MOVEA(XXO,VYO)
      IF(NOTAT.EQ.0)CALL ANOTE(BLRJ,XXO,VYO,3)
30    CONTINUE
C
C..... LEFT SIDE OF MAP
C
      IF(NOTAT.EQ.0)CALL ANOTE((CLAT+DEGNS),XXO,VYO,7)
      BLON=BLON-DEGEU
      DO 40 J=1,NTCNS
      BLRJ=BLAT-FLOAT(J)*TICSZ
      CALL NMERCC(BLRJ,BLON,X,Y)
      XXO=X-XO+XORG
      VYO=Y-YO+YORG
      CALL DRAWA(XXO,VYO)
      XZ=XXO+XTIC
      CALL DRAWA(XZ,VYO)
      CALL MOVEA(XXO,VYO)
      IF(NOTAT.EQ.0)CALL ANOTE(BLRJ,XXO,VYO,4)
40    CONTINUE
C
C..... CENTRAL TIC MARKS INSIDE MAP AREA
C
      NCNS=NTCNS-1
      NCEU=NTCEU-1
      DO 50 J=1,NCEU
      DO 50 K=1,NCNS
      XZ=CLAT+FLOAT(K)*TICSZ
      YZ=CLON+FLOAT(J)*TICUZ
      CALL NMERCC(XZ,YZ,X,Y)
      XXO=X-XO+XORG
      VYO=Y-YO+YORG
      CALL MOVEA((XXO-XYU),VYO)
      CALL DRAWA((XXO+XYU),VYO)
      CALL MOVEA(XXO,(VYO-XYU))

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      XZ=-XORG+XMAX
      CALL MOVEA(XZ,-YORG)

C
      RETURN
      END
      SUBROUTINE NMERC(AL,BL,X,Y)

C
C----- TRANSVERSE MERCATOR PROJECTION
C----- 5 SPHEROIDS
C-----YEAR      EQUATORIAL    POLAR      COMP-    PRINCIPAL
C-----NAME      AXIS METERS  AXIS METERS RESSION  USER
C  1  1909
C  HAYFORD      6378388.      6356912.      297.0  U.S.A. --INTERNATIONAL
C  2  1866
C  CLARK       6378206.4      6356583.8      295.0  U.S.A.
C  3  1880
C  CLARK       6378249.145    6356514.8696    293.5  SOUTH AFRICA
C  4  1830
C  EVEREST     6377276.345    6356075.4134    300.8  INDIA
C  5  1841
C  BESSEL     6377397.155    6356078.9629    299.15  GERMANY,INDONESIA,NETHERLANDS
C  6  1858
C  AIREY      6377563.      6356257.      299.3  GREAT BRITANN
C  7  1948
C  KRASSOVSKY 6378245.      6356863.      298.3  RUSSIA, EASTERN COUNTRIES
C  8  1967
C  I.U.G.G.   6378160.      6356775.      298.25  INTERNATIONALLY ADOPTED.
C
C
      DIMENSION TANPHI(5),COTPHI(5),A(5),B(5),AZ(5),BZ(5)
      EXTERNAL TAN
      REAL KO

C
C--- SPHEROID DEFINITIONS
C
C
C----- INITIAL ENTRY DEFINES PROJECTION
      ENTRY NMERCP(AL,BL,X,Y)
      PSCEU=X
      PSCNS=Y
      RETURN

C
C
      ENTRY NMERCI(AL,BL,X,Y)
      AL= CENTRAL MERIDIAN      BL= SCALE
      X= SPHEROID NUMBER        Y= (IGNORED)
      IF(PSCEU.LE.0.)PSCEU=1.
      IF(PSCNS.LE.0.)PSCNS=1.
      AZ(1)=6378388.
      AZ(2)=6378206.4
      AZ(3)=6378249.145
      AZ(4)=6377276.345
      AZ(5)=6377397.155

C
      BZ(1)=6356911.946
      BZ(2)=6356583.8
      BZ(3)=6356514.896
      BZ(4)=6356075.413
      BZ(5)=6356078.96

C
      KO=0.996
      PI=3.1415926
      ADJ=0.0174533
      ALT=AL
      SC=BL
      IX=X
      IF(IX.GT.5.OR.IX.LT.1)GOTO 100
      GOTO 101
C-----CHOOSE THE CLARK 1866 SPHEROID BY DEFAULT
100      IX=2
101      AA=AZ(IX)
      BB=BZ(IX)

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CCCCCCCC

2

9

?

