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SFARF: Software for Classification of Fourier Shape of the Fold around Tamadhaun, District Almora, Uttarakhand

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Abstract

Fourier (harmonic) analysis is a very simplified graphical method of plotting fold shapes in two dimensions. The authors have developed software (SFARF) to directly assign the class of fold shapes on the basis of the value of the ratio b3 / b1 (Fourier Coefficient). The various fold forms obtained by the software around Tamadhaun area reveal that fold developed in quartzite occurring in the study area vary in the range between sine-waves and parabolas to almost sine-wave, whereas the folds which are developed in phyllite and schist rocks are statistically between sine-waves to almost chevron.

Introduction

The Tamadhaun area covering an area of about 120 sq. km (Fig.1) is situated in Almora district and can be approached by road from Kathgodam which is the nearest railway terminal. The area around Tamadhaun forms the southern limb of Dudatoli Syncline where the Dudatoli – Almora Crystalline (Heim and Gansser, 1939) and phyllite (Kumar *et al.* 1974) are exposed (Fig 1). The area under investigation has undergone repeated phases of folding and faulting. The superposed mesoscopic structures observed by the authors also reveal that the area under investigation has suffered polyphase deformations (Shrivastava and Thomas, 1990; Thomas, 1991, 93, Shrivastava *et al.,* 2003).

The different folds developed in the area were studied with the help of Fourier (harmonic) analysis. One basic method used in mathematics for analyzing the curvature variation is to try a series of simple x – y functions and the technique is known as harmonic or Fourier analysis. Fourier (harmonic) analysis is a very simplified graphical method of plotting fold shapes on a two dimensional graphic (Hudleston, 1973). To express the slope of any curve, this analysis uses series of trigonometric functions, which is as follows:

$$f(x, y) = a_o + a_1 \text{Cos}X + a_2 \text{Cos}2X + a_3 \text{Cos}3X + \ldots\ldots + b_1 \text{Sin}X + b_2 \text{Sin}2X + b_3 \text{Sin}3X + \ldots \quad (1)$$

The curve is specified by various ‘a’ and ‘b’ parameters known as **Fourier Coefficients,** which refer to the amplitude of the various cosine and sine components.

