

CROSSBED: An Application For Determining Paleocurrent Direction from Polydeformed Cross-bedding Data

Introduction

The CROSSBED application is designed to retro-deform cross-bedding data to determine the paleocurrent direction. The application is designed for process cross-bedding from polydeformed terranes in a 2-step process:

1. Step 1 rotation: the rotation necessary to make the data station top/bottomset bed coplanar to the regional “tangent sheet layer” is calculated. The data station foreset attitude is rotated in the same manner. If the top/bottomset bed is overturned, the absolute value of the rotation is greater than 90 degrees. In **Figure 1** the angles α_1 and α_2 represent two examples of this rotation about the regional fold hinge. Rotating the top/bottomset bedding attitudes to be coplanar with the tangent sheet layer in effect retro-deforms the folded layer into a single plane.

2. Step 2 rotation: the second rotation is determined by calculating the rotation needed to move the regional tangent sheet layer attitude to the horizontal. The foreset attitude is rotated in this manner. The down-dip plunge and bearing is the paleocurrent direction. If a “simple” rotation is selected this step is skipped. The rotation of the tangent sheet layer to the horizontal attitude is indicated by angle δ in **Figure 1**.

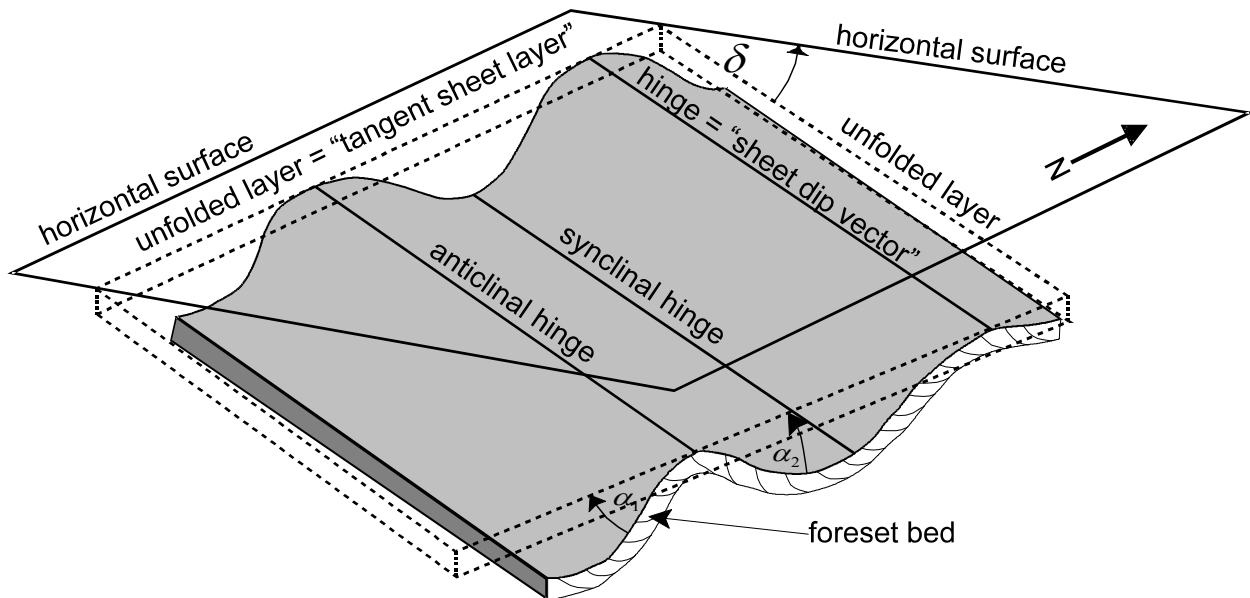


Figure 1: Hypothetical retrodeformation geometry requiring two stages of rotation.

Any type of paleocurrent data, including cross-bedding, may be retro-deformed to its original attitude as long as the primary top/bottomset bedding attitude is known at the location where the

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foreset attitude is measured and recorded. If paleocurrent data is measured from a terrane where regional folds plunge significantly, the user will need to determine the attitude of the "tangent sheet layer" attitude. The tangent sheet layer is defined as the attitude of the plane that would contain the regional fold hinge as the true dip vector. If the regional fold hinge is determined visually or statistically (i.e. plotting poles to top/bottomset attitudes to define a cylindrical fold girdle) on a stereographic projection, rotating the hinge point to the east-west line of the stereonet and tracing the great circle that the hinge falls upon will define the regional tangent sheet layer attitude. **Figure 1** displays the geometry of a plunging regional fold containing cross-bedding in a schematic example of a regionally folded terrane with a plunging hinge. Note that the rotation required to make the top/bottomset attitude coplanar with the regional tangent sheet layer is generally unique for each data observation, and therefore quite tedious to process manually. The rotation axis for the Step 1 rotation is defined by the pole to the plane that contains the top/bottomset pole, and the regional tangent sheet layer pole. This rotation axis will always fall on the regional tangent layer attitude great circle. **Figure 2** displays an example of the retro-deformation process given the following data:

- Regional tangent layer attitude: N 30 E 64 E
- Top/Bottomset attitude: N 10 W 72 W
- Foreset attitude: N 13 W 76 W

In this example the step 1 rotation is -58 degrees about the step 1 rotation axis (see **Figure 2**) that rotates the pole to the top/bottomset attitude (TP) to the pole to the regional tangent layer (RP). The foreset pole is rotated in the same manner moving the FP to FP' in **Figure 2**. Both of the step 1 rotations occur about the step 1 rotation axis, that is itself the pole to the plane containing TP and RP. The plane containing TP and RP is indicated in **Figure 2** by the great circle passing through these two points. Because of the geometrical model used by CROSSBED rotations viewed down-plunge of the rotation axis are positive if counterclockwise, and negative if clockwise. Therefore, visualization of TP being rotated through less than 90 degrees to the RP

