

Dips

Plotting, Analysis and Presentation of
Structural Data Using Spherical
Projection Techniques

User's Guide

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Introduction

DIPS is a program designed for the interactive analysis of orientation based geological data. The program is a tool kit capable of many different applications and is designed both for the novice or occasional user, and for the accomplished user of stereographic projection who wishes to utilize more advanced tools in the analysis of geological data.

DIPS allows the user to analyse and visualise structural data following the same techniques used in manual stereonet. In addition, many computational features are available, such as statistical contouring of orientation clustering, mean orientation calculation and qualitative and quantitative feature attribute analysis.

DIPS has been designed for the analysis of features related to the engineering analysis of rock structures, however, the free format of the DIPS data file permits the analysis of any orientation based data.

About this Manual

This manual consists of the following tutorials:

1. Two basic tutorials, to get new users acquainted with the basic features of the program:
 - Quick Tour of DIPS
 - Creating a DIPS File
2. Two advanced tutorials, to show how DIPS can be used for various types of analyses, which may not have been obvious without illustration:
 - Toppling, Planar Sliding, Wedge Sliding
 - Oriented Core and Rockmass Classification

This manual is intended as a hands-on, getting started user's guide. For more information on any DIPS options which are not discussed in these pages, consult the DIPS Help system.

NOTE that the example files used in this manual, and provided with the DIPS program, are intended for use in training and education only. They should not be used as data sets for research.

In this manual, instructions such as:

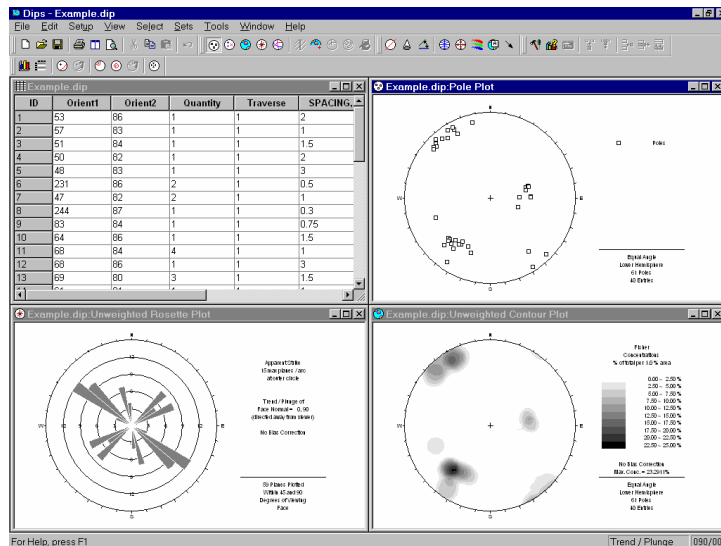


Select: View → Pole Plot

are used to navigate the menu selections.

When a toolbar button is displayed in the margin, as shown above, this indicates that the option is available in a DIPS toolbar. *This is always the recommended and quickest way to use the option.*

Quick Tour of Dips



This “quick tour” will familiarize the user with some of the basic features of DIPS.

If you have not already done so, run DIPS by double-clicking on the DIPS icon in your installation folder. Or from the Start menu, select Programs → Rocscience → Dips → Dips.

If the DIPS application window is not already maximized, maximize it now, so that the full screen is available for viewing the data.

EXAMPLE.DIP File

In your DIPS installation folder you will find an Examples folder, containing several example DIPS files. This Quick Tour will use the EXAMPLE.DIP file in the Examples folder. To open the EXAMPLE.DIP file:



Select: File → Open

Navigate to the Examples folder in your DIPS installation folder, and open the EXAMPLE.DIP file.

You should see the spreadsheet view shown in Figure 2-1. A DIPS file is always opened by displaying a spreadsheet view of the data. The DIPS spreadsheet is also called the Grid View throughout this manual. Maximize the Grid View.

