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A Customized Database for the Analysis of Complicated Folding Structures, An Example from Wadi Fatima Area, Kingdom of Saudi Arabia

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ABSTRACT. Documenting structural data in database rather than flat files has been a great stimulation as it permits manipulating data in many forms and aspects that are necessary in the process of structural analysis. The highly complicated structural features gave rise to several structural elements in the area north of Wadi Fatima, Kingdom of Saudi Arabia. This required customizing a database for accommodating those diversified measurements in a relational fashion for the subsequent display, analysis and computation, according to the user's options using Visual Basic under Windows environment. Structural elements can be either merged or split into subsets based on station/substation measurements, to delineate domains of structural homogeneity. Folding analysis on stereoplots with fold girdles and principal axes of folding can be done using simple menus and commands.

Data can be entered through a menu for creating/updating the database files or it can be entered through any text editor according to a given data model. The database is provided with simple online help and supported with many warning messages to ensure proper use. The flexibility of the present database structure enables easy remodeling to fit structural data from complicated structural areas.

Introduction

Wadi Fatima is located at the western edge of the Arabian Shield about 50 km northeast of Jeddah, where the Precambrian basement rocks are overlain by a sequence of sedimentary section forming five prominent mountains (Fig. 1). This sedimentary sequence, known as Fatima Formation, is shortened consistently as indicated by northeast-southwest trending folds. Nebert *et al.* (1974) systematically mapped the Fatima Formation and produced the most comprehensive study of Wadi Fatima area. Moore and Al-Rehalil (1989), conducted a regional geological compilation of Makkah quadrangle including Wadi Fatima area. Zakir and Moustafa (1992) carried out a detailed structural analysis in Jabal Abu Ghurrah at the easternmost exposure of the Fatima Formation and they indicated that, the formation was subjected to a NNW-SSE tangential compression. The main access to the area is the Jeddah-Makkah highway to Bahrah, and then from Bahrah to Al-Jamum paved road.

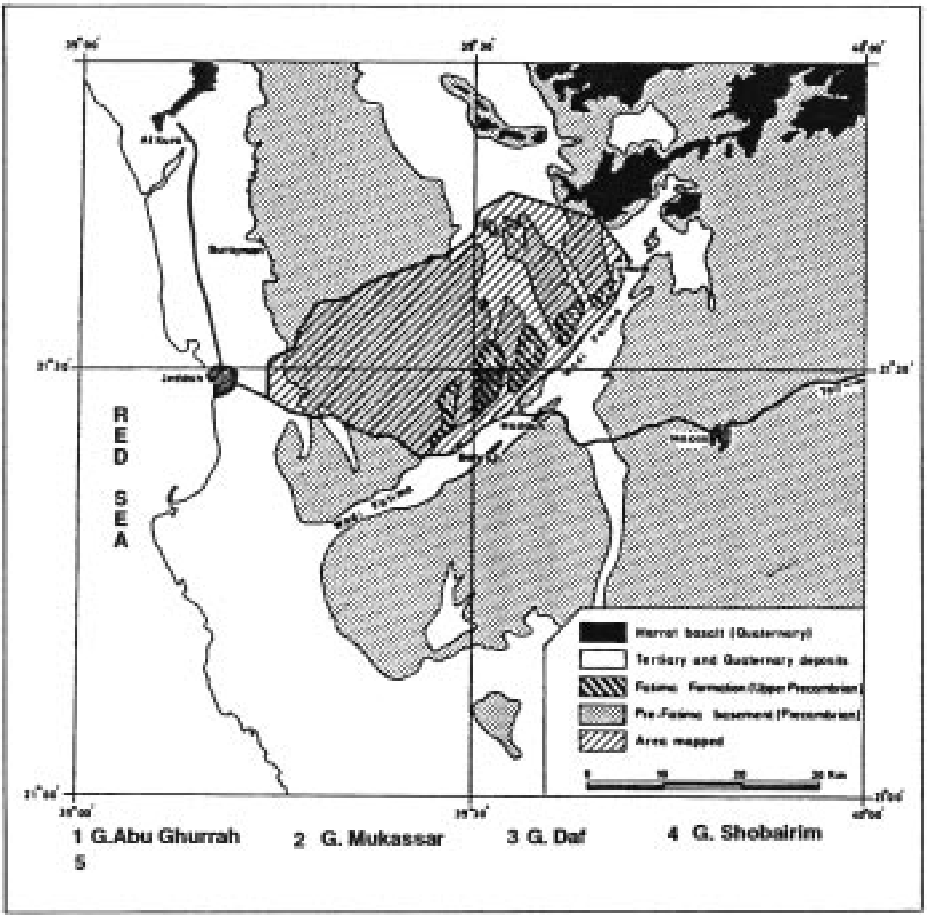

FIG. 1. Location of north Wadi Fatima area.

Structural data related to those conspicuous mountains have been partially documented in the database, while those collected from the eastern part of Jabal Shobairim (Fig. 2) are particularly used for demonstration.