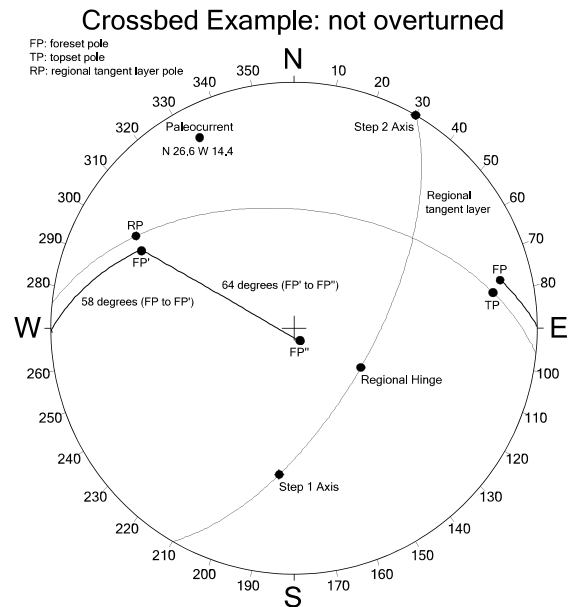


Figure 2: Example of rotation path for retro-deformation.

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position in **Figure 2** must be clockwise (i.e. -58 degrees).

Rotation of FP by -58 degrees to FP' about the step 1 axis is indicated by the small circle path in **Figure 2**. Unless the top/bottomset bedding is overturned, the absolute value of the rotation is always less than 90 degrees. In the case of overturned top/bottomset bedding the absolute value of the step 1 rotation is greater than 90 degrees- in the **Figure 3** example -168 degrees. The step 2 rotation is always less than 90 degrees since it simply removes the dip from the regional tangent layer attitude.

File Formats

The initial screen window of the CROSSBED application displays 2 child windows- the "Edit" window that should contain the input file, and the "Results" window that contains the output results of the retro-deformation. When either of the child windows has the input focus choosing the "File" > "Save" option will write the window contents to a disk file. Below is a discussion of the "Edit" and "Results" window file formats.

Input File Format

The input file format consists of a planar foreset attitude followed by a top/bottomset attitude and an optional ID label. The format of the planar attitudes may vary among several common types. This can be set in the "Settings" menu (see discussion below). In the **Figure 4** example the "Edit" window contains several foreset followed by top/bottomset attitude pairs in quadrant planar format. Note that the foreset attitude is always first on each line. A data identifier string may follow the top/bottomset attitude. If the top/bottomset attitude is overturned, an "O" should

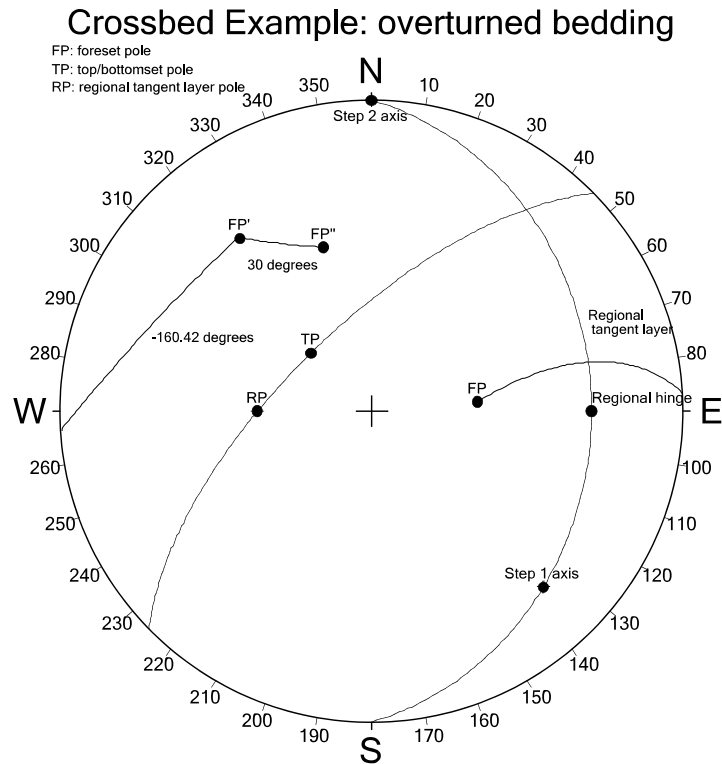


Figure 3: Example of crossbed rotation path with overturned bedding.

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follow the attitude (see **Figure 4** edit window example).

Output File Format

The output of the application is contained in the "results" child window (**Figure 4**). The contents of this window may be saved as a text file that may be used as input for the stereographic analysis program NETPROG. The rotated position of the foreset poles are included in the results file. In addition, the rotation path of the foreset pole may be optionally included as a series of user-defined annotations, as in the **Figure 4** example. **Figure 5** displays the CROSSBED output results in the NETPROG application main window. Note that the small circle paths of the 2-step rotation retro-deformation are plotted along with the retro-deformed foreset pole. The small circle step-1 paths greater than 90 degrees are produced by the overturned top/bottomset beds (see **Figure 4**).