8

10

20


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PART1=0.
PART2=0.
DO 30 I=1,4
RA2=A(I)*2
RB2=B(I)*2
PART2=PART2+(RA2-RB2)*(1./SQRT(1.+COTPHI(I+1)**2))/A(I+1)
30 PART1=PART1+2*(I-4)*(RA2-RB2)
ONE=K0*AA*((.25-PART1)*2.*PHI4/(A(3)+B(3))+PART2)/4.
ONE=ONE*INV
40 TWO=C15*1.E8/2.*C3
THREE=C15*1.E16/24.*CSL*C5*(5.-T2L+9.*C11+4.*C12)
FOUR=C14*1.E4*SIN1
FIVE=C14*CSL*1.E12/6.*C4*(1.-T2L+C11)
A6=C2*1.E24*C7/720.*C15*CSL**2*(61.-58.*T2L+
174L+270.*C11-330.*C10)
Z26=C1*1.E20*C6*C14*CSL**2/120.
B5=(5.-18.*T2L+T4L+14.*C11-58.*C10)
B5=B5*Z26
X=(-(FOUR*P+FIVE*P**3+B5)/SC)*PSCU
C
Y=((ONE+TWO*P**2+THREE*P**4+A6)/SC)*PSCNS
RETURN
END
FUNCTION TAN(ARG)
C.....THIS JUST IN CASE THER IS NO TAN FUNCTION ON COMPILER
TAN=SIN(ARG)/COS(ARG)
RETURN
END
FUNCTION SGNF(ARG)
C
C.....SET THE SIGN OF ARG
C
IF(ARG.GT.0.) SGNF=1.
IF(ARG.LT.0.) SGNF=-1.
IF(ARG.EQ.0.) SGNF=0.
RETURN
END
SUBROUTINE ANOTE(ANGL,XX,YY,KIND)
C
C ANOTE WILL PLACE EITHER THE MINUTES VALUE OR THE WHOLE
C DEGREE VALUE IN AN APPROPRIATE POSITION NEXT TO A TICK MARK
C LOCATED AT (X,Y).
C KIND TELLS WHICH EDGE OF THE MAP THE ANNOTATION IS TO BE MADE.
C 1 - LOWER EDGE
C 2 - RIGHT EDGE
C 3 - TOP EDGE
C 4 - LEFT EDGE
C
C-----
C DIMENSION XNUM(8)
C
C----- CHECK FOR A VALID EDGE DESIGNATOR
C IF(KIND.GT.8.OR.KIND.LT.1)RETURN
C
X=XX
Y=YY
AN=ABS(ANGL*10.)
IAN=AN
REMM=FLOAT(IAN)/10.
C
GOTO(10,20,30,40,50,60,70,80),KIND
C----- BOTTOM OF MAP
C
10 CONTINUE
ENCODE(8,111,XNUM) REMM
CALL MOUREL(-100,-50)
CALL AOUTST(8,XNUM)
GOTO 100
C
C----- RIGHT EDGE OF MAP
C
20 CONTINUE