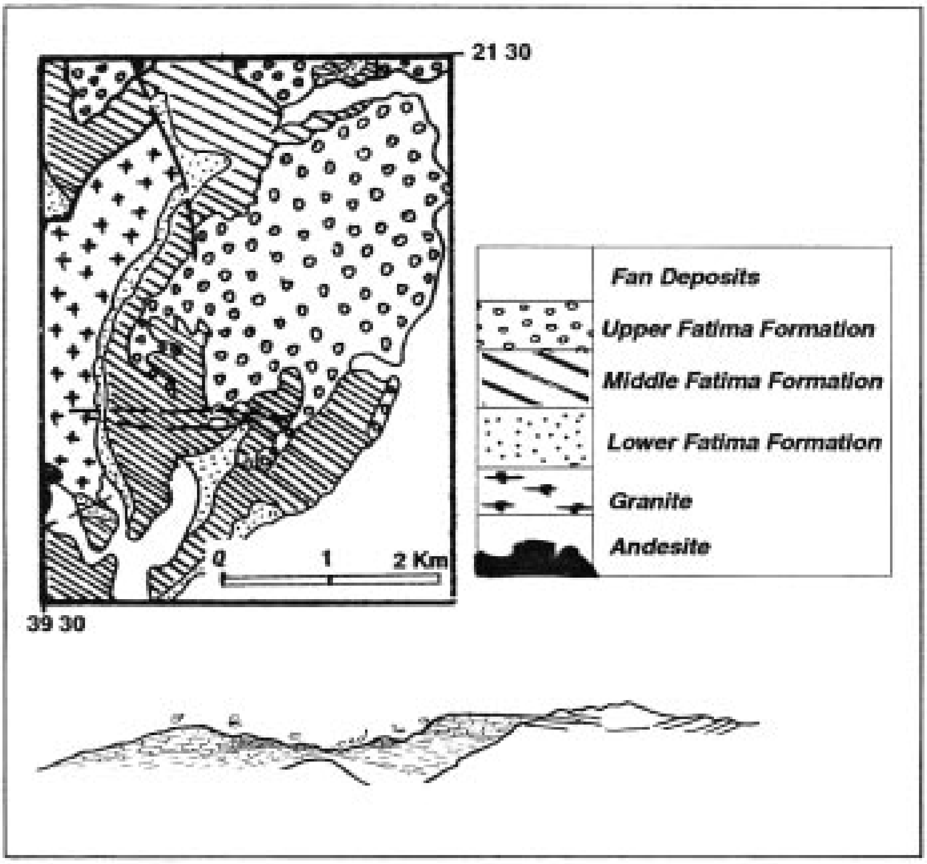

FIG. 2. Geologic map of the eastern part of Jabal Shobairim, modified after Nebert *et al.,* 1974.

The remarkable intensive folding and fracturing affecting Fatima Formation poses some questions about the way of documenting measurements for subsequent analysis and interpretation. In the first place, a special database should be design so that different types of data can easily be manipulated, through merging and splitting to define homogenous structural domains. The available on market S/W such as Rock Ware or Dips can hardly coup with such requirements. The file structure of such S/W is so rigid, that the user can neither split complicated data nor related data can be grouped together. The analysis of complicated folding structure is mainly based on the concept of structural domains (Turner and Weiss, 1963). Accordingly, any complicated folding structure can be divided into sets of homogenous domains so that the plot of lineations or poles to folded surfaces is disposed about a great circle (cylindrical folding). Further, the calculated fold axes are re-plotted (synoptic diagram) for the calculation of refolding axis

The present code was first written for an ICL, 1900 series main frame computer for the analysis of folding structures of Wadi Atalla, Central Eastern Desert of Egypt (Mostafa, 1979). Later on, the code was rewritten for the PC computer under DOS environment (Mostafa, 1990). In the last case, some basic subroutines were added to replace those called from the ICL Library (FPROOT1) to solve the eigenvalue/eigenvectors problem. Needless to say, those two versions of programming are nothing but text-based; where the user has no way of selecting from options or changing the order of procedures as dictated by the program. In the present study, the code was again written as Graphical User Interface (GUI) under Visual Environment as Windows Application. Microsoft Visual Basic (Version 5) is used for such an application. Although GUI environments require more complexes programming tools, users still feel free to select from menus and option buttons and previewing plots before printing.

Map Units

The exposed rocks of Jabal Shobairim area belong to two main series of rocks, namely the pre-Fatima basement and the Fatima Formation (Fig. 1&2). The pre-Fatima basement consists mainly of granite intruding the metamorphic rocks represented by hornblende schist, amphibolite and marble. Both the granite and metamorphic rocks are intruded by E-W and NE-SW trending andesite dykes and covered by volcanoclastics. The granites are 773±16 Ma old (Rb/Sr, whole rock age; Duyverman *et al.,* 1982)

The Fatima Formation consists of non-metamorphosed to very slightly metamorphosed (lower green schist facies) sedimentary rocks (Moore and Al-Rehalaili, 1989). Fatima Formation is divided into three main units:

i – Lower green clastic unit
ii – Middle carbonate unit of predominant yellowish-white color
iii – Upper clastic unit of a characteristic red color interbedded with pyroclastics and volcanics.

These three main units were named the lower, middle and upper members of the Fatima Formation respectively.

The lower Fatima member consists mainly of green siltstone, claystone, shale and coarse to fine grained arkosic and tuffaceous sandstone. Basal conglomerate bed(s) are exposed in many locations in the northern part of the area and includes sub-angular to rounded fragments derived from the underlying granite and older rocks. Cross stratification, current ripple marks and mud cracks characterize this member and indicate a shallow water environment of deposition.

The middle Fatima member includes a brownish-red, medium grained sandstone unit at the base and a yellowish white to gray limestone unit at the top with characteristic stromatolitic bed in the upper part. A thick andesite sill exists near the top of the middle Fatima member with thin limestone section overlying the andesite sill, and is thermally backed into white to olive green marble that marks the upper contact of the middle member.

The upper Fatima member consists of brick red siltstone and sandstone that exhibit ripple marks graded bedding and mud cracks. The siltstone-sandstone unit is interbedded and covered with andesite sills and flows and volcanoclastic and agglomerate beds.

Presentation of Orientation Data

The analysis and presentation used with vectorial data markedly differ from those applied to scalar variables. Scalars are quantities having magnitudes that can be described by a single number such as temperature, radioactivity and elevations. Vectors are quantities having magnitudes, directions and points of application. In our case, a vector's magnitude is arbitrarily assigned a unit value giving all observations equal weight. Vector sense is determined by the geological assumption that pole to bedding or foliation points towards younger or older successions as explicitly declared. If vectors lack sense they will be regarded as orientation measurements such as fold axes, rodding, elongated pebbles and poles to joint planes, because one end of the line can not be distinguished from the other.