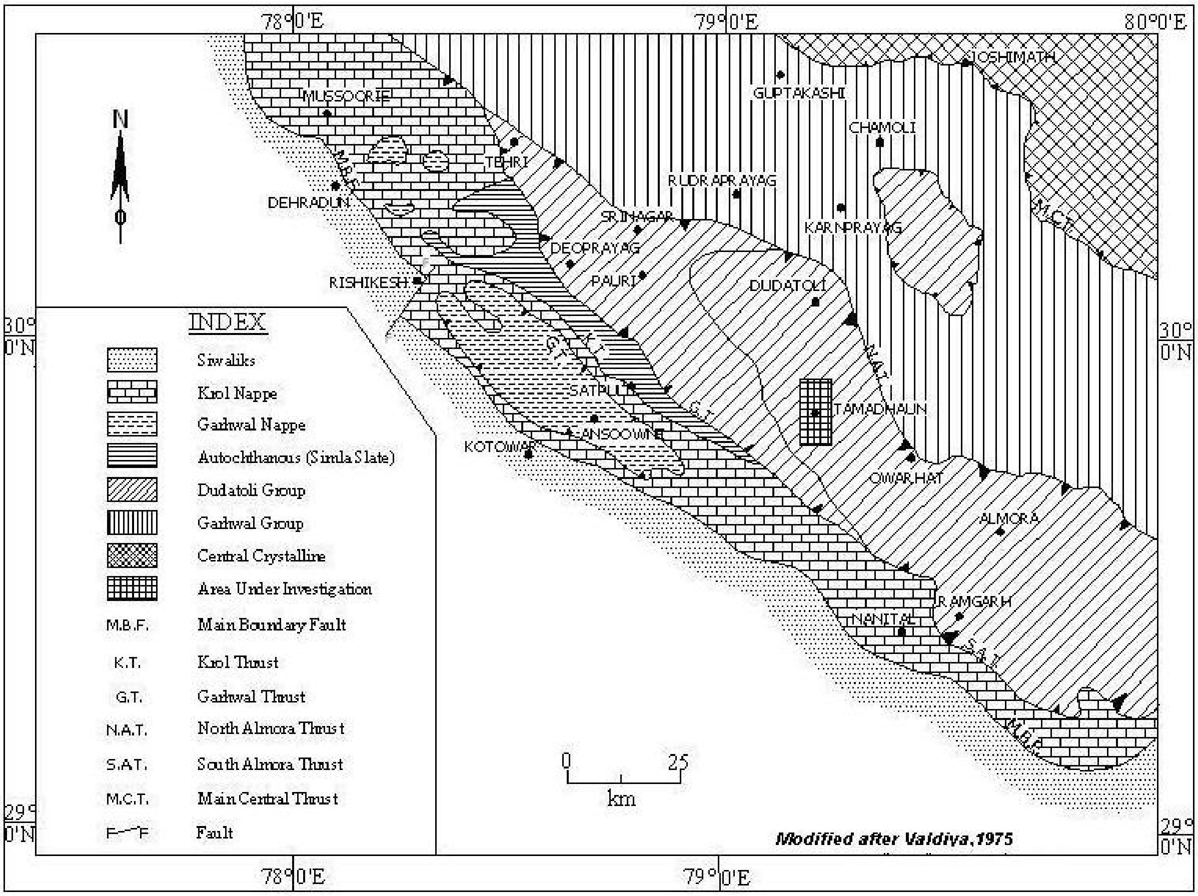


Fig.1: Simplified geological map of Kumaon Himalaya showing area of study

To make the analysis we first select a sector of complete layer between an inflexion (i) line and a hinge line (h). The coordinate axis 'y' is chosen so that it passes through the inflexion point (i) and is parallel to the axial surface of the fold. The x–axis of the coordinate system passes through inflexion point (i) perpendicular to the y–axis so that this originated from point "I" (Fig. 2A) with this coordinate frame, all the a – type Fourier coefficient became zero, only the b – type Fourier coefficient can be represented in the function and it has given to the changes in shapes of successive quarter wave sectors they must also be zero. Therefore, the reduced Fourier series can represent fold sector.

$$f(x, y) = b_1 \text{ Sin } X + b_3 \text{Sin} 3X + b5 \text{ Sin} 5X + \qquad .. (2)$$

It is clear that the successive coefficients in this series become smaller and in mathematical terminology the series converges very rapidly. Only the first three coefficients provide significant input into the description of the wave shape, and the third of these takes on a very small value.

The length of the line defining quarter wave base (W) is first measured and then divided into three equal parts. A normal on each trisecting points of the quarter wave base line is drawn so that it cuts the curved sector of the fold. The length of each of the three normal D_1, D_2, & D_3 (Fig. 2A) are measured. The quarter wave base (W) is then converted into **"π/2"** units, by dividing **"π/2 with W".** The parameter Y_1, Y_2, & Y_3 are then calculated by multiplying ($x = \pi/2W$) with D_1, D_2, & D_3 respectively as follows:

$$Y_1 = D_1 * X$$

$$Y_2 = D_2 * X$$

$$Y_3 = D_3 * X$$

$$\text{Where} \quad X = (\pi/2W) \qquad .. (3)$$

Stabler (1968) has proposed that Fourier coefficient b_1, b_2 and b_3 can be calculated by using equation (3) as follows:

$$b_1 = (Y_1 + \sqrt{3}Y_2 + Y_3) /3$$

$$b_2 = (2Y_1 - Y_3) /3 \qquad ... (4)$$

$$b_3 = (Y_1 - \sqrt{3}Y_2 + Y_3) /3$$

From the above equation b_2 and b_3 are providing the principal features of the fold shape and the positive values of b_3 reduce the amplitude effect of b_1, while negative values increases it (Huddleston, 1973). The other significant effect of the b_3 coefficient is to modify the shape of the sinusoidal b_1 components (Singh and Gairola, 1992; Thomas, 1993). Positive values of b_3 broaden the hinge region and tend to produce box – fold shapes (Thomas, 1993). Whereas negative values tend to steep and straighten the fold limbs and produces more chevrons like style (Thomas, 1993) (fig.2b).

The fifth (b_5) Fourier component / harmonic is very small and exerts very little geometric effect on the style, Huddleston (1973) has given a graphical method for plotting fold shapes by representing graphically b_1 as abscissa and b_3 as ordinate (Fig.3). Each fold shape has a characteristic b_3/b_1 ratio viz. Chevron, Sinusoidal, Parabolic, Semi-ellipse and box folds have b_3/b_1 values as 0.11, 0.000, 0.037, 0.165 and 0.333 respectively (Huddleston, 1973). Singh and Gairola (1992) modified the Huddleston's (1973) classification of fold shapes from eight types of fold shapes to sixteen types.