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        ENCODE(8,111,XNUM) REMM
        CALL MOUREL(50,0)
        CALL AOUTST(6,XNUM)
        GOTO 100
C
C----- TOP OF MAP
C
30      CONTINUE
        ENCODE(8,111,XNUM) REMM
        CALL MOUREL(-100,50)
        CALL AOUTST(8,XNUM)
        GOTO 100
C
C----- LEFT EDGE OF MAP
C
40      CONTINUE
        ENCODE(8,111,XNUM) REMM
        CALL MOUREL(-200,0)
        CALL AOUTST(8,XNUM)
        GOTO 100
C
C----- SOUTHEAST CORNER, LATITUDE
50      CONTINUE
        ENCODE(8,111,XNUM) REMM
        CALL MOUREL(50,0)
        CALL AOUTST(8,XNUM)
        GOTO 100
C
C----- NORTHEAST CORNER, LONGITUDE
60      CONTINUE
        ENCODE(8,111,XNUM) REMM
        CALL MOUREL(-100,50)
        CALL AOUTST(8,XNUM)
        GOTO 100
C
C----- NORTHWEST CORNER, LATITUDE
70      CONTINUE
        ENCODE(8,111,XNUM) REMM
        CALL MOUREL(-200,0)
        CALL AOUTST(8,XNUM)
        GOTO 100
C
C----- SOUTHWEST CORNER, LONGITUDE
80      CONTINUE
        ENCODE(8,111,XNUM) REMM
        CALL MOUREL(-100,-50)
        CALL AOUTST(8,XNUM)
100     CONTINUE
        CALL MOVEA(XX,YY)
111     FORMAT(F5.1)
        RETURN
        END

```

APPENDIX B

Sample Output

Sample Data

1	4.	30.17920	96.92060	QHG	55.0	75.0	26.0	1	66.	30.15230	96.88620	ECA	50.0	54.0	37.0
1	5.	30.17850	96.91960	QHG	51.0	64.0	25.0	1	67.	30.15190	96.88570	ECA	46.0	58.0	36.0
1	6.	30.17810	96.91920	QHG	49.0	71.0	27.0	1	68.	30.15160	96.88520	ECA	45.0	60.0	37.0
1	7.	30.17770	96.91870	QHG	53.0	68.0	27.0	1	69.	30.15120	96.88480	ECA	43.0	66.0	37.0
1	8.	30.17740	96.91820	QHG	47.0	75.0	25.0	1	70.	30.15080	96.88430	ECA	40.0	65.0	38.0
1	9.	30.17700	96.91770	QHG	40.0	82.0	25.0	1	71.	30.15040	96.88380	ECA	39.0	68.0	37.0
1	10.	30.17660	96.91720	QHG	37.0	87.0	27.0	1	72.	30.15010	96.88330	ECA	34.0	68.0	39.0
1	11.	30.17620	96.91680	QHG	37.0	89.0	28.0	1	73.	30.14930	96.88240	ECA	34.0	71.0	41.0
1	12.	30.17550	96.91580	QHG	37.0	95.0	28.0	1	74.	30.14900	96.88190	ECA	37.0	69.0	44.0
1	13.	30.17510	96.91530	QHG	41.0	91.0	27.0	1	75.	30.14860	96.88140	ECA	30.0	77.0	44.0
1	14.	30.17470	96.91490	QHG	43.0	89.0	28.0	1	76.	30.14820	96.88090	ECA	29.0	79.0	45.0
1	15.	30.17440	96.91440	QHG	47.0	83.0	29.0	1	77.	30.14780	96.88050	ECA	26.0	82.0	48.0
1	16.	30.17400	96.91390	QHG	49.0	81.0	30.0	1	78.	30.14750	96.88000	ECA	28.0	83.0	50.0
1	17.	30.17360	96.91340	QHG	50.0	79.0	28.0	1	79.	30.14710	96.87950	ECA	34.0	79.0	52.0
1	18.	30.17320	96.91290	QHG	49.0	80.0	26.0	1	80.	30.14630	96.87860	ECA	34.0	79.0	54.0
1	19.	30.17250	96.91200	QHG	51.0	74.0	26.0	1	81.	30.14600	96.87810	ECA	28.0	96.0	52.0