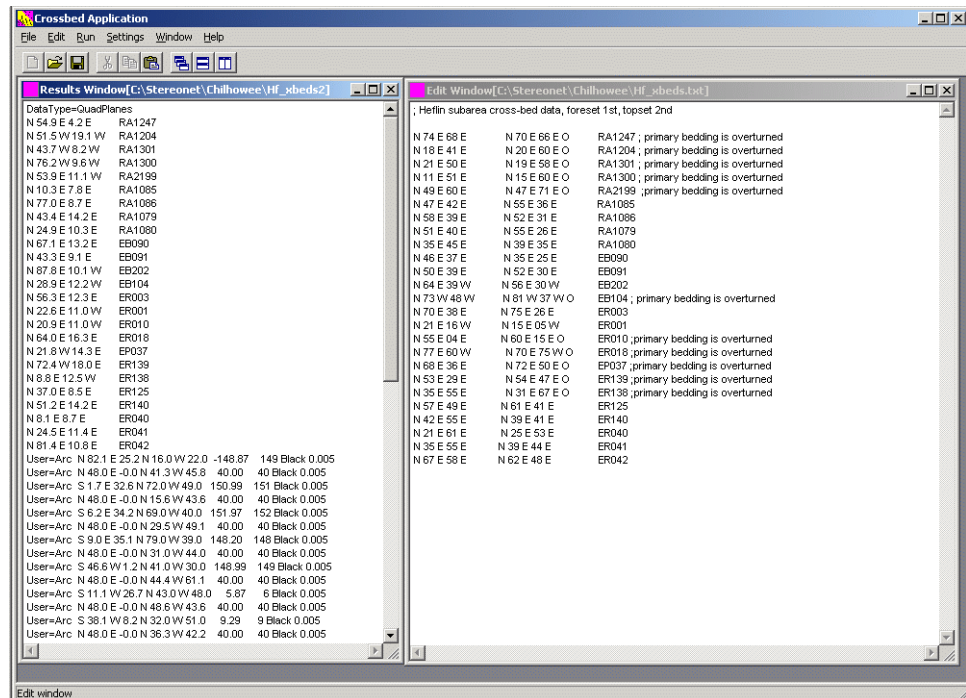


Figure 4: Example input and output windows in CROSSBED.

The NETPROG application (see later section on working with external applications) contains all of the options necessary to generate publication quality diagrams, including contoured equal-area and rose diagrams. The NETPROG application can also evaluate the statistical significance of orientation trends in the data set. If the user wishes to plot the retro-deformed foreset beds as a paleocurrent rose-type diagram, the output format should be set to "Azimuth/Quadrant Foreset True Dip" type (see "settings" menu discussion below), and the rotation path should be deselected. The same retro-deformed data plotted in **Figure 5** is plotted in **Figure 6** with these settings so that the paleocurrent direction is indicated in a Rose-type diagram. The statistical

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least-squares vector fit is also plotted in **Figure 6** indicating a mean paleoslope true dip attitude of 5, S45E.

The CROSSBED Menu System

Configuring and data processing is accomplished through the main menu system of the CROSSBED application. Below is a description of each of the main and submenu items, and how they are used to process data.

The File Menu

The file menu contains dialogs for opening and saving data files. In many cases the input data files may be created in other applications such as spreadsheets and database management systems. A separate discussion with examples of how this may be accomplished is discussed in a later section.

The “Open” Menu Item in the File Menu

Selecting the menu choice “File” > “Open” allows the user to open an existing data file that is formatted specifically for CROSSBED. Activating this menu option will display a standard “File Open” operating system dialog that will display all files with a “.TXT” extension in the default folder (**Figure 7**). Selecting a text file and then clicking on the “Open” button will load the file into the “Edit” child window. The edit window is a fully functional text editor, therefore, it is possible to type in all of the data manually into the editor and then save the data to a disk file. It is also possible to

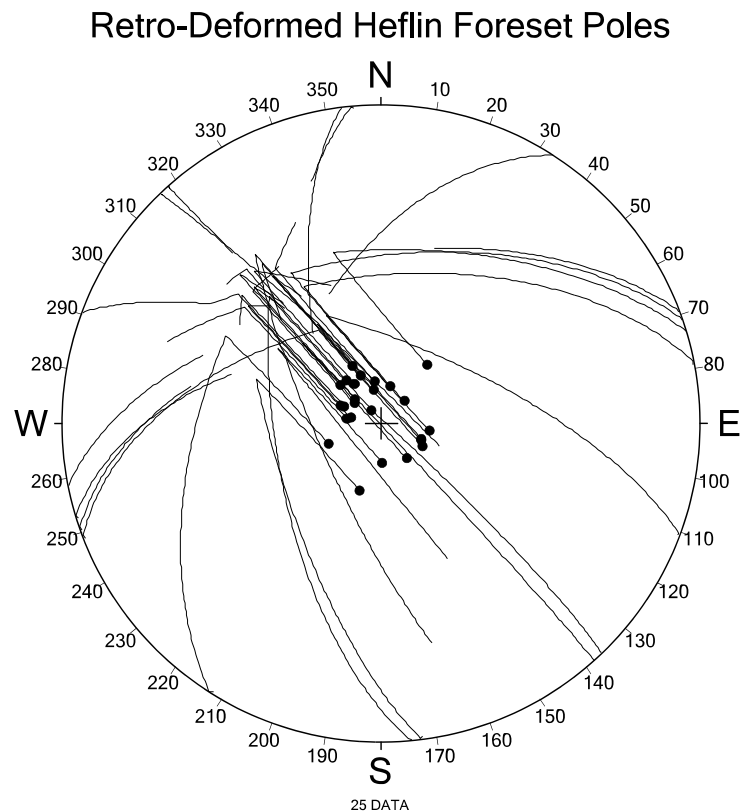


Figure 5: Retro-deformed Heflin area foreset poles with 2-step rotation paths.

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open an existing file, and then add new data to the editor window, and then save all of the data to a file. If the file name already exists, the user will be prompted to verify that the file should be over-written.