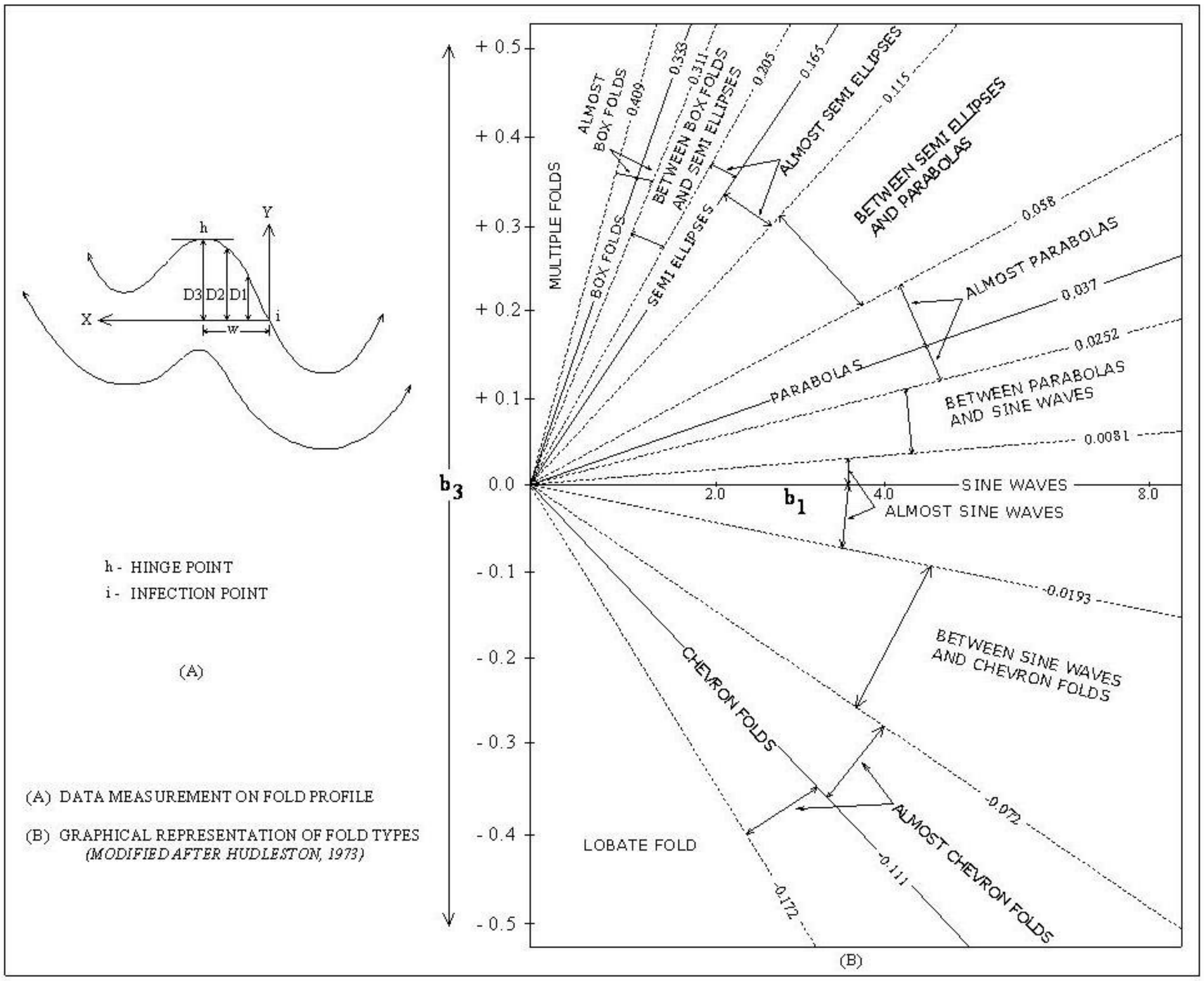


Fig.2: (A) Data measurement on fold profile, (B) Graphical representation of fold types (modified after Hudleston, 1973)