1	20.	30.17210	96.91150	QHG	47.0	76.0	29.0	1	82.	30.14560	96.87760	ECA	33.0	89.0	55.0
1	21.	30.17180	96.91100	QHG	44.0	78.0	30.0	1	83.	30.14520	96.87710	ECA	33.0	82.0	59.0
1	22.	30.17140	96.91060	QHG	43.0	79.0	30.0	1	84.	30.14480	96.87660	ECA	28.0	95.0	57.0
1	23.	30.17100	96.91010	QHG	39.0	72.0	31.0	1	85.	30.14450	96.87620	ECA	30.0	96.0	55.0
1	24.	30.17060	96.90960	QHG	42.0	66.0	34.0	1	86.	30.14370	96.87520	ECA	28.0	109.0	52.0
1	25.	30.17020	96.90910	QHG	40.0	69.0	36.0	1	87.	30.14330	96.87470	ECA	33.0	103.0	49.0
1	26.	30.16950	96.90820	QHG	36.0	71.0	37.0	1	88.	30.14300	96.87430	ECA	39.0	93.0	42.0
1	27.	30.16910	96.90770	QHG	33.0	68.0	37.0	1	89.	30.14260	96.87380	ECA	43.0	89.0	44.0
1	31.	30.16760	96.90580	QHG	26.0	72.0	34.0	1	90.	30.14220	96.87330	ECA	47.0	90.0	40.0
1	33.	30.16650	96.90440	QHG	32.0	69.0	34.0	1	91.	30.14180	96.87280	ECA	57.0	76.0	39.0
1	34.	30.16610	96.90390	QHG	40.0	59.0	34.0	1	92.	30.14150	96.87230	ECA	53.0	72.0	39.0
1	35.	30.16580	96.90340	QHG	45.0	47.0	35.0	1	93.	30.14070	96.87140	ECA	55.0	72.0	38.0
1	36.	30.16540	96.90290	QHG	45.0	48.0	35.0	1	94.	30.14040	96.87090	ECA	60.0	74.0	39.0
1	37.	30.16500	96.90240	QHG	48.0	44.0	35.0	1	95.	30.14000	96.87040	ECA	61.0	78.0	40.0
1	38.	30.16460	96.90200	QHG	43.0	44.0	37.0	1	96.	30.13960	96.87000	ECA	62.0	78.0	43.0
1	39.	30.16390	96.90100	QHG	43.0	43.0	36.0	1	97.	30.13920	96.86950	ECA	63.0	78.0	45.0
1	40.	30.16350	96.90050	QHG	43.0	36.0	36.0	1	98.	30.13890	96.86900	ECA	63.0	88.0	45.0
1	41.	30.16320	96.90010	QHG	36.0	49.0	34.0	1	99.	30.13850	96.86850	ECA	72.0	93.0	47.0
1	42.	30.16280	96.89960	QHG	36.0	56.0	32.0	1	100.	30.13810	96.86800	ECA	73.0	91.0	49.0
1	43.	30.16240	96.89910	QHG	38.0	62.0	30.0	1	101.	30.13770	96.86760	ECA	77.0	98.0	47.0
1	44.	30.16200	96.89860	QHG	35.0	61.0	30.0	1	102.	30.13740	96.86710	ECA	81.0	93.0	47.0
1	45.	30.16170	96.89810	QHG	42.0	62.0	30.0	1	103.	30.13700	96.86660	ECA	82.0	100.0	45.0
1	46.	30.16090	96.89720	QHG	43.0	58.0	31.0	1	104.	30.13660	96.86610	ECA	83.0	110.0	42.0
1	47.	30.16050	96.89670	QHG	45.0	61.0	32.0	1	105.	30.13630	96.86570	ECA	86.0	106.0	42.0
1	48.	30.16020	96.89620	QHG	48.0	60.0	32.0	1	106.	30.13550	96.86470	ECA	87.0	102.0	39.0
1	49.	30.15980	96.89580	QHG	48.0	63.0	33.0	1	107.	30.13510	96.86420	ECA	89.0	105.0	36.0
1	50.	30.15940	96.89530	QHG	53.0	50.0	35.0								
1	51.	30.15900	96.89480	QHG	56.0	54.0	32.0								
1	52.	30.15870	96.89430	QHG	51.0	53.0	32.0								
1	53.	30.15790	96.89340	QHG	55.0	53.0	31.0								
1	54.	30.15760	96.89290	QHG	54.0	51.0	31.0								
1	55.	30.15720	96.89240	QHG	53.0	46.0	32.0								
1	56.	30.15680	96.89190	QHG	56.0	35.0	34.0								