The attitudes of orientation measurements are all measured by compass. For each measurement, two angles are recorded; u and v (spherical polar coordinates). The angle u denotes the azimuth from the north in clock-wise direction and v is the angle of dip/plunge (Fig. 3). The measured attitude may be parallel to the line of maximum dip of a plane (planar element) or it may be parallel to the line itself (linear element). The measured stations are labeled on maps with the identified rock type and the required notes. Orientation data can be presented by the two following techniques:

a) Spherical/Cartesian Coordinates

For the purpose of analysis, the measured attitudes whether of linear or planar elements can be regarded as a set of three dimension vectors. The attitude of planar feature is represented by a vector of unit length perpendicular to the plane. The attitude of a linear feature is represented by a unit vector parallel to it. The presumed positive sense direction is in accommodation to the projection of poles disposed on the lower hemisphere. Figure 3 shows the original (geographic) coordinates, a set of three mutually perpendicular axes intersecting at the origin of a unit sphere where vectors originate. The process of decomposing a vector into its three components is a basic one for the subsequent analysis and computation. The original measurements might be expressed in terms of axes positively directed to north (1-axis), east (2-axis) and vertically downwards (3-axis) satisfying the Right Hand Rule. It can be simply proved by trigonometry, that with these axes the direction cosines (l, m, n) of the line OP (measured in spherical polar coordinates) plunging v degrees in a direction u degrees east of north are:

$$l = Pcx = \cos v . \cos u \qquad m = Pcy = \cos v . \sin u \qquad n = Pcz = \sin v$$

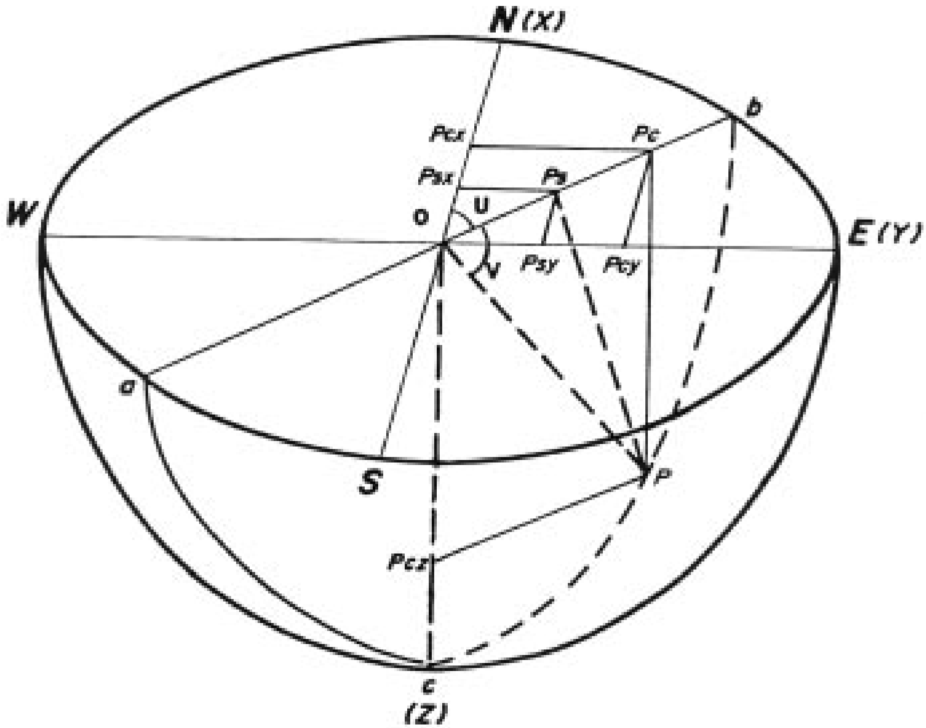

FIG. 3. Presentation of linear element/pole to planar element in spherical polar coordinates $P(u, v)$.
Projections:
a. cartesian (Pcx Pcy Pcz)
b. stereographic (Psx Psy)

The sum of squares of direction cosines is unity

$$l^2 + m^2 + n^2 = 1 \qquad \text{Pythagorean theorem}$$

It is convenient to adopt a more compact notation similar to that used in solid geometry and factor analysis (Harman, 1960). For a set of measured vectors, the direction cosines of the i-th measurement can be denoted as d_{i1}, d_{i2}, and d_{i3}; where the first subscript denotes the number of measurement and the second subscript denotes the axis from which the cosine is measured. The vector (di_1 di_2 di_3) can be more compactly denoted as d_i. The entire array of N such measurements arranged in n rows and three columns comprises the data matrix D. Underlining is used to indicate vectors and capital letters to indicate matrices.

The vector set A can be expressed by the data matrix D of the direction cosines as follows

$$D^T = \begin{pmatrix} d_{11} & d_{21} & d_{31} & d_{41} \text{-----------------} d_{n1} \\ d_{12} & d_{22} & d_{32} & d_{42} \text{-----------------} d_{n2} \\ d_{13} & d_{23} & d_{33} & d_{43} \text{-----------------} d_{n3} \end{pmatrix}$$

The superscript T denotes that the matrix is transposed, *i.e.,* rows and columns are interchanged. The following computations stem from the matrix D using the symbol i to indicate summation of the expression that follows for all values of i from 1 to N.

1 – Sum of direction cosines on each axis is as follows

1 – axis; Σd_{i1}
2 – axis; Σd_{i2}
3 – axis; Σd_{i3}

2 – The variance-covariance or dispersion matrix C is formed by summing squares of direction cosines on each axis, and summing cross products of direction cosines between the appropriate pairs of axes.

$$C = \begin{pmatrix} \Sigma(d_{i1}.d_{i1})/N & \Sigma(d_{i1}.d_{i2})/N & \Sigma(d_{i1}.d_{i3})/N \\ \Sigma(d_{i2}.d_{i1})/N & \Sigma(d_{i2}.d_{i2})/N & \Sigma(d_{i2}.d_{i3})/N \\ \Sigma(d_{i3}.d_{i1})/N & \Sigma(d_{i3}.d_{i2})/N & \Sigma(d_{i3}.d_{i3})/N \end{pmatrix}$$

The matrix C can be written in a compact notation as follows

$$C = \begin{pmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{pmatrix}$$

The general term in C is c_{ij}.

The terms in the leading diagonal where $i = j$ are sum of squares of direction cosines on each of the three defined axes. The other terms where i & j are sum of cross products of direction cosines between the defined pairs of axes. The terms $c_{ij} = c_{ij}$, $i = j$. The matrix C is symmetric with real elements. According to Bellman (1970) and Carr (1995) a symmetric real matrix is characterized by:

1 – The matrix coincides with its transpose.
2 – All the eigenvalues of a symmetric matrix with real elements are real.
3 – The characteristic equation of a symmetric real matrix has only real roots (eigenvalues).
4 – The eigenvectors of a symmetric real matrix corresponding to distinct eigenvalues are orthogonal among themselves.
5 – Any real symmetric matrix can be reduced to diagonal form by means of a similarity transformation, the elements of the leading diagonal are the eigenvalues.
6 – For every linear transformation with a real symmetric matrix there is an orthogonal basis (consisting of real eigenvestors of the given matrix) in which the transformation matrix is diagonal.