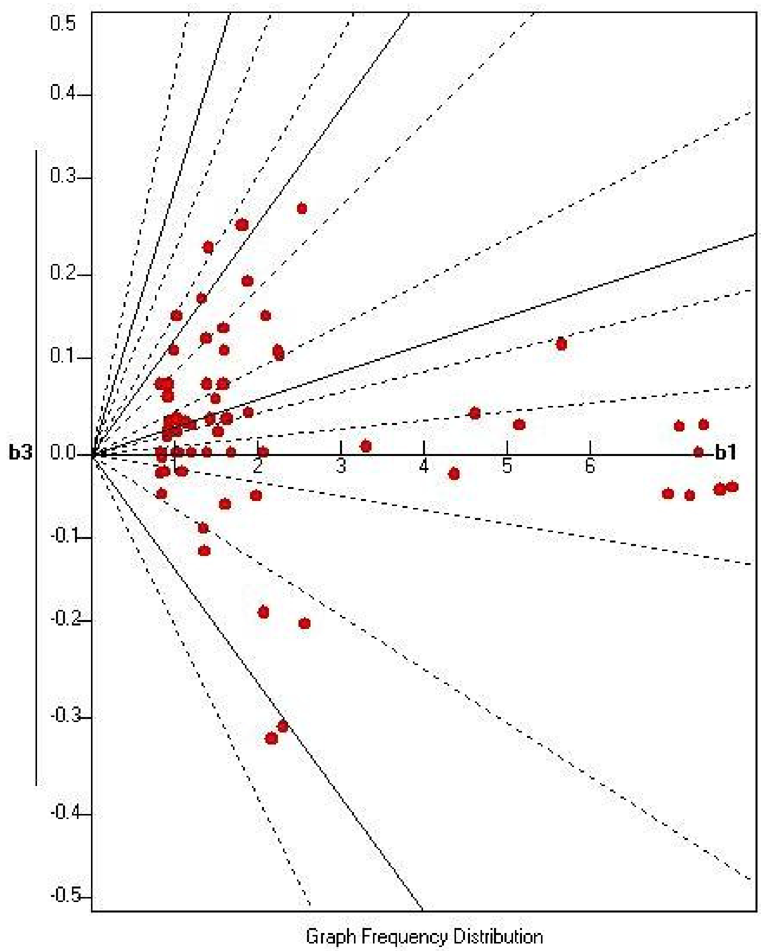


Fig.3: The graphical representation of various fold forms obtained by the Fourier analysis of the folds around Tamadhaun.

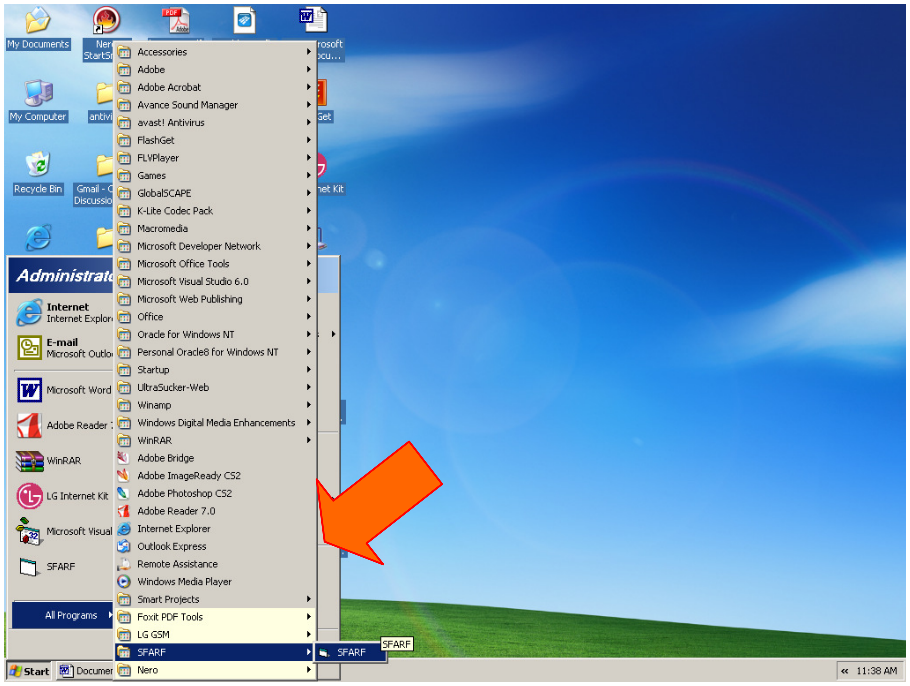
Thomas (1993) and Thomas and Thomas (2003) further modified the classification with replacement of cuspate fold by Lobate and developed a computer program in visual basic, which calculate the parameters b_1, b_3 and b_5 and ratios of b_3 and b_1. It directly assigns the class of fold shapes on the basis of the value of the ratio b_3 / b_1 (Table-1 and 2).

2. SFARF (Software for Fourier Analyses of Rock Folds) HELP

Execution of the software is very simple and user friendly.