The “Save” Menu Item in the File Menu

The “File” > “Save” option in the main menu is used to save the contents of either the “Edit” or “Results” window to a disk file. When the “Save” option is selected the CROSSBED program detects which of the two child windows has the focus, and then saves the contents of the window to a disk file. If the file name indicated already exists the program will ask if the user wants to overwrite the existing file. The file used in the save operation is added to the child window caption (“Edit” or “Results”) inside the square brackets. If the contents of the “Results” window have not been saved the brackets will be empty. If a file name has already been indicated by the user in a save operation, a subsequent save will re-use the file name. If the user indicates “yes” to overwriting the existing file, the same file will then contain the current contents of the active child window.

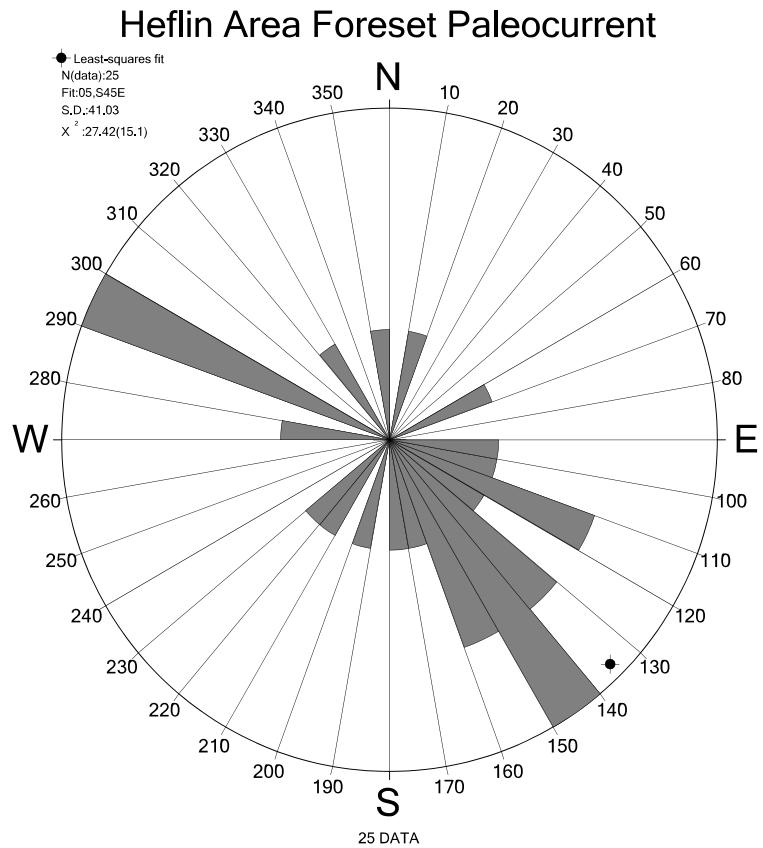


Figure 6: Rose-type diagram of the retro-deformed Heflin paleocurrent data.

The “Save As” Menu Item in the File Menu

The “Save As” dialog activated from the “File” menu activates the same operating system dialog that the “Save” option activates. See the above discussion of the “Save” option.

The “Exit” Menu Item in the File Menu

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The “Exit” option in the main “File” menu will exit the CROSSBED application, abandoning any data contained in the child windows. Make sure that you have saved any newly added data before selecting this option. You can also exit the program by selecting the “X” icon in the upper right corner of the main application window.

The Edit Menu

The “Edit” main menu is mainly used to copy and paste text from one window to another, or from one application to another. The paste operation is especially important when “pasting” data from external applications.

The “Cut” Menu Item in the Edit Menu

Selecting the CUT menu item under the EDIT menu allows for the deletion of selected text in the currently active editor window. Although the text will disappear from the edit window, it will be copied to the windows clipboard where it may be “pasted” into another Windows application. The will cause the same effect when text is highlighted.

The “Copy” Menu Item in the Edit Menu

Selection of the COPY item in the edit menu will cause any selected text to be copied to the Windows system clipboard. The contents of the clipboard can be pasted into other application usually be selecting the applications PASTE item from the applications EDIT menu. Typically this operation is used to copy-and-paste the results of the CROSSBED retro-deformation into another spreadsheet or database application. Highlighting text for copying is most easily accomplished by dragging the pointing device with the left button held down. Holding down the

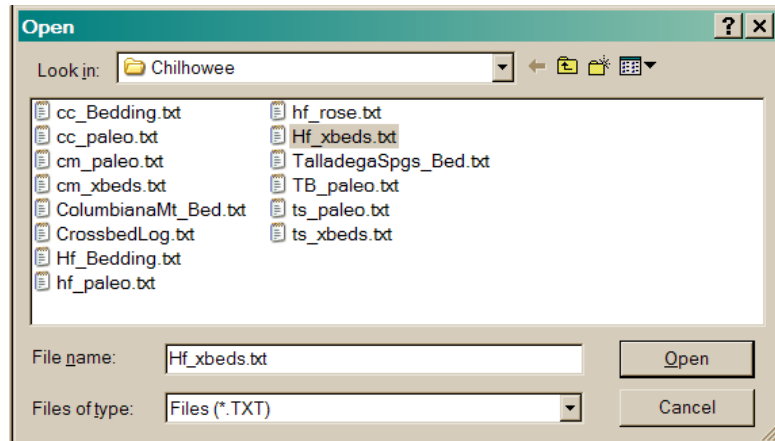


Figure 7: Dialog opened with the “File” > “Open” option.