ID	Orient1	Orient2	Quantity	Traverse	SPACING.M	TYPE	SURFACE
1	53	86	1	1	2	joint	smooth
2	57	83	1	1	1	joint	smooth
3	51	84	1	1	1.5	joint	smooth
4	50	82	1	1	2	joint	sl.rough
5	48	83	1	1	3	joint	rough
6	231	86	2	1	0.5	joint	rough
7	47	82	2	1	1	shear	slickens
8	244	87	1	1	0.3	joint	v.rough
9	83	84	1	1	0.75	joint	rough
10	64	86	1	1	1.5	joint	smooth
11	68	84	4	1	1	bedding	sl.rough
12	68	86	1	1	3	shear	slickens
13	69	80	3	1	1.5	bedding	sl.rough
14	61	81	1	1	1	bedding	sl.rough
15	300	64	3	1	0.2	joint	v.rough
16	295	68	1	1	0.5	joint	rough
17	320	75	1	1	0.5	joint	sl.rough
18	316	70	1	1	1	joint	smooth
19	315	65	2	1	1	joint	smooth
20	320	68	1	1	2	shear	slickens
21	312	72	2	2	0.4	joint	smooth
22	346	68	3	2	0.7	joint	rough
23	308	65	1	2	1	qtzvein	sealed
24	310	86	1	2	1.5	joint	smooth
25	310	84	4	2	0.3	joint	sl.rough
26	308	62	1	2	1	shear	slickens
27	308	62	1	2	1	joint	smooth
28	170	47	1	2	1.5	joint	smooth
29	320	68	3	2	0.25	qtzvein	sealed
30	322	68	1	2	1	shear	slickens
31	320	68	2	2	0.3	qtzvein	sealed
32	168	50	1	2	5	fault	gouge
33	174	46	1	2	1	shear	slickens

Figure 2-1: Grid View of EXAMPLE.DIP file.

We won't worry about the details of this file yet, except to note that it contains 40 rows, and the following columns:

- Two Orientation Columns
- A Quantity Column
- A Traverse Column
- Three Extra Columns

In the next tutorial, we will discuss how to create the EXAMPLE.DIP file from scratch.

Pole Plot



Creating a Pole Plot is just one mouse click away. Select the Pole Plot option in the View toolbar or the View menu.

Select: View → Pole Plot

A new view displaying a Pole Plot will be generated, as shown below.

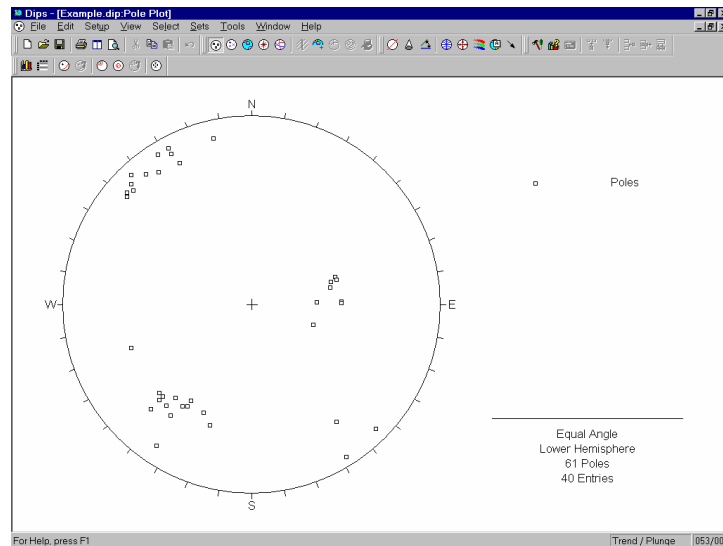


Figure 2-2: Pole Plot of EXAMPLE.DIP data.

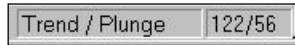
Each pole on a Pole Plot represents an orientation data pair in the first two columns of a DIPS file.

The Pole Plot can also display feature attribute information, based on the data in any column of a DIPS file, with the Symbolic Pole Plot option. This is covered later in this tutorial.

Convention

As you move the cursor around the stereonet, notice that the cursor orientation is displayed in the Status Bar.

The format of these orientation coordinates can be toggled with the Convention option in the Setup menu:



- If the Convention is Pole Vector, the coordinates will be in Trend / Plunge format, and represent the cursor (pole) location directly. This is the default setting.
- If the Convention is Plane Vector, the coordinates will correspond to the Global Orientation Format of the current document (eg. Dip/DipDirection , Strike/DipRight , Strike/DipLeft), and represent the PLANE corresponding to the cursor (pole) location.



TIP – the Convention can be quickly toggled by clicking on the box in the Status Bar to the left of the coordinate display, with the LEFT mouse button. This is the quickest and most convenient way of toggling the Convention.

The Convention also affects the format of certain data listings in DIPS (eg. the Major Planes legend, the Edit Planes and Edit Sets dialogs), and the format of orientation data input for certain options (eg. Add Plane and Add Set Window dialogs).