These characters of the symmetric real matrix are the foundations for the subsequent computation in folding analysis.

b) Stereographic Projection (Equal Area)

Stereographic projection or stereogram is two-dimensional mode-representing points distributed on the surface of a sphere. This mode is commonly used in structural geology, petrofabrics and cartography. The equal area stereographic projections are only used throughout the present work. Stereograms are projection for points disposed on the surface of lower hemisphere of radius R. For the purpose of automatic plotting of the data it is required to manipulate analytically the equation of projection and finding out the indices of the projected point in a two dimension Cartesian coordinates. Figure 3 shows the vector OP plots at point Ps with coordinates Psx and Psy when projected from the lower hemisphere by an equal area projection as follows

$$OP = 2\sqrt{R}\sin(45 - v/2)$$

The coordinates (x, y) of the point P are computed as follows

$$x = Psx = 2\sqrt{R}\sin(45 - v/2).\ \cos\ u$$

$$x = Psy = 2\sqrt{R}\sin(45 - v/2).\ \sin\ u$$

where, R is the radius of the sphere and u & v are the direction and amount of dip of the given line Op. The coordinates of the point g' (x, y) are referred to the origin of the stereogram. For automatic plotting it is better to translate the origin O a distance R to the west and a distance R to the south. The origin O occupies the lower left corner of a square of side R long. The new set of coordinates is modified for automatic plotting as follows

$$x = R + (2\sqrt{R}\sin(45 - v/2).\ \cos\ u)$$

$$y = R + (2\sqrt{R}\sin(45 - v/2).\ \sin\ u)$$

Folding Analysis

Folds might be regarded as three-dimensional bodies that could be randomly oriented in space. Recent studies treat the geometrical measurements of the folded surfaces in order to find out the symmetry elements inherited in the folds that can be taken for further and concrete definition and classification of folds.

Structural measurements are generally referred to geographic (original) axes as oriented objects in three-dimension space. These reference axes bear no relation to the measured structure. As pointed out by Paterson and Weiss (1961), the investigator frequently wishes to consider three-dimensional phenomena in terms of their symmetry, similar to that in crystallography, crystal faces are fully described with reference to the symmetry elements using Miller indices. Symmetry arguments are well known in structural geology. For instance, a geologist may consider a structure in terms of folding parallel to the fold axis and folding normal to the fold axis in the belief that these directions are related to the stress pattern that produced the fold. Paterson and Weiss (1961) showed that the symmetry argument is implicit in the conclusions of many other geologists who may relate, for example, the symmetry of a sedimentary deposit to the symmetry of the current movement which produced it. Paterson and Weiss (1961) quote Curie (1884) as stating "When certain cause produces certain effects, the elements of symmetry of the cause must be found again in the effects produced". This is the impressive concept of cause and effect.

Three numbers representing the cosines of the angles between the measurement and each of the three reference axes can express each measurement of orientation data. If the numbers are regarded as the original variable techniques similar to those of factor analysis can be used to compute new variables, which have real physical significance. The new variables are for the same measurements but referred to new axes, which are three mutually perpendicular lines in space referred to as the principal axes. The process in referring measurements to symmetry axes of folding is similar to that used in factor analysis. Having analyzed a distribution of three dimension vectors into components, which have meaning in terms of the symmetry of the distribution; standard statistical methods might be applied subsequently to analyze these components. The breakdown of a complex distribution into components allows quantitative methods to be applied in fields where such an approach had not previously been widely used (Loudon, 1964).

a) Variance-Covariance Matrix

The variance-covariance matrix C completely summarizes the data matrix derived in our case from folding measurements. But, it does not at first appear to give the geologist any information of value. Matrices, which refer to different folds, can not be used to compare the properties of the folds unless the folds happen to be similarly oriented in space. The reason for this is that the reference axes are arbitrary lines directed in north, east and vertically downward directions and the axes are not related to the particular fold under consideration. The values of the variance and covariance terms in the matrix reflect the amount of folding in different directions but the directions, do not have any apparent geological significance.

Folding is frequently described by a set of vectors normal to the folded surface. These are graphically disposed on a stereogram for investigating the pattern of fold with reference to the geographic (original) axes. On the other side vectors describing a folded surface can be numerically analyzed with reference to the original axes as an oriented object in three-dimension space. These geographic axes bear no relation to the measured structure and the investigator wishes to consider three dimension phenomena in terms of their symmetry. The latter will eventually reflect the symmetry of the applied force. In this way folds that are similar in style but randomly oriented in space will have the same statistical indices when referred to their principal axes. The computational methods use the following equations

$$d_{i1} = x = l = \cos u.\cos v,$$

$$d_{i2} = y = m = \sin u.\cos v$$

$$d_{i3} = z = n = \sin v$$

Where, (d_{ij}) is the general term in the data matrix D and i denote the i-th measurement and j denotes the order of the axis.

The variance-covariance matrix C is computed from the matrix D by finding means of sum of squares and sum of products on the appropriate axes. The matrix C is symmetric and real (positive definite), which is associated with real positive eigenvalues. The eigenvectors E corresponding to distinct eigenvalues are orthogonal among themselves (Davis, 1986 and Carr, 1995), *i.e., $CE = \lambda E$*

or $(C - \lambda I)\ E = 0$. For a given eigenvalue, there exists a vector E satisfying the equation if and only if $(C - \lambda I) = 0$, which means the matrix $(C - \lambda I)$ is singular. Having found the values of λ's from $(C - \lambda I) = 0$, the orthogonal matrix E can be calculated from the matrix equation $(C - \lambda I)\ E = 0$.

The original data (d_{ij}) can now be rotated to refer to the principal axes thus

$$t_{ij} = d_{ij} . E$$

b) Principal Axes of Folded Surfaces

The concept of computing the principal axes of a distribution is similar to the technique used in factor analysis by Harman (1960) which has been used in geology by Imbrie (1963). Loudon (1964) applied the method on a rather simple type of folds in two dimensions and has deepened the concept of rotating the original data matrix to refer to the symmetry axes, which have geological significance. The rotation of the data matrix D to refer to the principal fold axes permits to get three uncorrelated variates $(t_{i1}\ t_{i2}\ t_{i3})$ instead of the correlated ones $(d_{i1}\ d_{i2}\ d_{i3})$. The original three-dimensional vector distribution can be regarded as broken down into three uncorrelated scalar distributions by rotation to a position where covariance terms vanish or tend to zero. Statistical methods can be applied much more readily to the uncorrelated components than to the original vectors (Loudon, 1964 and Whitten.1966).