How to start

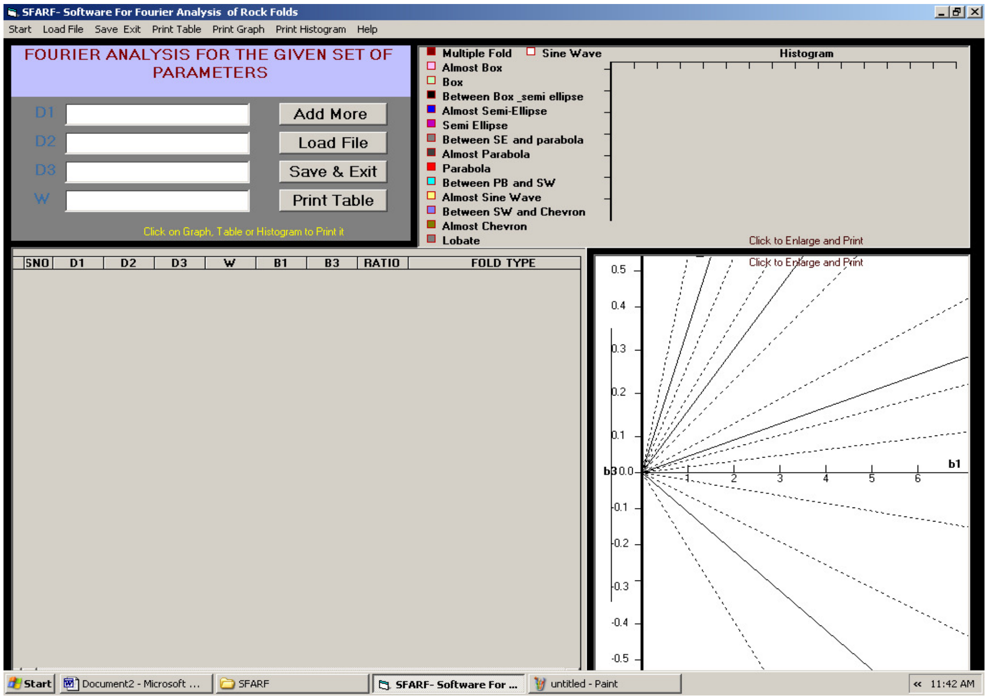
a. Click **Start -> All programs -> SFARF- > SFARF**



b. If you want to use any previous files then name the file with path and select **Load File**

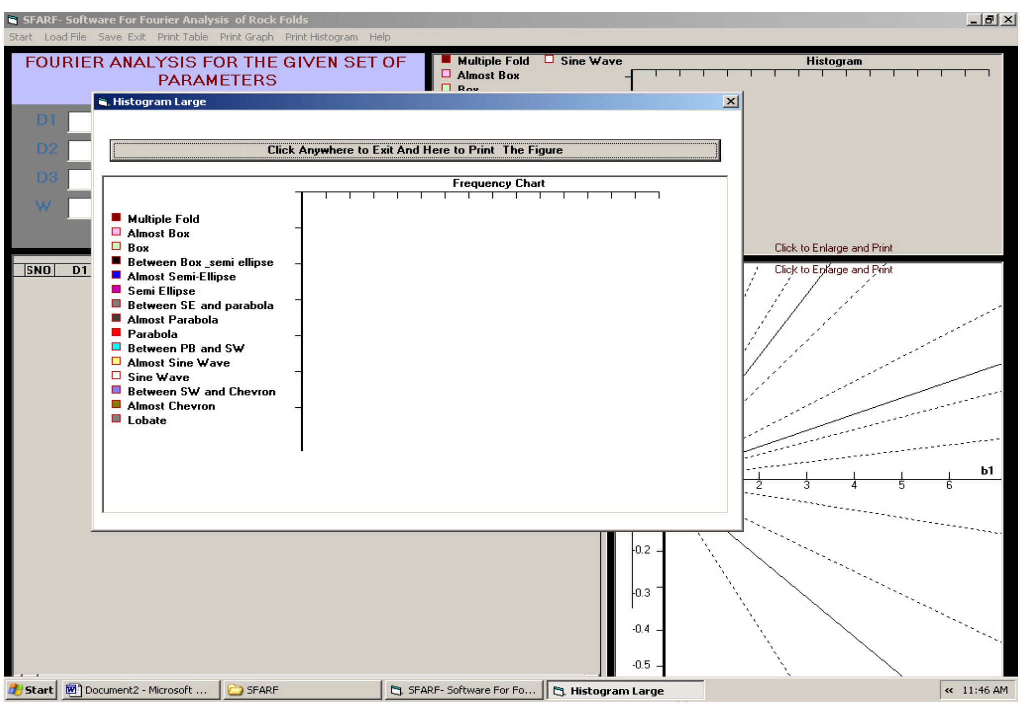
c. If you want a new dataset file then click **New File**