Finally note that in DIPS, poles are ALWAYS plotted using the Trend and Plunge of the pole vector with respect to the reference sphere. **THE CONVENTION OPTION DOES NOT AFFECT THE PLOTTING OF DATA, OR THE VALUES IN THE GRID IN ANY WAY !!**

Legend

Note that the Legend for the Pole Plot (and all stereonet plots in DIPS) indicates the:

- Projection Type (Equal Angle) and

- Hemisphere (Lower Hemisphere).

These can be changed using Stereonet Options in the Setup menu (Equal Area and Upper Hemisphere options can be used). However, for this tutorial, we will use the default projection options.

Note that the Legend also indicates “61 Poles, 40 Entries”.

- The EXAMPLE.DIP file has 40 rows, hence “40 entries”.
- The Quantity Column in this file allows the user to record multiple identical data units in a single row of the file. Hence the 40 data entries actually represent 61 features, hence “61 poles”.

Let’s move on to the Scatter Plot.

Scatter Plot

While the Pole Plot illustrates orientation data, single pole symbols may actually represent several unit measurements of similar orientation.

Select the Scatter Plot option in the View toolbar or the View menu, to generate a Scatter Plot.



Select: View → Scatter Plot

A Scatter Plot allows the user to better view the numerical distribution of these measurements, since coincident pole and closely neighbouring pole measurements are grouped together with quantities plotted symbolically. The Scatter Plot Legend indicates the number of poles represented by each symbol.

Let’s move on to the Contour Plot, which is the main tool for analyzing pole concentrations on a stereonet.

Contour Plot



Select the Contour Plot option from the View toolbar or the View menu, and a Contour Plot will be generated.

Select: View → Contour Plot

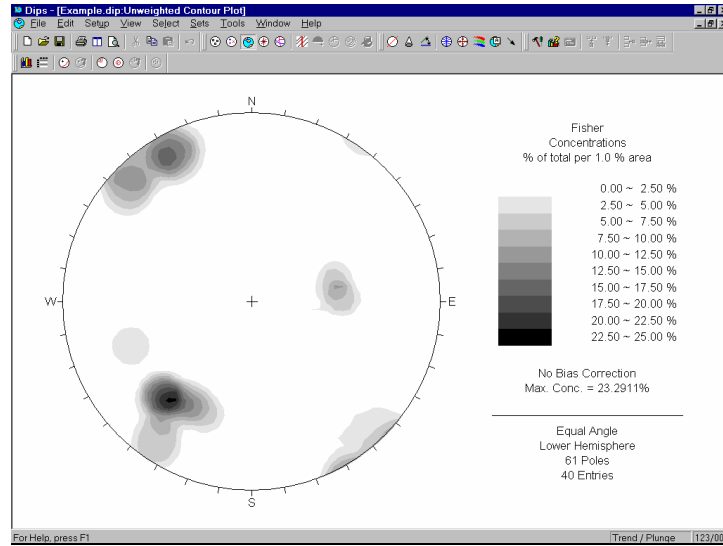


Figure 2-3: Contour Plot of EXAMPLE.DIP data.

The Contour Plot clearly shows the data concentrations. It can be seen that there are three data clusters in the EXAMPLE.DIP file, including one that wraps around to the opposite side of the stereonet.

Since this file only contains 40 data entries, the data clustering in this case was apparent even on the Pole Plot. However, in larger DIPS files, which may contain hundreds or even thousands of entries, cluster recognition will not necessarily be visible on Pole or Scatter Plots, and Contour Plots are necessary to identify major data concentrations.

Weighted Contour Plot

Since this file contains Traverse information (Traverses are discussed in the next tutorial), a Terzaghi Weighting can be applied to Contour Plots, to correct for sampling bias introduced by data collection along Traverses.

To apply the Terzaghi Weighting to the Contour Plot:



Select: View → Terzaghi Weighting

Note the change in the Contour Plot. Applying the Terzaghi Weighting may reveal important data concentrations which were not apparent on the unweighted Contour Plot. The effect of applying the Terzaghi Weighting will of course be different for each file, and will depend on the data collected, and the traverse orientations.

DO NOT USE WEIGHTED CONTOUR PLOTS FOR APPLICATIONS UNLESS YOU ARE FAMILIAR WITH THE LIMITATIONS. For a discussion of sampling bias and the Terzaghi Weighting procedure, see the DIPS Help system.

To remove the Terzaghi Weighting and restore the unweighted Contour Plot, simply re-select the Terzaghi Weighting option.