Again, the equation $(C - \lambda I)\ E = 0$ has a solution if and only if the matrix $(C - \lambda I)$ is singular, *i.e.* the determinant $IC - \lambda I = 0$, this when written in full gives

$$\begin{pmatrix} c_{11-\lambda_1} & c_{12} & c_{13} \\ c_{21} & c_{12-\lambda_1} & c_{23} \\ c_{31} & c_{32} & c_{33-\lambda_1} \end{pmatrix} = 0$$

This gives a cubic equation in (λ)

$\lambda^3 + a_2\lambda^2 + a_1\lambda + a_0 = 0$, where

$a_2 = -(c_{11} + c_{22} + c_{33})$, sum of the leading diagonal in C

$a_1 = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} + \begin{pmatrix} c_{11} & c_{13} \\ c_{31} & c_{33} \end{pmatrix} + \begin{pmatrix} c_{22} & c_{23} \\ c_{32} & c_{33} \end{pmatrix}$, sum of the principal minors

$a_0 = -\begin{pmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{pmatrix}$, the determinant of the matrix C

The above cubic equation is the characteristic equation of the matrix C (Bellman, 1970). So far we are dealing with a positive definite matrix C the latent roots of the characteristic equation are always positive and real. From the theory of equations, Cardan's method has been simplified by Mostafa(1979) for solving such a special case to calculate the eigenvalues (λ's) and eigenvectors (E).

$$E = \begin{pmatrix} e_{11} & e_{12} & e_{13} \\ e_{21} & e_{22} & e_{23} \\ e_{31} & e_{32} & e_{33} \end{pmatrix}$$

The three columns in the matrix E represent the direction cosines of the principal axes of folding. While E is an orthogonal matrix it transforms the distribution from one Cartesian coordinates (geographic) to another (principal fold axes) as follows

$$t_i = d_i \,.\, E$$

The rotated vector of the *i*-th measurement is

$$t_i = (\, t_{i1} \;\; t_{i2} \;\; t_{i3})$$

Each of the variates t_{i1}, t_{i2} and t_{i3} are uncorrelated and has direct geological significance, and can be treated independently of the other two.

Based on the characters of the orthogonal matrices the relation $E.E. = I$ holds true.

Software Documentation

Full documentation of the software (S/W) permits future upgrading and also to help users for proper performance. The items of S/W will be discussed as follows:

1. Interacting Windows with Database

Folding Analysis Window.
Refolding Analysis Window.
Preview/Print strereoplots Window.
Data Entry Window.

2. Modules

Reading file of database Module.
Stereoplots Module.
Computing principal folding axes Module.

3. Computational Subroutines

DCTRANS transforms data from spherical coordinates (*phi,* theta) to Cartesian coordinates (x, y, z). The subroutine also computes the variance-covariance matrix C as well as sum of direction cosines along the geographic axes.

EIGEN computes the eigenvalues (λ) and eigenvectors (E) from the matrix C.

ANGLE computes the attitude of the principal fold axes from the matrix E.

ROTATE rotates original data to refer to the principal axes of fold instead of referring to the geographic axes.

4. Plotting Subroutines

Plotting lines/poles to planes (point diagram).
Plotting lines/poles to planes with fitted fold girdle (pie diagram).

5. Procedural Subroutines

These are activated through mouse generated event.

6. Arrays

Different arrays are used for storing data and getting communication between subroutines.

Orientation data are plotted from lower hemisphere using equal area projection by default. Equal angle projection can be optionally selected.

User's Guide:

On starting the database, a logo is displayed which gives two choices:

1 – Folding analysis.
2 – Data entry.

– The folding analysis can be managed from three windows. The first one is the Folding Analysis Window (Fig. 4a,b) which provides a list to select the database to load, and a drop down menu containing different types of structural elements to select from.
– Station names are listed in the station list box. Double clicking a selected station directly lists substations in the substation list box.
– Choose between point diagrams with or without fitted fold girdles and – fold axes according to a selection from an option menu.
– The stereo plots are either one big plot or eight small satellite plots – according to a selection from an option menu.