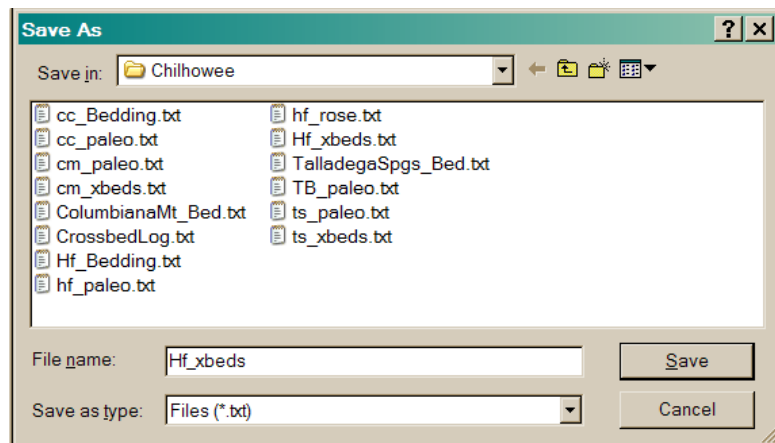


Figure 8: The “File Save” option from the “File” menu.

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shift key while move the pointer with the cursor keys or the mouse will cause the same effect.

The “Paste” Menu Item in the Edit Menu

Selection of the “Paste” item in the “Edit” menu will place the contents of the Windows clipboard text into the currently active child window (edit or results). The active window that has the focus will have a title bar background with the default windows background color. The inactive window's title bar will have a gray background color. Usually, the paste item will be used to paste data from another application into the edit window. For example, a data query may be used in Access to produce a CROSSBED compatible input file, and then copied to the clipboard. The “Paste” menu would then be used in CROSSBED in the Edit window to paste the results into the window. The shift+insert key combination is a shortcut for the paste-from-clipboard command (this is true in any windows program).

The “Clear” Menu Item in the Edit Menu

Selection of the “Clear” menu item in the “Edit” menu will delete all text in the currently active window. This command is normally selected to either clear the results window in preparation for processing another data set, or to begin a new data set in the edit window.

The “Run” Menu

The “Run” menu is chosen when data has been entered or loaded into the “Edit” window and all settings for data format have been set. The only item on this menu is the “Process data” item that processes the retro-deformation and lists the results in the “Results” window.

The “Process Data” Menu Item in the Edit Menu

If you select the “Process Data” command under the “Run” menu CROSSBED will begin to scan the contents of the current edit window and process the data while writing output results to the “Results” window. The output in the results window is fully formatted for the NETPROG application, therefore, you can and should save it to a disk file immediately after creating it. The results window is a functional text editor window, so you may modify the results window to suit your purpose. A log file named "CrossbedLog.txt" is created concurrently with the output in the results window. It will contain a record of each processed data pair, including the rotation axes and amounts used in the retro-deformation steps. Note that all of the above files created by CROSSBED are ASCII text files that can be viewed and edited by virtually any text editor including the “Notepad” editor that comes with Windows.

The Settings Menu

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The items in the “Settings” menu determine the input and output data format, and the reference regional sheet tangent layer attitude (see **Figure 1**).

The “Regional Attitude” Menu Item in the Settings Menu

The “Regional Attitude” item in the Settings Menu determines the attitude of the tangent sheet layer attitude. This is the layer that the top/bottomset bedding is rotated to co-planar orientation in the 1st-step rotation. The regional attitude should be determined by statistically analyzing the folded bedding to determine the best-fit cylindrical fold hinge. The fold hinge will then be the true-dip vector of the regional tangent sheet layer. **Figure 9** displays the dialog window activated by choosing the “Regional Attitude” menu item. The regional attitude may be entered in several different planar attitude formats indicated in the list box in the right side of the window:

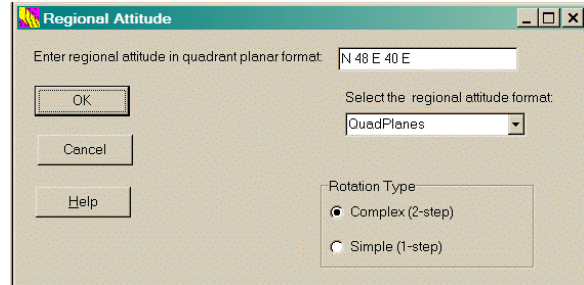


Figure 9: The Regional Attitude dialog window.

<u>Format Keyword</u>	<u>Description</u>
QuadPlanes	Quadrant planar attitude format: N 45 E 30 E
AzPlanes	Azimuth planar attitude format: 045 30 E
DipAzimuth	Dip azimuth, dip angle first: 30 135
	(Note: all of the above are equivalent planar attitudes.)

When entering an attitude in the upper right edit box make sure that the attitude format matches the format settings in the format list box. All elements of the attitude should be separated by at least one blank. For the dip quadrant direction use only an “E” or “W”. Do not use an “N” or an “S” even if the dip direction is due north or south. In cases where the true dip direction is due north or south use the following rule:

If the strike is N 90 E and the true dip is 30 south: N 90 E 30 E
 if the strike is N 90 E and the true dip is 30 north: N 90 E 30 W

The “Rotation Type” radio buttons in the lower right of the of the dialog window control the type of rotation- either a complex 2-step or a simple 1-step process. The 2-step process rotates the top/bottomset and paired foreset so that the top/bottomset attitude is co-planar to the regional tangent sheet layer attitude. The regional tangent layer is then rotated about its strike line to

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remove the dip, moving the foreset beds to their depositional attitude. In the 1-step simple rotation the top/bottomsets with paired foresets are simply rotated to be co-planar with the regional tangent sheet layer.