1	57.	30.15640	96.89140	QHG	49.0	43.0	34.0								
1	58.	30.15600	96.89100	QHG	52.0	43.0	34.0								
1	59.	30.15530	96.89000	QHG	55.0	44.0	34.0								
1	60.	30.15490	96.88950	QHG	53.0	46.0	35.0								
1	61.	30.15460	96.88910	QHG	53.0	50.0	33.0								
1	62.	30.15420	96.88860	QHG	56.0	52.0	34.0								
1	63.	30.15380	96.88810	QHG	57.0	55.0	33.0								
1	64.	30.15340	96.88760	QHG	57.0	57.0	34.0								
1	65.	30.15310	96.88710	ECA	56.0	53.0	36.0								

MEAN VECTOR

47.570 71.600 37.020

COVARIANCE MATRIX

198.147 38.473 -7.880
-38.473 324.384 63.160
-7.880 63.160 65.131

EIGENVALUES

347.543 191.394 48.725

PRINCIPAL COMPONENTS

FIRST	SECOND	THIRD
0.23383	0.96582	0.11185
0.95021	-0.20264	-0.23674
0.20598	-0.16164	0.96511

CORRELATION WITH ORIGINAL ELEMENTS

0.30968	0.94922	0.05547
0.98354	-0.15565	-0.09175
0.47582	-0.27709	0.83476

HISTOGRAM FOR COMPONENT 1

CELL WIDTH - 0.100

J START H(J),...H(J+9)

NUMBER OF CELLS 101

THE TOTAL NUMBER OF POINTS

	100											
1	-5.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	-4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	-3.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	-2.00	0.	1.	1.	0.	1.	3.	3.	4.	0.	3.	0.
41	-1.00	4.	4.	4.	5.	0.	3.	5.	4.	5.	0.	0.
51	0.00	2.	5.	3.	8.	3.	4.	2.	2.	0.	4.	0.
61	1.00	0.	4.	1.	0.	1.	2.	1.	0.	2.	1.	0.
71	2.00	1.	0.	2.	0.	1.	0.	0.	0.	0.	0.	0.
81	3.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
91	4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
101	5.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

HISTOGRAM FOR COMPONENT 2

CELL WIDTH - 0.100

J START H(J),...H(J+9)

NUMBER OF CELLS 101

THE TOTAL NUMBER OF POINTS

	100											
1	-5.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	-4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	-3.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.
31	-2.00	1.	1.	2.	2.	0.	4.	1.	2.	0.	2.	0.
41	-1.00	4.	2.	2.	3.	4.	5.	3.	3.	2.	3.	0.
51	0.00	4.	5.	5.	3.	2.	6.	0.	5.	8.	5.	0.
61	1.00	0.	1.	1.	1.	0.	1.	0.	0.	2.	1.	0.
71	2.00	0.	1.	1.	0.	1.	0.	0.	0.	0.	0.	0.
81	3.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
91	4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
101	5.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

HISTOGRAM FOR COMPONENT 3

CELL WIDTH - 0.100

J START H(J),...H(J+9)

NUMBER OF CELLS 101

THE TOTAL NUMBER OF POINTS

	100											
1	-5.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	-4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	-3.00	0.	0.	0.	0.	0.	0.	0.	1.	2.	0.	0.
31	-2.00	1.	0.	2.	0.	3.	1.	2.	4.	1.	0.	0.
41	-1.00	1.	1.	3.	1.	1.	1.	3.	3.	5.	5.	0.