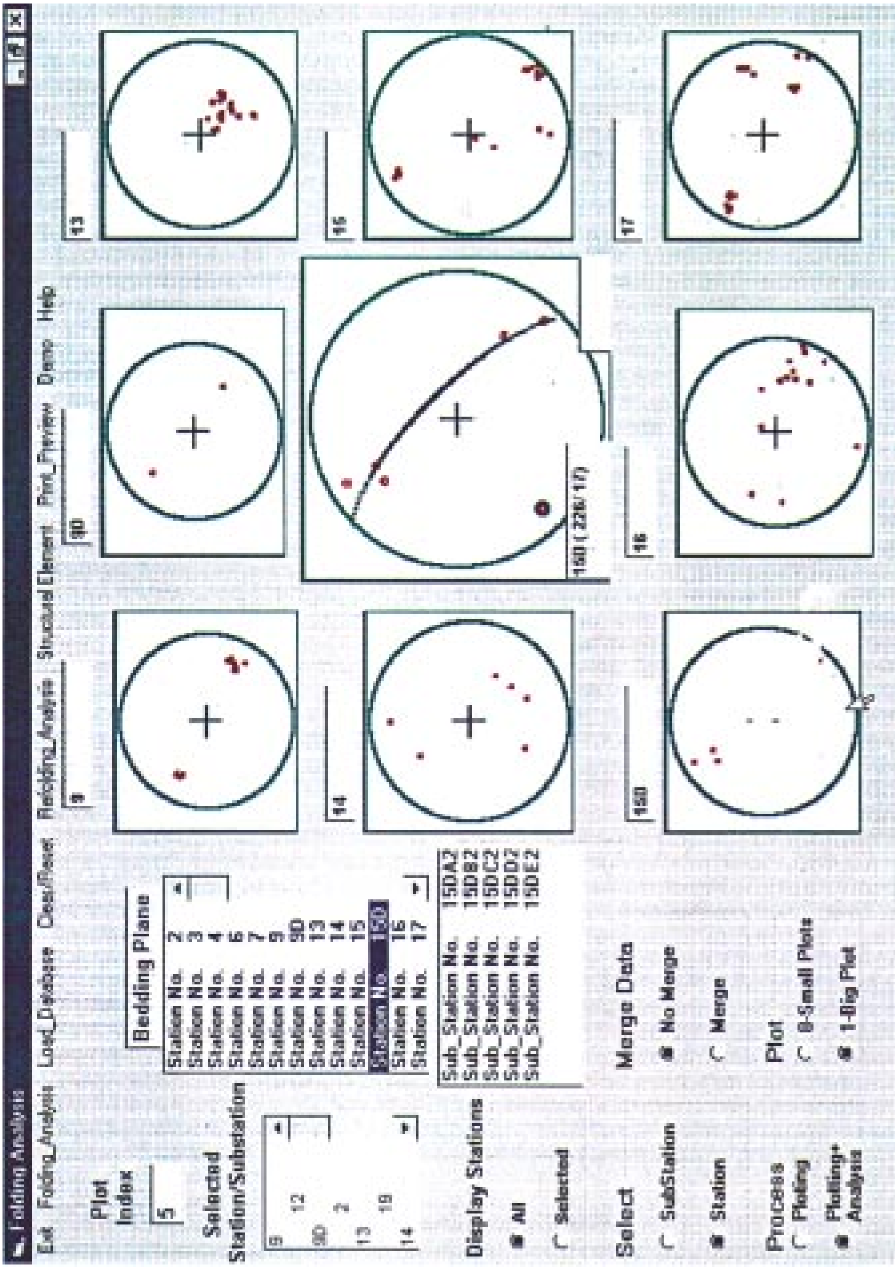

FIG. 4(a). Folding analysis window.

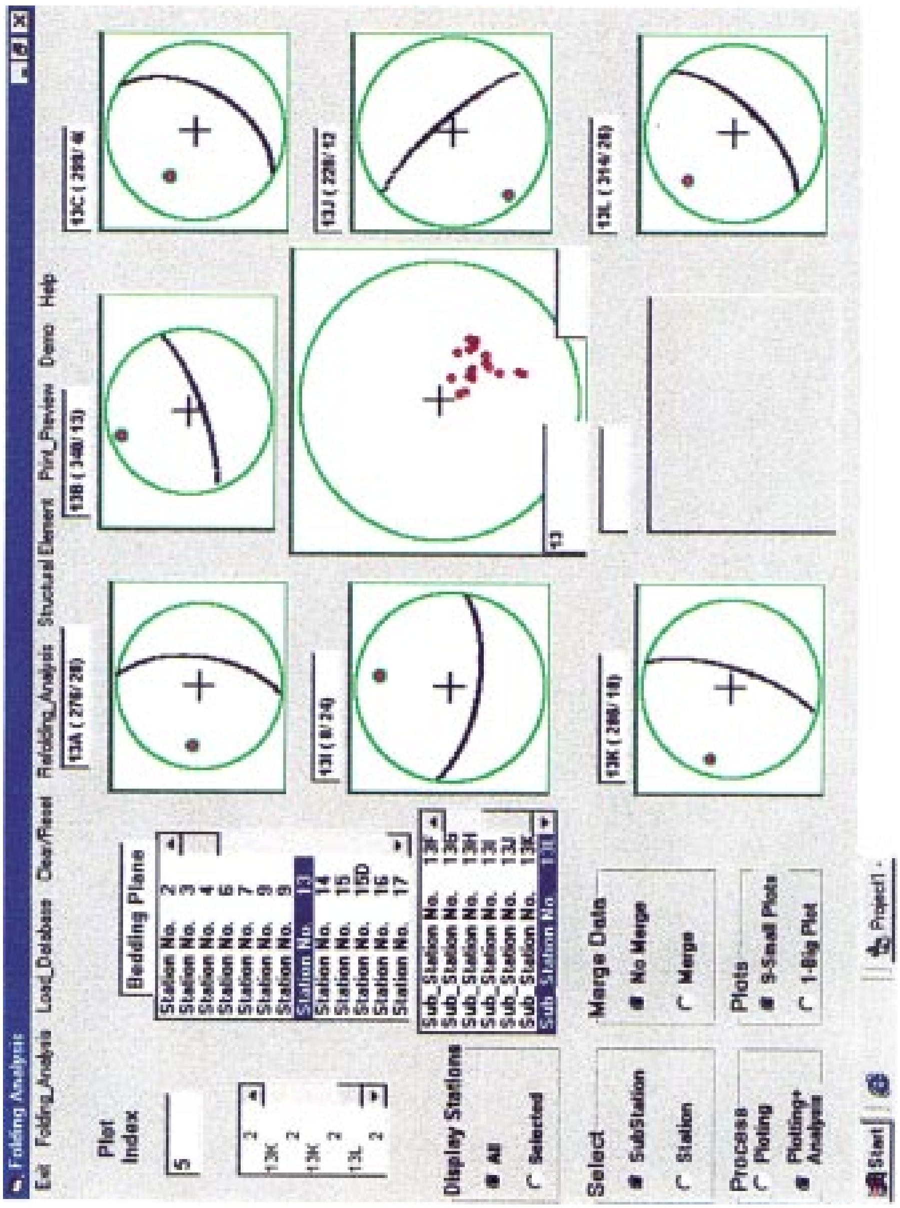

FIG. 4(b). Folding analysis window.

– To plot a station/ substation data on big plot double click on the station/ substation name in the appropriate list box after selecting one big plot option.

– To plot stations/substations data on small plots click on the small plot to set focus on, and then double click station/substation name in the appropriate list box after selecting nine-plot option.

– Data may also be merge from different station/substation in one plot after selecting eight-plot option.

– Do not forget to clear/reset the merge flag when turned to another operation.

– One big plot may be used for displaying complicated data of certain station. Meanwhile, on the small plots, data related to substations is displayed. Thus, the complicated fold can now be decomposed into sub-domains.

– Having decomposed a complicated fold into sub-domains go to the second window (Refolding Window, Fig. 5) to assemble the different fold axes on one plot fitted with a fold girdle whose pole represents the refolding axes.