Select: View → Terzaghi Weighting

Contour Options

Many Contour Options are available allowing the user to customize the style, range and number of contour intervals. We will not explore the Contour Options in this Quick Tour, however, the user is encouraged to experiment. Contour Options is available in the Setup menu, or by right-clicking on a Contour Plot.

Stereonet Options

At this point, let's examine the Stereonet Options dialog, which configures the basic stereonet parameters for the Contour Plot and all other stereonet plots in DIPS.

Right-click on the Contour Plot and select Stereonet Options, or select Stereonet Options from the Setup menu.

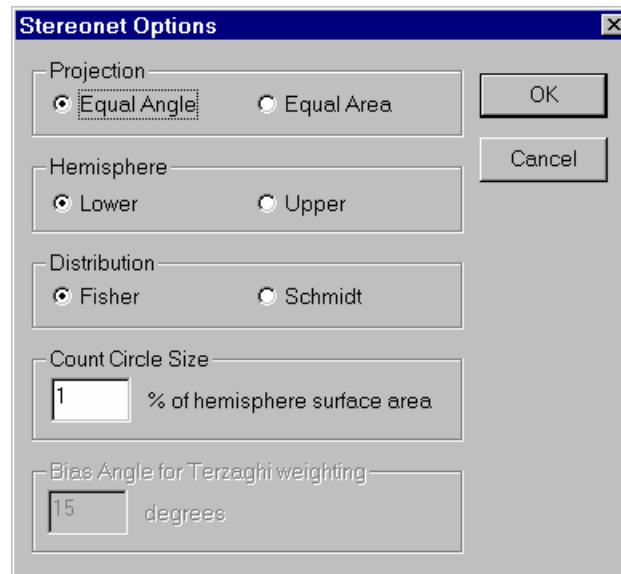


Figure 2-4: Stereonet Options dialog.

If you examine the Contour Plot legend, you will notice that all of the Stereonet Options are recorded here, including the Distribution method (Fisher in this case) and the Count Circle size (1% in this case) used to obtain the contours. Select Cancel to return to the Contour Plot.

See the Stereonet Options topic in the DIPS Help system, for complete details about all of the DIPS Stereonet options.

Rosette Plot

Another widely used technique for representing orientations is the Rosette Plot.

The conventional rosette plot begins with a horizontal plane (represented by the equatorial (outer) circle of the plot). A radial histogram (with arc segments instead of bars) is overlain on this circle, indicating the density of planes intersecting this horizontal surface. The radial orientation limits (azimuth) of the arc segments correspond to the range of STRIKE of the plane or group of planes being represented by the segment. *In other words, the rosette diagram is a radial histogram of strike density or frequency.*

To generate a Rosette Plot, select Rosette Plot from the View toolbar or the View menu.



Select: View → Rosette Plot

Although the default Rosette Plot uses a horizontal base plane, an arbitrary base plane at any orientation can be specified in the Rosette Options dialog. For a non-horizontal base plane, the Rosette Plot represents the APPARENT STRIKE of the lines of intersection between the base plane and the planes in the DIPS file.

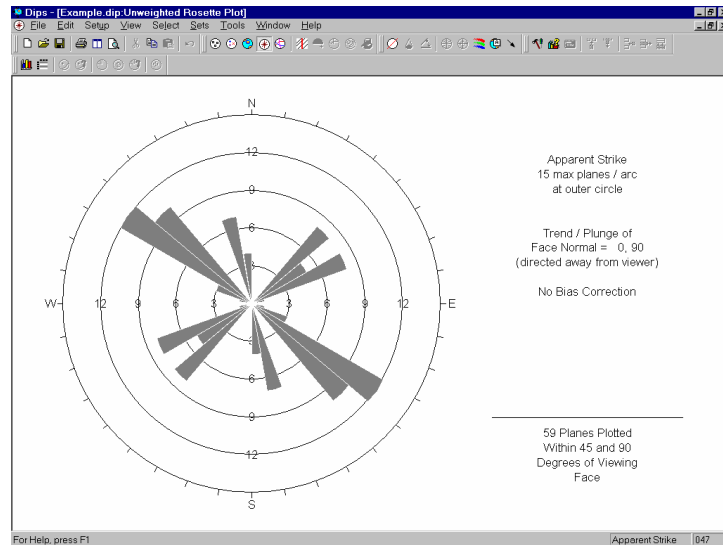


Figure 2-5: Rosette Plot of EXAMPLE.DIP data.