The “Input Format” Menu Item in the Settings Menu

The “Input Format” menu item dialog sets the format of the input data in the edit window. The default is quadrant planar for both the foreset and top/bottomset columns (columns 1 and 2 respectively), however either column may be entered as azimuth planar or dip azimuth attitude format. See the above discussion on the attitude format options for the regional tangent sheet layer for a description

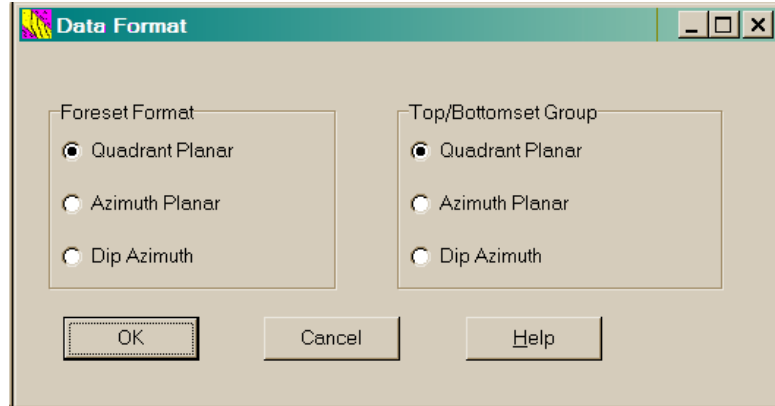


Figure 10: Input format dialog window.

of the various formats. In **Figure 10**

the layout of the dialog is displayed with the possible options. **Figure 4** displays an example of input data from the Heflin, AL, area in quadrant planar format. Note that in the 2nd top/bottomset column that overturned beds are indicated with a following “O” after the dip quadrant direction indicator.

The “Output Format” Menu Item in the Settings Menu

The “Output Format” menu item is used to set the output format for the results window. The possible output formats for the retro-deformed foreset beds are described below:

<u>Format</u>	<u>Description</u>
Quadrant Planar Attitude of Foreset	Quadrant planar attitude of retro-deformed foreset (ex. N 30 E 17 E)
Azimuth Planar Attitude of Foreset	Azimuth planar attitude of retro-defromed foreset (ex. 030 17 E)
Dip azimuth Planar Attitude of Foreset	Dip azimuth planar attitude of retro-deformed foreset (ex. 17 150)
Azimuth Linear Pole to Foreset	Azimuth linear attitude of retro-deformed foreset pole.

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Quadrant Linear Pole to Foreset

Quadrant linear attitude of retro-deformed foreset pole.

Quadrant Linear Foreset True Dip

Quadrant linear attitude of retro-deformed foreset true dip.

Azimuth Linear Foreset True Dip

Azimuth linear attitude of retro-deformed foreset true dip.

The first 3 options generate output in the results window in quadrant planar, azimuth planar, or dip azimuth attitudes. When this data is processed by NETPROG the planar attitudes are usually plotted as poles. If the “plot rotation paths” option is “on”, the retro-deformation paths of the foreset poles are plotted as a series of small circle paths. Because the retro-deformed position of the foreset poles are plotted as symbols, the resulting NETPROG plot can be interpreted in terms of the retro-deformation path. **Figure 5** is an example of this type of plot. Note that in this diagram the small circle paths greater than 90 degrees are overturned beds.

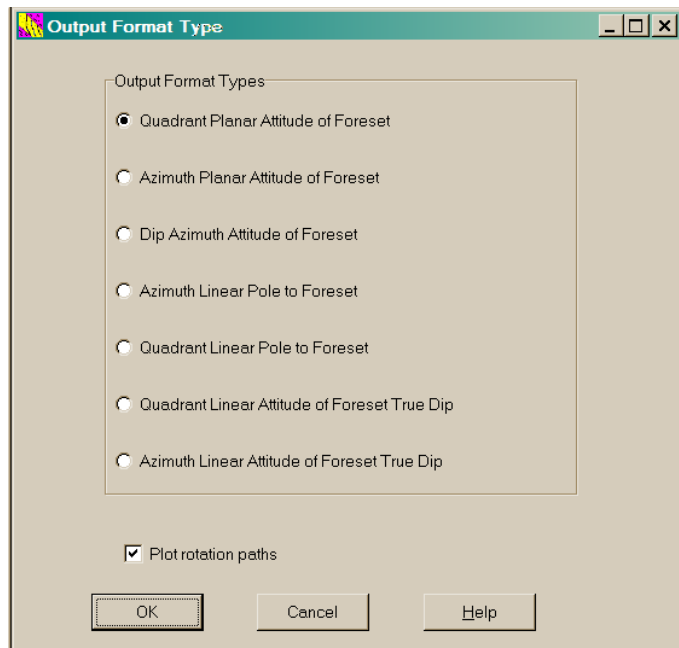


Figure 11: Output format dialog window.

The Quadrant Linear Pole and Azimuth Linear Pole options will write the results as linear “Pole” attitudes. The main use of these options would be to simply convert the retro-deformed planar foresets to a linear pole attitude.

The last 2 options produce linear attitudes of the true dip vector of the retro-deformed foreset beds. The main use of these options is to convert the retro-deformed foreset to a paleocurrent direction. Choosing one of these options allows the results window to be used in NETPROG as a Rose-type diagram. **Figure 6** is an example using the Heflin area data.

The “Plot rotation paths” check box in the lower left portion of the dialog window controls whether or not the retro-deformation path is included in the results window as annotations. If the user wishes to evaluate the retro-deformation paths of the foresets, this option should be checked. If the results window contains foreset true dip paleocurrent direction data (i.e. the last 2 output formats) this option should be unchecked.

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The Window Menu

The “Window” menu contains options that control the display of the edit and results child windows of the main CROSSBED application window.