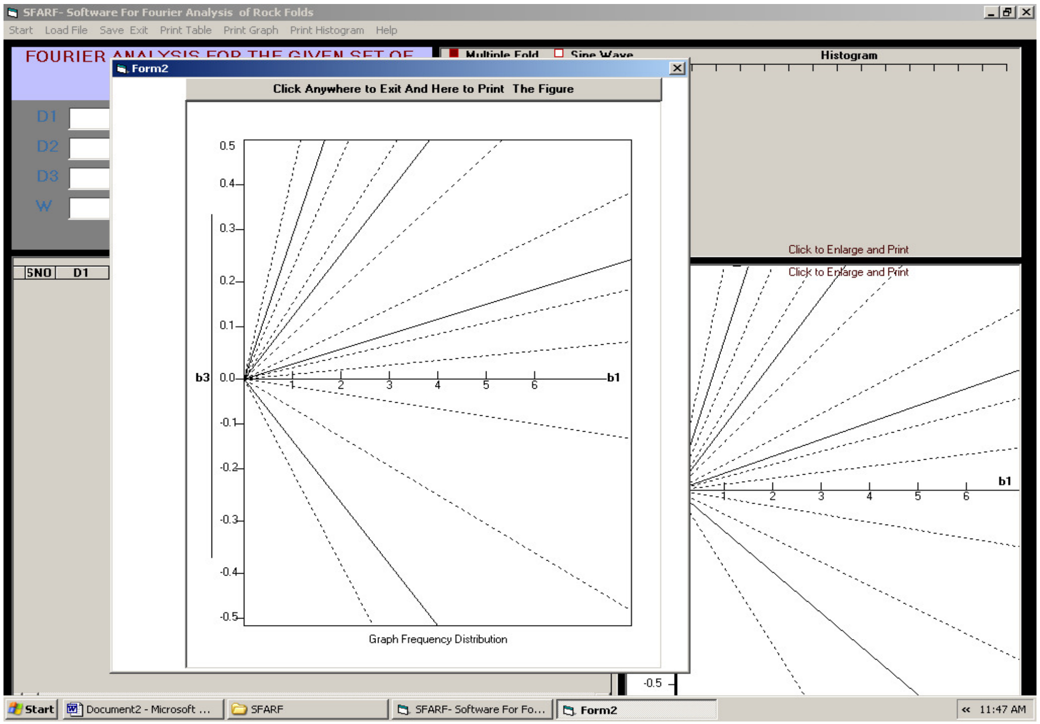
d. Enter the data on the left top section



e. As you will enter the data the entries in the table below will occur automatically and by same time you can see the histogram showing up along with the graph plotting.

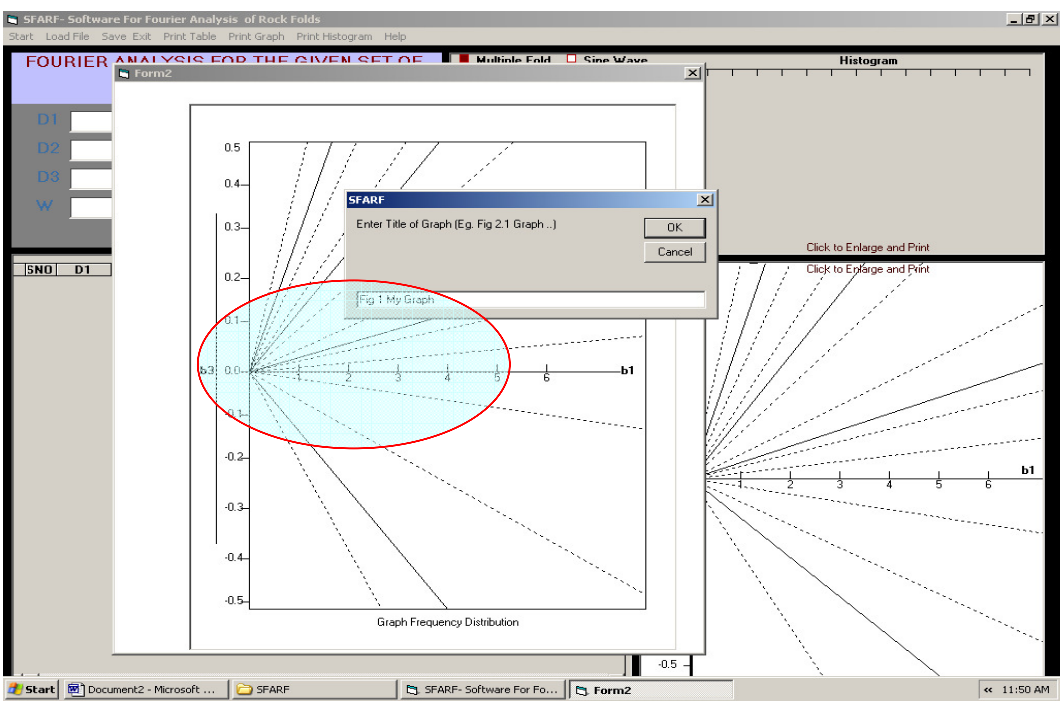
f. You can click on graph, histogram and table to enlarge it and print it





Click anywhere except the button on graph and histogram to return to the main screen.

When you click the print button for graph and histogram you are asked for the label you want to put on you can put any label you wish to.



Printing the Table

There is a limitation to this software that you can print only one table in a session. So be sure that your entries are complete when you choose to print.

In other case you might need to save the file and restart the application, load the same file and print the table with new entries.

The files will be saved by default in the installation directory (by default C:\Program Files\SFARF)

Saving the File

Click on Save and Exit

On the dialogue box put the name of the file without extension file will be saved and you will return to the main screen.