Rosette Applications

The rosette conveys less information than a full stereonet since one dimension is removed from the diagram. In cases where the planes being considered form essentially two dimensional geometry (prismatic wedges, for example) the third dimension may often overcomplicate the problem. A horizontal rosette diagram may, for example, assist in blast hole design for a vertical bench where vertical joint sets impact on fragmentation. A vertical rosette oriented perpendicular to the axis of a long topsill or tunnel may simplify wedge support design where the structure parallels the excavation. A vertical rosette which cuts a section through a slope under investigation can be used to perform quick sliding or toppling analysis where the structure strikes parallel to the slope face.

From a visualisation point of view and for conveying structural data to individuals unfamiliar with stereographic projection, rosettes may be more appropriate when the structural nature of the rock is simple enough to warrant 2D treatment.

Weighted Rosette Plot

The Terzaghi Weighting option can be applied to Rosette Plots as well as Contour Plots, to account for sampling bias introduced by data collection along Traverses.

- If the Terzaghi Weighting is NOT applied, the scale of the Rosette Plot corresponds to the actual “number of planes” in each bin.
- If the Terzaghi Weighting IS applied, the scale of the Rosette Plot corresponds to the WEIGHTED number of planes in each bin.



Do not use weighted plots for applications unless you are familiar with the limitations. See the DIPS Help system for more information.

Adding a Plane

The Add Plane option allows the user to graphically add a pole / plane to a stereonet plot (Pole, Scatter, Contour or Major Planes plots).

First let's switch the plot type back to a Contour Plot, since planes cannot be added on the Rosette Plot.



Select: View → Contour Plot

Now select Add Plane from the Select toolbar or the Select menu.



Select: Select → Add Plane

1. Move the cursor over the Contour Plot. When the cursor is INSIDE the stereonet, an arc or “great circle” representing the plane corresponding to the cursor location (pole) will appear. Move the cursor around the stereonet, and observe the position of the corresponding plane.
2. Note that the cursor coordinates are visible in the status bar. When the plane / pole is at a desired orientation, click the LEFT mouse button INSIDE the stereonet. (Remember that the coordinate Convention can be toggled in the Status Bar).
3. The Add Plane dialog will appear, allowing you to modify the graphically entered orientation (if necessary), and also provide ID, labeling (optional) and visibility information.

For this example, enter ID = 1, Label = plane1, and leave the Visibility checkboxes at their default selections. Select OK.

The plane / pole will be displayed on the plot, according to the visibility settings chosen, as shown in Figure 2-7.

If the graphically entered orientation is not correct, then simply enter the correct values in the Add Plane dialog.

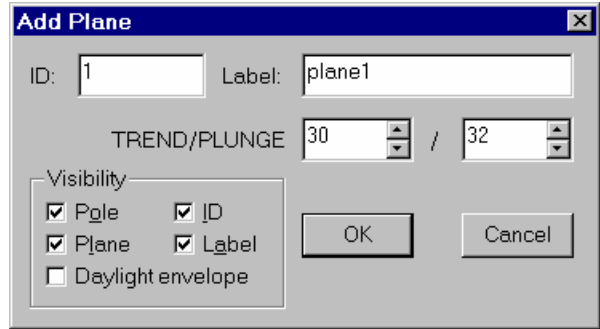


Figure 2-6: Add Plane dialog.

NOTE: The visibility settings that you choose in the Add Plane dialog can be modified AT ANY LATER TIME in the Edit Planes dialog.

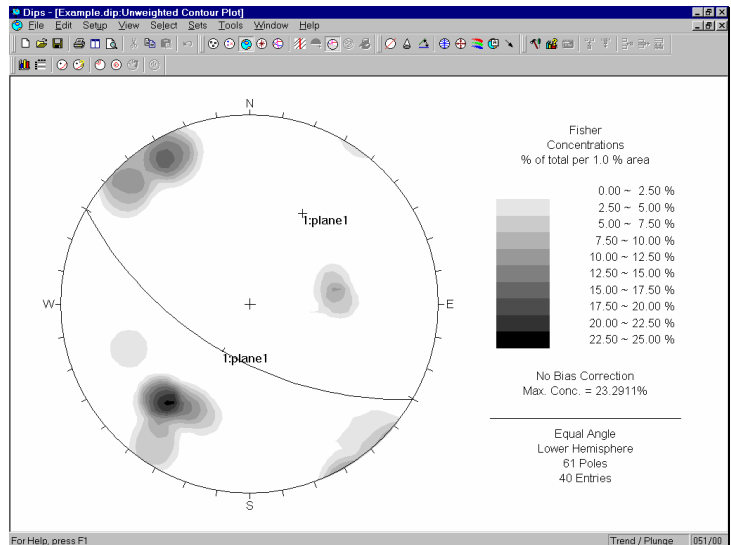


Figure 2-7: Added plane / pole displayed on Contour Plot.