The “Cascade” Menu Item in the Window Menu

Selecting the “Cascade” windows option in the “Window” menu will cause both child windows to be displayed so that both child window captions are visible, and the window with the focus is in the foreground.

The “Tile Horizontally” Menu Item in the Window Menu

The “Tile Horizontally” option will cause both child windows to be sized to take up exactly half of the area of the CROSSBED application window. The dividing line between the two child windows runs horizontally midway through the CROSSBED application window.

The “Tile Vertically” Menu Item in the Window Menu

The “Tile Vertically” menu option in the “Windows” menu operates in the same way as the above “Tile Horizontally” option except that the dividing line runs vertically midway through the CROSSBED application window area.

The “Minimize All” Menu item in the Windows Menu

The “Minimize All” menu option in the “Windows” menu will cause both of the edit and results child windows to become minimized as icons and re-located to the lower left portion of the CROSSBED application window.

The Help Menu

The “Help” menu contains links to the CROSSBED help system that consists of a PDF file with bookmarks to specific help topics related to CROSSBED. The menu also contains the “About” and “How to Use Help” dialog windows.

The “How to Use Help” Menu Item in the Help Menu

Selecting the menu item will display a dialog window containing directions on how to effectively use the Adobe PDF reader to open and read the CROSSBED help document.

The “Help File” Menu Item in the Help Menu

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Selecting the “Help File” menu item in the “Help” menu will activate the Adobe PDF reader to load “Crossbed_Help.pdf” file located at the URL or disk file path indicated in the “Crossbed.ini” file.

The “About” Menu Item in the Help Menu

The “About” menu item displays a dialog window containing version information for the CROSSBED application, and an e-mail address for the author. Use this to contact the author of the program.

CROSSBED Input Data File Format

Input data for CROSSBED should be loaded or typed into the “Edit” window. The data should consist of 2 planar attitudes and an optional sample I.D. label for each line. The foreset attitude should be first, followed by the top/bottomset. If the top/bottomset bedding is overturned an “O” should follow that attitude. Any text to the right of a semi-colon (;) is treated as a comment. Blank lines are ignored by CROSSBED.

```
; Bulls Gap crossbed data
N 67 E 42 E      N 75 E 34 E      NT617
N 15 E 45 E      N 40 E 46 E      NT617
N 30 E 45 E      N 75 E 40 E      NT619
N 45 E 43 E      N 55 E 28 E      NT620
N  2 E 16 E      N 30 E 23 E      NT623
N 72 W 28 W      N 72 E 29 E      NT625
N 82 E 39 E      N 67 E 34 E      NT625
N 39 E 35 E      N 67 E 24 E      NT628
N 47 E 22 E      N 15 E 20 E      NT630
```

Although the above example data are aligned in columns this is not necessary as long as elements of both attitudes are separated by at least one blank. The above data are in quadrant planar format, however, Azimuth planar and dip azimuth formats are also supported.

CROSSBED Output Data File Format

The output results of the CROSSBED program is displayed in the “Results” child window. If this window has the focus, and the “File” > “Save” or “File” > “Save As” menu item is selected, the results are saved to a text file that can be used as input for the stereonet analysis and plotting application NETPROG. Using the above input data example (Bulls Gap) with a regional tangent sheet attitude of N30E, 35 SE would produce the following results:

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```

DataType=QuadPlanes
N 32.9 E 9.4 E NT617
N 64.3 W 17.8 E      NT617
N 31.7 W 30.3 E      NT619
N 26.1 E 16.0 E      NT620
N 70.5 E 11.5 W      NT623
N 4.7 W 17.0 W NT625
N 52.2 W 10.2 W      NT625
N 1.7 W 17.4 E NT628
N 68.1 W 11.5 W      NT630
User=Arc  S 34.9 E 32.4 N 23.0 W 48.0      25.05      25 Black 0.005
User=Arc  N 30.0 E -0.0 N 59.3 W 45.6      35.00      35 Black 0.005
User=Arc  N 59.4 E 19.0 N 75.0 W 45.0      12.75      13 Black 0.005
User=Arc  N 30.0 E -0.0 S 90.0 W 52.5      35.00      35 Black 0.005
User=Arc  S 49.8 E 34.6 N 60.0 W 45.0      27.35      27 Black 0.005
User=Arc  N 30.0 E -0.0 S 87.2 W 34.7      35.00      35 Black 0.005
User=Arc  S 15.8 E 26.7 N 45.0 W 47.0      14.69      15 Black 0.005
User=Arc  N 30.0 E -0.0 N 61.4 W 39.0      35.00      35 Black 0.005
User=Arc  N 30.0 E -0.0 N 88.0 W 74.0      -12.00     12 Black 0.005
User=Arc  N 30.0 E -0.0 N 76.5 W 62.8      35.00      35 Black 0.005
User=Arc  S 22.1 E 28.9 N 18.0 E 62.0      22.62      23 Black 0.005
User=Arc  N 30.0 E -0.0 N 34.7 W 67.1      35.00      35 Black 0.005
User=Arc  S 38.3 E 33.0 N 8.0 W 51.0      20.73      21 Black 0.005
User=Arc  N 30.0 E -0.0 N 42.2 W 55.1      35.00      35 Black 0.005
User=Arc  S 7.9 E 23.3 N 51.0 W 55.0      20.83      21 Black 0.005
User=Arc  N 30.0 E -0.0 N 71.7 W 39.5      35.00      35 Black 0.005
User=Arc  N 45.1 E 10.4 N 43.0 W 68.0      -16.41     16 Black 0.005
User=Arc  N 30.0 E -0.0 N 41.4 W 51.9      35.00      35 Black 0.005

```

The above output file contains the retro-deformed attitude of the foreset beds listed in the above input file in lines 2-10. The first line contains a data type command that would be used by the stereographic analysis application NETPROG if the file were used as an input file for that application. The lines 11-28 contain a series of user-defined annotation commands for NETPROG that display the foreset pole small-circle arc paths of the retro-deformation process. These would be plotted on the diagram as in the **Figure 5** example. Note that there are 2 small circle arc paths for each data for the complex 2-step retro-deformation process. The format of the small circle arc command:

```

user = Arc {attitude of rotation axis} {attitude of start of arc} {rotation angle in degrees}
{rotation steps} {color} {arc line width in inches}

```

The sense of the rotation is counter-clockwise for positive angles as viewed in the down-plunge

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direction of the rotation axis. The format of the small circle are command is explained in detail in the NETPROG application help file.

CROSSBED Log File

Each time the “Run” > “Process Data” menu item is selected to retro-deform the data in the “Edit” window the results of the retro-deformation process used to bring the foreset attitudes to their original depositional attitude is written to a text “log” file named “CrossbedLog.txt”. This file is useful for documenting the details of the retro-deformation process used by CROSSBED. The below log file was produced by CROSSBED during the 2-step retro-deformation of the above Bulls Gap data set:

```
----- Complex 2-step rotation -----  
Sample I.D.=NT617  
1st rotation angle alpha= 25.05  
Rotation axis=145.1 32.4  
Foreset pole start attitude=337.0 48.0  
Foreset pole 1st rotation attitude=300.7 45.6  
2nd rotation angle gamma= 35.00  
2nd rotation axis attitude=30.0 0.0  
Foreset pole 2nd rotation attitude=302.9 80.6  
Foreset paleocurrent (down-dip) attitude=9.38 122.85  
----- Complex 2-step rotation -----  
Sample I.D.=NT617  
1st rotation angle alpha= 12.75  
Rotation axis=59.4 19.0  
Foreset pole start attitude=285.0 45.0  
Foreset pole 1st rotation attitude=270.0 52.5  
2nd rotation angle gamma= 35.00  
2nd rotation axis attitude=30.0 0.0  
Foreset pole 2nd rotation attitude=205.7 72.2  
Foreset paleocurrent (down-dip) attitude=17.79 25.66  
----- Complex 2-step rotation -----  
Sample I.D.=NT619  
1st rotation angle alpha= 27.35  
Rotation axis=130.2 34.6  
Foreset pole start attitude=300.0 45.0  
Foreset pole 1st rotation attitude=267.2 34.7  
2nd rotation angle gamma= 35.00  
2nd rotation axis attitude=30.0 0.0  
Foreset pole 2nd rotation attitude=238.3 59.7  
Foreset paleocurrent (down-dip) attitude=30.34 58.28
```

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```
----- Complex 2-step rotation -----  
Sample I.D.=NT620  
1st rotation angle alpha= 14.69  
Rotation axis=164.2 26.7  
Foreset pole start attitude=315.0 47.0  
Foreset pole 1st rotation attitude=298.6 39.0  
2nd rotation angle gamma= 35.00  
2nd rotation axis attitude=30.0 0.0  
Foreset pole 2nd rotation attitude=296.1 74.0  
Foreset paleocurrent (down-dip) attitude=16.04 116.07  
----- Complex 2-step rotation -----  
Sample I.D.=NT623  
1st rotation angle alpha= -12.00  
Rotation axis=30.0 0.0  
Foreset pole start attitude=272.0 74.0  
Foreset pole 1st rotation attitude=283.5 62.8  
2nd rotation angle gamma= 35.00  
2nd rotation axis attitude=30.0 0.0  
Foreset pole 2nd rotation attitude=160.5 78.5  
Foreset paleocurrent (down-dip) attitude=11.50 340.49  
----- Complex 2-step rotation -----  
Sample I.D.=NT625  
1st rotation angle alpha= 22.62  
Rotation axis=157.9 28.9  
Foreset pole start attitude=18.0 62.0  
Foreset pole 1st rotation attitude=325.3 67.1  
2nd rotation angle gamma= 35.00  
2nd rotation axis attitude=30.0 0.0  
Foreset pole 2nd rotation attitude=85.3 73.0  
Foreset paleocurrent (down-dip) attitude=16.99 265.27  
----- Complex 2-step rotation -----  
Sample I.D.=NT625  
1st rotation angle alpha= 20.73  
Rotation axis=141.7 33.0  
Foreset pole start attitude=352.0 51.0  
Foreset pole 1st rotation attitude=317.8 55.1  
2nd rotation angle gamma= 35.00  
2nd rotation axis attitude=30.0 0.0  
Foreset pole 2nd rotation attitude=37.8 79.8  
Foreset paleocurrent (down-dip) attitude=10.20 217.76  
----- Complex 2-step rotation -----  
Sample I.D.=NT628  
1st rotation angle alpha= 20.83  
Rotation axis=172.1 23.3
```


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```
Foreset pole start attitude=309.0 55.0
Foreset pole 1st rotation attitude=288.3 39.5
2nd rotation angle gamma=      35.00
2nd rotation axis attitude=30.0 0.0
Foreset pole 2nd rotation attitude=268.3 72.6
Foreset paleocurrent (down-dip) attitude=17.38 88.29
----- Complex 2-step rotation -----
Sample I.D.=NT630
1st rotation angle alpha=  -16.41
Rotation axis=45.1 10.4
Foreset pole start attitude=317.0 68.0
Foreset pole 1st rotation attitude=318.6 51.9
2nd rotation angle gamma=      35.00
2nd rotation axis attitude=30.0 0.0
Foreset pole 2nd rotation attitude=21.9 78.5
Foreset paleocurrent (down-dip) attitude=11.50 201.91
```

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Selected References

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