51	0.00	1.	5.	7.	7.	3.	6.	7.	2.	4.	4.	0.
61	1.00	2.	2.	0.	1.	1.	0.	3.	0.	1.	0.	0.
71	2.00	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
81	3.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
91	4.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
101	5.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

PC-1

PC-2

PC-3

TEXAS GULF COAST 1 DETAILED AREA C

TEST DATA SET

PRINC COMP 1 SENSITIVITY 2.00 - 3.00 MM PNTS PLOTTED 4

TEXAS GULF COAST 1 DETAILED AREA C

TEST DATA SET

PRINC COMP 3 SENSITIVITY 2.00 - 3.00 MM PNTS PLOTTED 3

TEXAS GULF COAST 1 DETAILED AREA C

TEST DATA SET

PRINC COMP 3 SENSITIVITY 2.00 - 3.00 MM PNTS PLOTTED 1

DOES THE USER REQUIRE INSTRUCTIONS TO RUN THIS PROGRAM (YES OR NO) ? NO
INPUT DATA FILE TO BE READ FROM ?
Unit-20 :/ACCESS-SEQINOU/MODE=ASCII

Enter new file specs. End with an \$(ALT)
*TEXASC.DAT\$

INPUT DATA FILE TO HOLD PRINCIPAL COMPONENTS ?
Unit-21 :/ACCESS-SEQINOU/MODE=ASCII

Enter new file specs. End with an \$(ALT)
*TEXASC.PC\$

HAVE PC S BEEN CALCULATED FOR THIS DATA SET BEFORE (YES,NO) ? NO
INPUT THE FORMAT OF THE DATA (80 CHARS) ?
(I4,7X,2F10.5,A5,3F6.1)
INPUT DATA FILE FOR PC 1 OUTLIERS USED IN THE MAP ?
Unit-23 :/ACCESS-SEQINOU/MODE=ASCII

Enter new file specs. End with an \$(ALT)
*TEXASC.PC1\$

INPUT DATA FILE FOR PC 2 OUTLIERS USED IN THE MAP ?
Unit-24 :/ACCESS-SEQINOU/MODE=ASCII

Enter new file specs. End with an \$(ALT)
*TEXASC.PC2\$

INPUT DATA FILE FOR PC 3 OUTLIERS USED IN THE MAP ?
Unit-25 :/ACCESS-SEQINOU/MODE=ASCII

Enter new file specs. End with an \$(ALT)
*TEXASC.PC3\$

FILE NAME HOLDING HEADER INFORMATION ?
Unit-22 :/ACCESS-SEQINOU/MODE=ASCII

Enter new file specs. End with an \$(ALT)
*TEXASC.HED\$

SELECT HISTOGRAM PLOTS, PRINTOUT, OR BOTH
PLOTS ONLY=+1, BOTH=0, PRINTOUT ONLY=-1 ? 0
INPUT THE LOWER LIMIT TO BE USED IN THE PLOTS ? -5.
INPUT THE UPPER LIMIT TO BE USED IN THE PLOTS ? 5.

THE NUMBER OF CELLS TO BE USED IN THE HISTOGRAMS = 101

GIVE SPECIAL DATA TITLE FOR MAP ?
TEXAS GULF COAST DATA
HAS HEADER FILE BEEN WRITTEN (YES,NO) ? YES
INPUT THE LOWER LIMIT SENSITIVITY
FOR THE OUTLIER MAPS ? 2.
INPUT THE UPPER LIMIT SENSITIVITY
FOR THE OUTLIER MAPS ? 3.
DOES THE USER WISH TO CALCULATE THE
CORRELATION OR COVARIANCE MATRIX (CORRE OR COVAR) ? COVAR
DOES THE USER WISH TO SORT THE DATA
ON A FLIGHT LINE BASIS (YES OR NO) ? NO
DOES THE USER WISH TO SORT ON A GEOLOGICAL BASIS (YES OR NO) ? NO
DOES THE USER WISH TO TAKE THE SQUARE ROOTS OF THE DATA ? YES

APPENDIX C

PCA Documentation File

THIS PROGRAM WAS DESIGNED TO USE THE PLOT10 AND AG2 GRAPHIC ROUTINES AND A TEKTRONIX 4015-1 TERMINAL WITH 4096 ADDRESSABLE POINTS AND A HARD COPY UNIT.