You can also exit from the application from here.

Discussion

For validation of the software (SFARF), several data had been manually calculated (Thomas, 1993 and Thomas and Thomas, 2003) and reprocessed through this Software. It was observed that all the results are same as manually calculated (Table-2 and Fig. 4). The various fold forms obtained by the Software around Tamadhaun area reveal, that quartzite are varying in the range between sine wave and parabolas to almost sine wave, whereas the folds which are developed in phyllite and schist rock are statistically almost chevron.

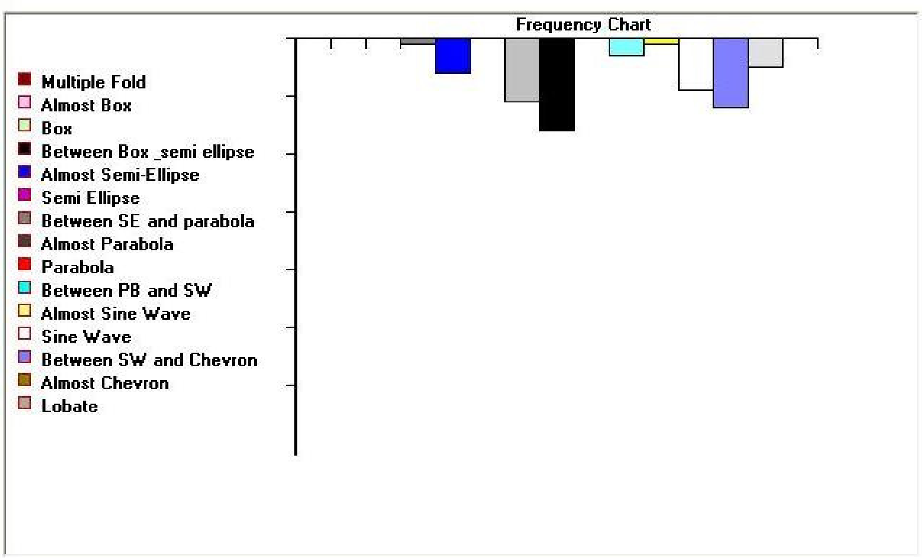


Fig. 4: Results obtained by Fourier analysis

Conclusion

The S/W developed for classification of fold shape is based on curvature variation i.e, Fourier analysis (harmonic) on the basis of (Hudleston, 1973 & Stabler, 1968) papers, This software is new and better than other software already available, because through this software, one can classify folds into sixteen types and simultaneously draw the two graphs (i.e. Fig. 3 & 4) and a table. The main aim of this paper is to publish the software for the geologists working in the field of structural geology.

Table -1: The class of fold shapes on the basis of the value of the ratio b_3/b_1 (Thomas, 1993)

Class of Fold Shapes	Value of the ratio of b_3/b_1
Multiple fold	>0.409
Almost Box fold	<0.409 to >0.333 and <0.333 to >0.311
Box fold	0.333
Between Box fold and Semi ellipse	<0.333 to >0.205
Almost Semi-ellipse	<0.205 to 0.165 and <0.165 to >0.115
Semi ellipse	0.165
Between Semi ellipse and parabola	<0.115 to >0.058
Almost Parabola	<0.058 to > 0.037 and <0.037 to >0.025
Parabola	0.037
Between parabola and sine wave	<0.025 to >0.0081
Almost sine wave	<0.0081 to >0.00 and <0.00 to > -0.0193
Sine wave	0.000
Between sine wave and chevron fold	< - 0.0193 to > - 0.072
Almost chevron fold	<-0.072 to >- 0.111 and <-0.111 to >-0.172
Chevron fold	-0.111
Lobate fold	<-0.172

Table - 2: Given values of D_1, D_2, D_3, W and results obtained by program b_3/b_1 and fold types

S.No.	D_1	D_2	D_3	W	b_3/b_1	Fold Type
1	0.90	1.20	1.30	0.70	0.117	Almost Semi-Ellipse
2	0.30	0.50	0.60	0.70	0.000	Sine Wave
3	0.65	1.15	1.20	0.85	0.026	Almost Parabola
4	0.65	0.90	0.95	0.70	0.111	Between Semi-Ellipse & Parabola
5	0.30	0.85	1.00	0.50	-0.144	Almost Chevron Fold
6	1.05	1.10	1.15	0.30	0.231	Between Box Fold & Semi-Ellipse
7	0.25	0.55	0.65	0.30	-0.081	Almost Chevron Fold
8	0.25	0.50	0.55	0.45	-0.030	Between Sine-Wave & Chevron Fold
9	0.30	0.50	0.55	0.60	0.029	Almost Parabola
10	0.20	0.35	0.40	0.60	0.000	Sine Wave
11	0.15	0.50	0.55	0.30	-0.160	Almost Chevron Fold