NOTE: planes created with the Add Plane option in DIPS are referred to as ADDED PLANES, to distinguish them from MEAN PLANES calculated from Sets. (Sets and mean planes are discussed in the next section).

Creating Sets

A Set as defined in DIPS, is a grouping of data created with the Add Set Window option. The Add Set Window option allows the user to draw windows around data clusters on a stereonet, and obtain mean orientations of data (poles) within the windows.

Before we go further, note the following:

- The windows created with Add Set Window are curvilinear four-sided windows, defined by two trend values and two plunge values at opposite corners.
- The windows are always formed in a **CLOCKWISE** direction, therefore you must always **START** a Set Window with one of the **COUNTER-CLOCKWISE** corners.

Let's create our first Set with the small data cluster at the right side of the stereonet.



Select: Sets → Add Set Window

1. Locate the cursor at APPROXIMATELY Trend/Plunge = 55 / 65, and click the **LEFT** mouse button. Remember that the cursor coordinates are displayed in the Status Bar.
2. Move the mouse in a **CLOCKWISE** direction, and you will see a curvilinear, four-sided Set Window opening up.
3. Move the cursor to APPROXIMATELY Trend/Plunge = 115 / 20, and click the **LEFT** mouse button. You will then see the Add Set Window dialog.

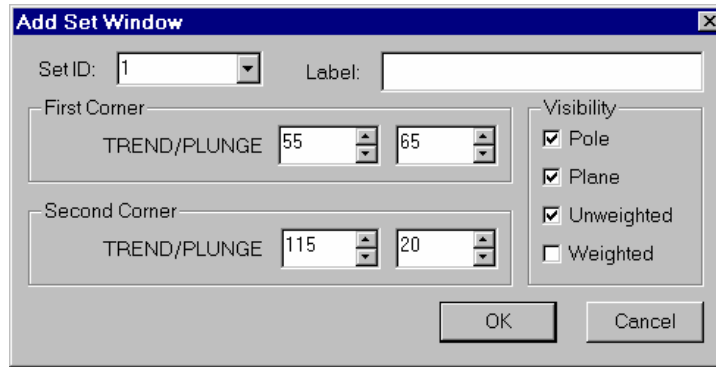


Figure 2-8: Add Set Window dialog.

4. Don't worry if the window coordinates are not exactly those shown above, as long as the window encloses the desired data. However, you may edit the coordinates at this time, if you wish.
5. We will accept the default Set ID and Visibility settings, so just select OK, and the Set will be created.

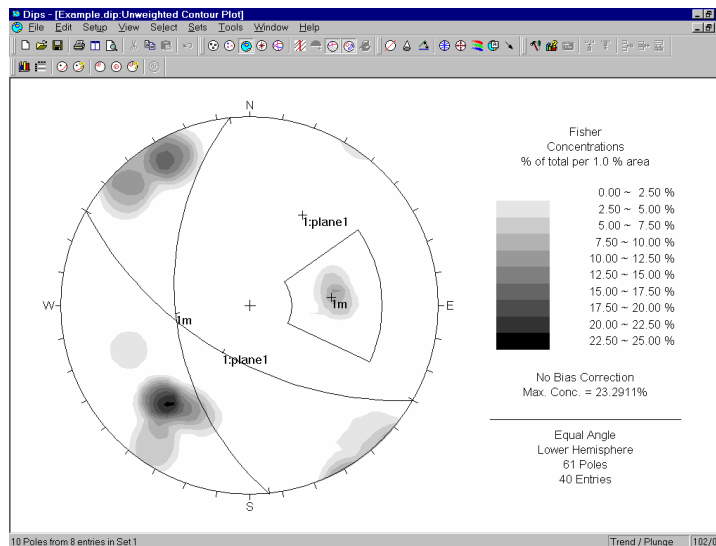


Figure 2-9: Set Window and Unweighted mean pole / plane displayed for Set 1.