THE INPUT PARAMETERS NECESSARY TO EXECUTE THE PRINCIPAL COMPONENT PROGRAM ARE AS FOLLOWS:

- 1) THE NAME OF THE DATA FILE TO BE PROCESSED.

NOTE : THIS DATA FILE MAY BE IN ANY FORMAT WITH THE LATITUDE FIRST , THE LONGITUDE SECOND AND THE K,U & T DATA LAST. THE K,U & T DATA MAY BE IN ANY ORDER.

- 2) THE NAME OF THE FILE WHICH WILL RECEIVE THE MEAN VECTOR, THE COVARIANCE MATRIX, THE EIGENVALUES, AND THE PRINCIPAL COMPONENT MATRIX. THIS IS NAMED XXXXXX.PC BY CONVENTION.

- 3) THE PROGRAM WILL NOW ASK IF THE PRINCIPAL COMPONENTS HAVE BEEN CALCULATED BEFORE. IF THE ANSWER IS YES THEN THE FILENAME SUPPLIED IN STEP 2 MUST CORRESPOND TO THE FILENAME USED BEFORE. THIS CAN RESULT IN SIGNIFICANT SAVINGS IN TIME DEPENDING ON THE SIZE OF THE DATA SET.

- 4) INPUT THE DATA FORMAT. THIS INPUT IS LIMITED TO 80 CHARACTERS AND MUST BEGIN AND END WITH PARENTHESES.

- 5) THREE FILENAMES MUST BE ENTERED NEXT. THESE FILES WILL RECIEVE THE DATA USED IN THE MAPS. THE CONVENTION FOR NAMING THESE FILES IS:

XXXXXX.PC1
XXXXXX.PC2
XXXXXX.PC3

- 6) THE PROGRAM WILL ERASE THE SCREEN AND ASK FOR THE FILENAME CONTAINING THE HEADER INFORMATION IF THE HEADER HAS BEEN CREATED PREVIOUSLY. IF NOT, THEN NAME THE FILE XXXXXX.HD.

- 7) AT THIS POINT THE USER IS ASKED TO SELECT HISTOGRAM PLOTS, PRINTOUTS OR BOTH BY INPUTING A (+1) FOR PLOTS ONLY, A (0) FOR BOTH, OR A (-1) FOR PRINTOUTS ONLY.

- 8) THE PROGRAM NOW ASKS FOR THE MINIMUM VALUE TO BE USED IN THE HISTOGRAMS. THIS VALUE MAY BE + OR - SO LONG AS IT IS LESS THAN THE MAXIMUM VALUE FOR THE HISTOGRAMS. THIS NUMBER IS INPUT IN FLOATING POINT.

- 9) THE MAXIMUM VALUE FOR THE HISTOGRAMS IS NOW LOADED. THIS NUMBER IS INPUT IN FLOATING POINT.

NOTE : THE USER MUST BEAR IN MIND THAT THE DATA PLOTTED IN THE HISTOGRAMS IS NORMALIZED DATA AND THE MIN & MAX VALUES INPUT IN STEPS 8 & 9 WILL BE REPRESENTATIVE OF THE STANDARD DEVIATION OF THAT DATA.

- 10) THE PROGRAM NOW CALCULATES AND PRINTS OUT THE NUMBER OF BENS USED IN THE HISTOGRAMS. THE NUMBER OF BENS WILL NOT EXCEED 401. THE BENS WILL REPRESENT .1 SIGMA UNLESS THE NUMBER EXCEEDS 401.

- 11) THE PROGRAM ASKS FOR A SPECIAL DATA TITLE FOR THE MAPS. ANY PERTINENT INFORMATION ABOUT THE DATA MAY BE ENTERED HERE.

- 12) THE PROGRAM NOW ASKS IF THE HEADER FILE HAS BEEN GENERATED PREVIOUSLY. IF THE ANSWER IS YES, THE PROGRAM PROCEEDS TO STEP 20. IF THE ANSWER IS NO, THE PROGRAM WILL PROCEED WITH THE NEXT STEP.

NOTE: IF THE ANSWER TO #3 IS YES, THEN PROCEED WITH #21.

- 13) IT NOW ASKS FOR THE NORTHWEST CORNER LATITUDE IN DECIMAL DEGREES.