12	0.45	0.70	0.80	1.00	0.041	Almost Parabola
13	0.40	0.70	0.85	0.95	-0.020	Between Sine-Wave & Chevron Fold
14	0.30	0.50	0.55	0.50	0.029	Almost Parabola
15	0.30	0.55	0.65	0.40	-0.026	Between Sine-Wave & Chevron Fold
16	0.30	0.40	0.42	0.60	0.127	Almost Semi-Ellipse
17	0.50	0.70	0.80	0.50	0.080	Between Semi-Ellipse & Parabola
18	0.30	0.50	0.60	1.00	0.000	Sine Wave
19	0.30	0.50	0.70	1.00	-0.054	Between Sine-wave & Chevron Fold
20	0.30	0.30	0.45	0.50	0.107	Between Semi-Ellipse & Parabola
21	0.08	0.11	0.12	0.35	0.102	Between Semi-Ellipse & Parabola
22	0.18	0.47	0.50	0.30	-0.094	Almost Chevron Fold
23	0.16	0.18	0.20	0.20	0.179	Almost Semi-Ellipse
24	0.30	0.35	0.40	0.30	0.153	Almost Semi-Ellipse
25	0.35	0.55	0.60	0.35	0.053	Almost Parabola
26	0.20	0.37	0.40	0.25	0.000	Sine Wave
27	0.35	0.55	0.70	0.60	0.000	Sine Wave
28	0.46	0.65	0.70	0.60	0.096	Between Semi-Ellipse & Parabola
29	0.20	0.40	0.48	0.75	-0.058	Between Sine-Wave & Chevron Fold
30	0.35	0.55	0.65	0.50	0.026	Almost Parabola
31	0.40	0.70	0.75	1.10	0.021	Between Parabola & Sine-Wave
32	0.45	0.65	0.72	0.60	0.078	Between Semi-Ellipse & Parabola
33	0.25	0.45	0.50	0.78	0.000	Sine Wave
34	0.25	0.38	0.40	0.60	0.078	Between Semi-Ellipse & Parabola
35	0.45	0.70	0.80	1.10	0.041	Almost Parabola
36	0.20	0.30	0.35	0.60	0.047	Almost Parabola
37	0.25	0.50	0.60	0.85	-0.058	Between Sine-Wave & Chevron Fold
38	0.30	0.60	0.65	0.95	-0.025	Between Sine-Wave & Chevron Fold
39	0.40	0.65	0.70	1.30	0.045	Almost Parabola
40	0.45	0.68	0.80	1.00	0.041	Almost Parabola
41	0.40	0.55	0.60	1.00	0.102	Between Semi-Ellipse & Parabola
42	0.30	0.68	0.80	0.70	-0.088	Almost Chevron Fold
43	0.15	0.20	0.25	0.60	0.067	Between Semi-Ellipse & Parabola
44	0.08	0.12	0.15	0.55	0.023	Between Parabola & Sine Wave
45	0.10	0.20	0.24	0.65	-0.058	Between Sine-Wave & Chevron Fold
46	0.20	0.35	0.40	0.50	0.000	Sine Wave
47	0.22	0.35	0.40	0.45	0.033	Almost Parabola
48	0.60	0.85	0.90	0.90	0.101	Between Semi-Ellipse & Parabola
49	0.70	0.88	0.95	1.00	0.142	Almost Semi-Ellipse
50	0.50	0.85	0.95	0.80	0.017	Between Parabola & Sine-Wave
51	0.50	0.78	0.85	0.50	0.056	Almost Parabola
52	0.45	0.60	0.70	1.00	0.091	Between Semi-Ellipse & Parabola
53	0.30	0.45	0.55	0.75	0.031	Almost Parabola
54	0.30	0.60	0.75	1.20	-0.072	Between Sine-Wave & Chevron Fold
55	0.25	0.49	0.51	0.80	-0.006	Almost Sine-Wave
56	0.20	0.40	0.50	0.80	-0.072	Between Sine-Wave & Chevron Fold
57	0.50	0.95	1.00	1.10	0.000	Sine Wave
58	0.35	0.55	0.65	0.80	0.026	Almost Parabola
59	0.60	1.10	1.35	1.00	-0.039	Between Sine-Wave & Chevron Fold
60	0.65	1.20	1.30	1.00	0.000	Sine Wave

61	0.70	1.10	1.20	1.10	0.053	Almost Parabola
62	0.60	1.00	1.05	0.95	0.044	Almost Parabola
63	1.10	1.65	1.85	1.75	0.060	Between Semi-Ellipse & Parabola
64	0.32	0.70	0.80	0.72	-0.069	Between Sine-Wave & Chevron Fold

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