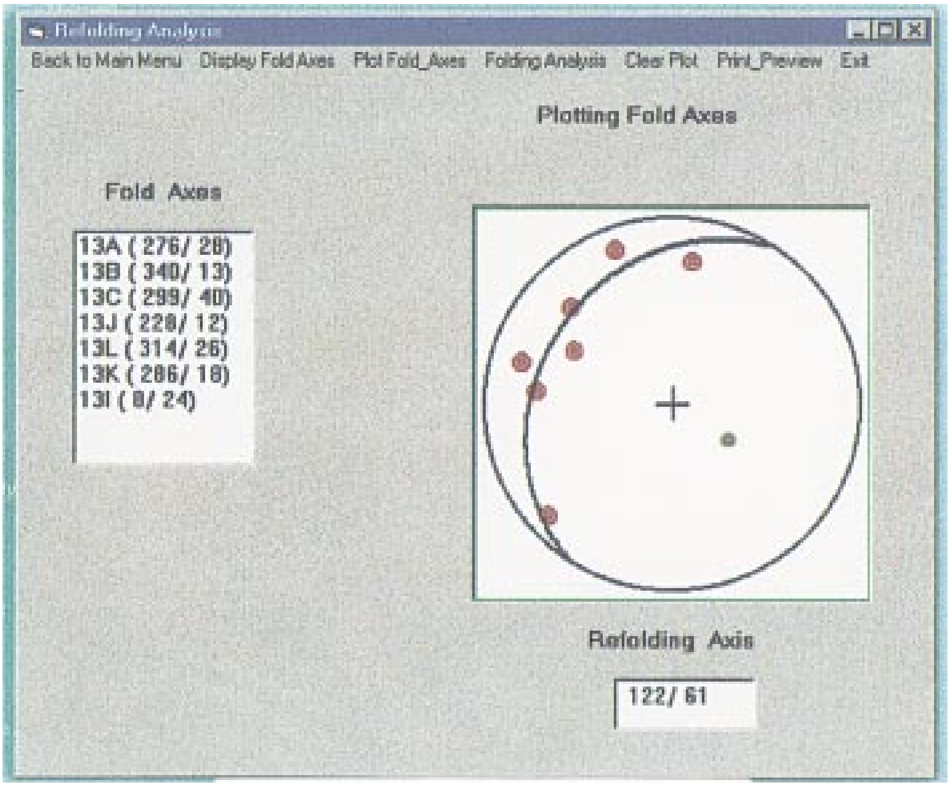

FIG. 5. Refolding analysis window.

– Facility is provided to discard one or more fold axes from the plot just to – improve the fitted girdle. This can be done through the Folding Analysis Window, where one can discard one or more odd plots that have no contribution to the folding pattern. One needs to double click the plot/plots to have them discarded.

– Plots from the first or second window can be previewed in the third – Preview Window (Fig. 6) before printing. Double clicking on the plot is needed to transfer it to the preview menu, where the previewed plots can be printed to fit an A4 page.

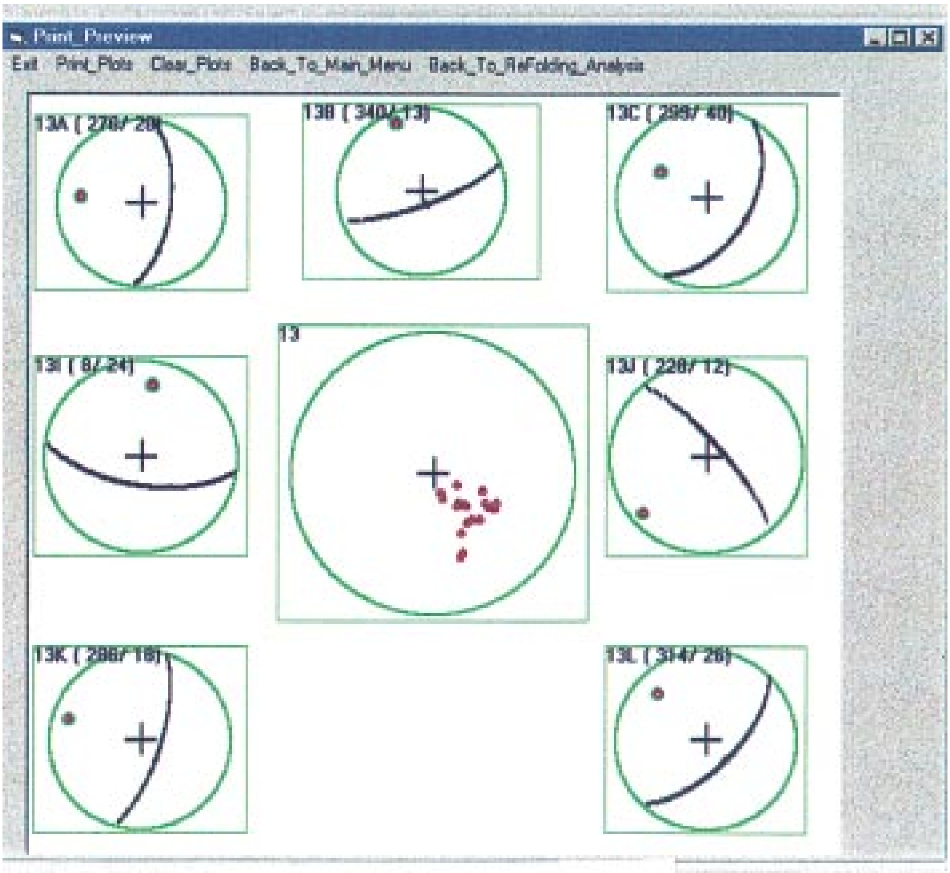

FIG. 6. Print preview window.

Entering data to the database file is done in two different methods:

1 – Via the data entry Window.

2 – Using a text editor according to a given data model file.

To enter data via the data entry window (Fig. 7), you are required to provide station/substation name, type of structural element and a string of the measurements themselves, delimited by spaces. Data is displayed while being entered and later transferred to a temporary file for further checking and editing. If they are valid, they are used to update/create the database-file.