- 14) IT NOW ASKS FOR THE NORTHWEST CORNER LONGITUDE IN DECIMAL DEGREES.
- 15) INPUT THE CENTRAL MERIDIAN IN DECIMAL DEGREES.
- 16) INPUT THE N-S MAP SIZE IN DECIMAL DEGREES.
- 17) INPUT THE E-U MAP SIZE IN DECIMAL DEGREES.
- 18) INPUT THE E-U TIC INTERVAL IN DECIMAL DEGREES.
- 19) INPUT THE N-S TIC INTERVAL IN DECIMAL DEGREES.
- 20) INPUT THE TITLE FOR THE MAPS (80 CHARACTERS MAX).
- 21) THE NEXT TWO INPUTS ARE USED TO SET THE BOUNDS FOR OUTLIER SELECTION. INPUT THE MINIMUM SENSITIVITY.
- 22) INPUT MAXIMUM SENSITIVITY.

NOTE: THESE SENSITIVITIES ARE THE BASIS FOR GENERATING THE MAPS OF THE OUTLIERS. THEY MAY BE ANY NUMBER + OR - SO LONG AS THE MAXIMUM VALUE IS GREATER THAN THE MINIMUM VALUE. ALL THE NORMALIZED DATA POINTS THAT FALL WITHIN THIS RANGE WILL BE PLOTTED.

- 23) THE PROGRAM NOW ASKS THE USER TO SELECT EITHER THE COVARIANCE MATRIX OR THE CORRELATION MATRIX. THE CORRELATION MATRIX IS USED WHEN CALCULATING PRINCIPAL COMPONENTS ON DATA OF DIFFERENT UNITS. INPUT (COVAR) FOR A COVARIANCE MATRIX OR (CORRE) FOR THE CORRELATION MATRIX.
- 24) THE PROGRAM NOW ASKS IF THE USER WISHES TO SORT THE DATA ACCORDING TO FLIGHT LINES. A YES OR NO ANSWER IS REQUIRED.
- 25) IF THE ANSWER TO QUESTION #24 IS YES THEN INPUT THE STARTING FLIGHT LINE NUMBER.
- 26) IF THE ANSWER TO QUESTION #24 IS YES THEN INPUT THE ENDING FLIGHT LINE NUMBER.
- 27) THE PROGRAM ASKS WHETHER OR NOT THE USER WISHES TO SORT THE DATA ACCORDING TO A CERTAIN GEOLOGY. A YES OR NO ANSWER IS REQUIRED.
- 28) IF THE ANSWER TO QUESTION #27 IS YES THEN INPUT THE DESIRED GEOLOGIC CODE (FORMAT A5).
- 29) THE PROGRAM NOW ASKS IF THE USER WISHES TO TAKE THE SQUARE ROOTS OF THE DATA. TAKING THE SQUARE ROOTS OF THE DATA IS A GOOD FIRST ORDER APPROXIMATION OF POISSON COUNTING STATISTICS. A YES OR NO ANSWER IS REQUIRED.
- 30) AT THIS POINT ALL USER INTERACTION IS COMPLETED. THE PROGRAM WILL MAKE PRINTOUTS AND PLOTS AND MAKE COPIES OF EACH AUTOMATICALLY.

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Additional documents in this series, "Statistical Techniques Applied to Aerial Radiometric Surveys (STAARS)", are currently in preparation and scheduled for release in the near future. Tentative titles and/or subject matter covered are as follows:

Introduction to STAARS Series

Principal Components Analysis as Applied to Aerial Data

One document has been released at this time - "Statistical Techniques Applied to Aerial Radiometric Surveys (STAARS): Percentile Estimation with the Normal and Lognormal Distributions, GJBX-123(80).

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