Mean Plane Display

When a Set is created, you will notice the following on the stereonet, as shown in Figure 2-9:

- The Set Window will be displayed.
- The mean pole / plane will be displayed according to the visibility settings chosen in the Add Set Window dialog. In this case, we have displayed the Unweighted mean pole vector and plane.
- Unweighted mean poles / planes are identified by an “m” beside the Set ID. Weighted mean poles / planes, if displayed, are identified by a “w” beside the Set ID.

Status Bar Display

After a Set is created, the Status Bar will display the number of poles in the Set. For this example, the Status Bar should now show:

10 poles from 8 entries in Set 1

The “8 entries” refers to the number of rows of the grid within the Set. Since we have a Quantity Column in this file, each row can represent multiple data units (poles). In this case, the 8 rows actually represent 10 poles.

Set Column

When the FIRST Set is created, a Set Column is automatically added to the Grid. The Set Column records the Set ID of data belonging to Sets. Let’s verify this.

Return to the Grid View (you may select from the list of open views in the Window menu).

- Notice the Set Column, which appears AFTER the Traverse Column.

A Set Column is automatically added to the Grid when the FIRST Set is created.

- Notice the data in the Set Column which is flagged with the Set ID = 1. These are the poles within the Set Window just created.

Now return to the Contour Plot view, and we will create another Set, this time with a window which wraps around the perimeter of the stereonet.

Wrapped Set Windows

After you have selected the FIRST corner of a Set Window with the Add Set Window option, you will notice that if the cursor moves beyond the stereonet perimeter, it will “wrap around” and re-appear on the opposite side of the stereonet, with the window still attached.

This allows data near the perimeter, on opposite sides of the stereonet, to be selected as one Set, as illustrated in Figure 2-10.

A wrapped Set Window in DIPS automatically calculates the correct mean vector for Sets which cross the equator.

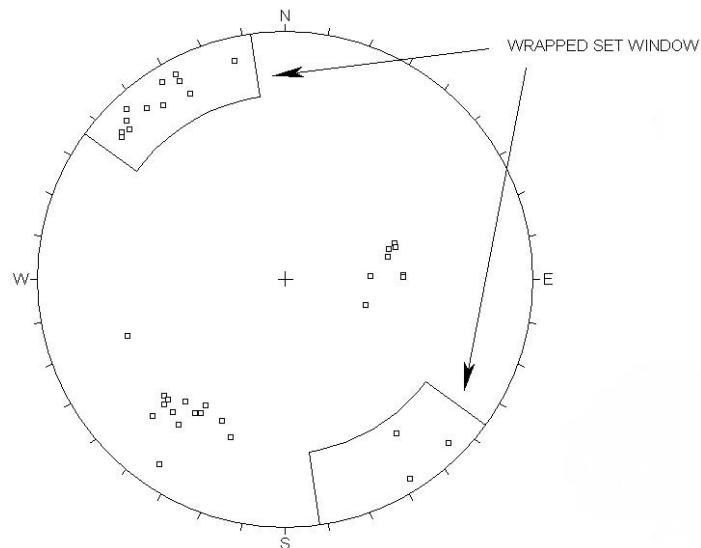


Figure 2-10: Wrapped Set Window.

This useful feature of DIPS automatically calculates the correct mean vector for Sets with poles plotting on opposite sides of the equator, since A MEAN ORIENTATION CALCULATED FROM THE LOWER HEMISPHERE ALONE WILL BE INCORRECT!!

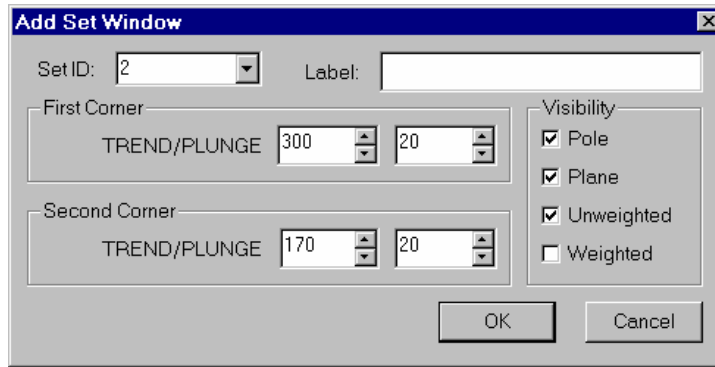
The poles within a wrapped Set window that plot on the opposite side of the stereonet, are incorporated into the vector addition AS NEGATIVE poles (ie. plunge = -plunge , trend = trend + 180), so that the mean will be correctly calculated.

Let's create a second Set using a wrapped Set Window.