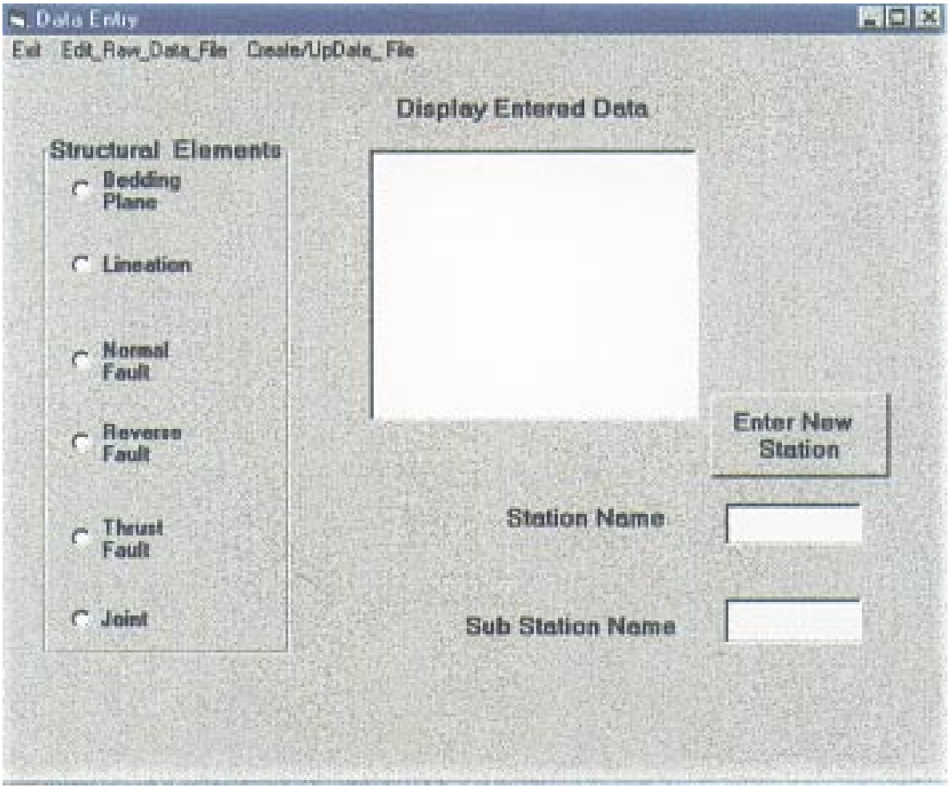

FIG. 7. Data entry window.

Entering data using a text editor is much simple and it can be done following the data file structure as shown in Fig. 8.

The previously discussed user's guide steps are part of the on line help.

Discussion

Samples of data from the eastern part of Jabal Shobairim are used for demonstration. Folding Analysis Window (Fig.4a) is provided with tools to plot and merge/split station/substation data of different structural types. Folding data are displayed as point diagrams with or without fitted fold girdle. The window shows plots of poles to bedding planes in different stations in Jabal Shobairim.

While some stations show simple folding patterns (#9,9D, and 15D), others show rather complicated folding patterns (#13,14,15,16 and 17). The central plot shows that measurements in station #15D are simply disposed about a great circle, with a sub-horizontal fold axis plunging 17 in the direction 226. Meanwhile, measurements in station #13 represent poles to a northwestern limb of a fold (Fig.4b) that has undergone flexing. According to substation measurements, this data has been further classified into homogeneous domains. Plotting fold axes from each such domain in one synoptic plot (Fig.5) shows that they are disposed about a great circle whose pole represents the refolding axis (122/ 61). One or more fold axes that are not disposed about the great circle can be canceled. From the Folding Analysis Window double clicking the aberrant domain(s) will cancel it. Repeating refolding analysis process will have the synoptic plot filtered.

Fig. 8. Samples of different types of structural datas held on the database file, Jabal Shoberim.

```
REM      STATION #6     FOLDED PART – TOP OF MIDDLE FATIMA
6, 1
1
9, BP
145  43  333  38  125  21  305  85  125  30  115  23
155  42  134  39  145  43
REM      STATION #7
7, 1
1
2, BP
175  34  165  30
REM      STATION #9(A1,B1,C1,D1,E1) FOLDED PART – MIDDLE FATIMA
9,5
9A1, 1
4, BP
304  69   300  58  300  57  298  55
9B1, 1
1, FH
034  02
9C1,  1
4, BP
117  60  120  58  119  61  115  57
9D1, 1
1, AP
125  83
9E1, 1
4 BP
292  65  295  62  289  290  62
```

Fig. 8. Contd.

```
REM   STATION #9D (A2, B2)     ANOTHER FOLD
9D, 2
9DA2, 2
1, BP
304   51
2, FH
025   04   021   10
9DB2,  1
1, BP
```

Legend:
Bedding Plane (DD/D) "BP", Axial Plane (DD/D) "AP", Fold Hinge (T/P) "FH", Cleavage (DD/D) "CLVG", Fold Limb (DD/D) "FDLMB", Lineation (T/P) "LN", Stretching Lineation (T/P) "STLN", JOINT (DD/D) "JT", Fault (DD/D) "NORFT", "REVFT", "THEFT".

The Print Preview Window (Fig.6) enables to transfer plots from other windows for previewing before printing.

The Data Entry Window (Fig.7) enables entering data of different structural types from different stations/substations. Data can be viewed/edited before transferring to the database files. Data can also be entered through a text editor according to the database file structure as shown in Fig. 8.

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إعداد وتصميم قاعدة بيانات خاصة لتحليل الطي المعقد في منطقة شمال وادي فاطمة – المملكة العربية السعودية

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المستخلص. تم خلال البحث الحالي إعداد وتصميم قاعدة بيانات خاصة لتحليل الطي المعقد في منطقة شمال وادي فاطمة بالمملكة العربية السعودية . تساعد هذه القاعدة في حفظ واسترجاع بيانات وعناصر تراكيب الطي المختلفة (خطية ومستوية) مما يسهل معالجة البيانات وذلك بفصل ودمج بيانات محطات القياس المختلفة للحصول على مايسمى بالنطق التركيبية المتجانسة والتي تتميز بأنها قد انطوت حول محور طي واحد . وعند إسقاط محاور الطي لتلك النطق على شبكة شميدت فإنها تقع على دائرة عظمى حيث يحدد محورها محور الطي الحديث ، مما يساعد في التعرف على التطور التركيبي بالمنطقة موضع الدراسة .

وقد استخدم في هذه الدراسة طرق المعالجة العددية لتحليل الطي بالإضافة إلى البرمجة باستخدام تطبيقات النوافذ . وقد روعي في تصميم هذه القاعدة تزويدها بما يؤكد سلامة ودقة الاستعمال ، كما تتميز بالمرونة حيث يمكن تشكيلها لتوائم أي بيانات تركيبية معقدة للمناطق المختلفة .