Select: Sets → Add Set Window

1. Locate the cursor at APPROXIMATELY Trend/Plunge = 300 / 20, and click the LEFT mouse button. Remember that the cursor coordinates are displayed in the Status Bar.
2. Move the cursor to the stereonet perimeter, and you will see that the Set Window reappears on the opposite side of the stereonet.
3. A wrapped Set Window may seem awkward at first, but is very simple once you get the hang of it. At worst, if you seem to “lose control”, right-click the mouse and select Cancel, and start again!
4. Move the cursor to APPROXIMATELY Trend/Plunge = 170 / 20, and click the LEFT mouse button. You will see the Add Set Window dialog.



5. Don't worry if the window coordinates are not exactly those shown above, as long as the window encloses the desired data. However, you may edit the coordinates at this time, if you wish.

6. We will accept the default Set ID (2 in this case) and Visibility settings, so just select OK, and the Set will be created.

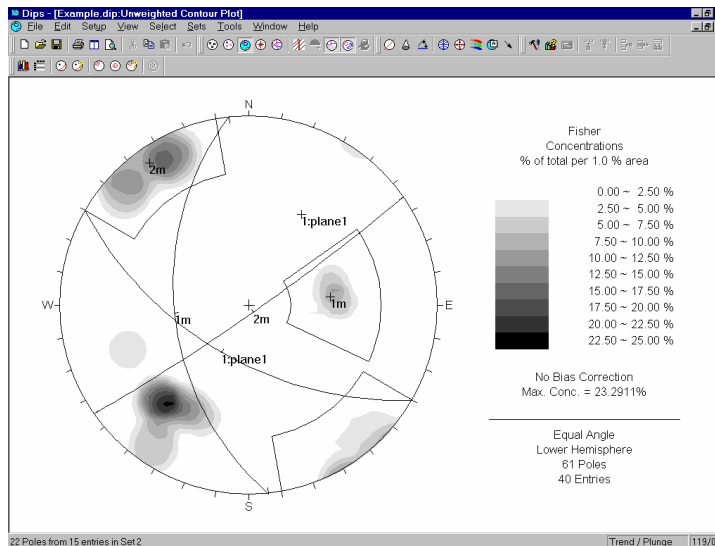


Figure 2-11: Set Windows and Unweighted mean poles / planes displayed for Sets 1 and 2.

As when we created the first Set, note that the Set Window and Unweighted mean pole / plane are displayed. Also, the Status Bar should read (if you selected all of the poles on both sides of the stereonet):

22 poles from 15 entries in Set 2

Finally, note that the Set Column in the Grid View is updated to record the data in both Sets 1 and 2. Note that data which does NOT currently belong to any Set has a BLANK entry in the Set Column.

Now create a third Set Window around the remaining data concentration on the Contour Plot. (A Set Window with corners at approximately Trend / Plunge = 190 / 40 and Trend / Plunge = 235 / 3 will do the job).

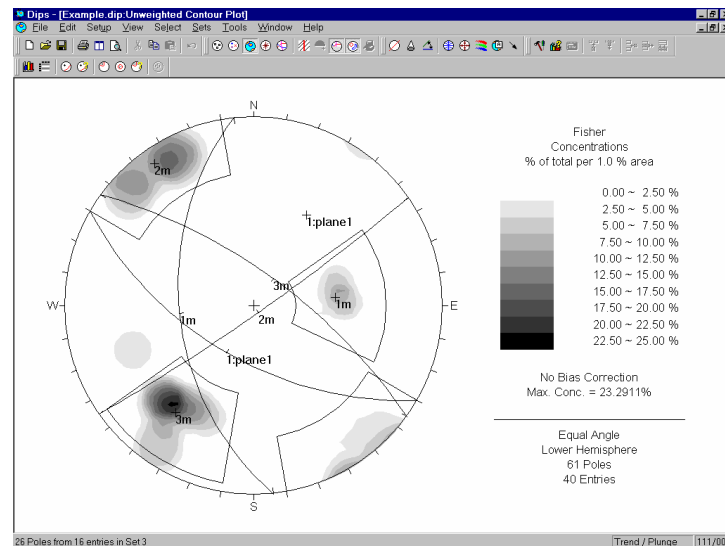


Figure 2-12: Set Windows and Unweighted mean poles / planes displayed for Sets 1, 2 and 3.

Set Information

Let's now look at the Info Viewer option, which provides a summary of your DIPS file, as well as a listing of all Added Planes (Add Plane option), and all Set information.



Select: File → Info Viewer

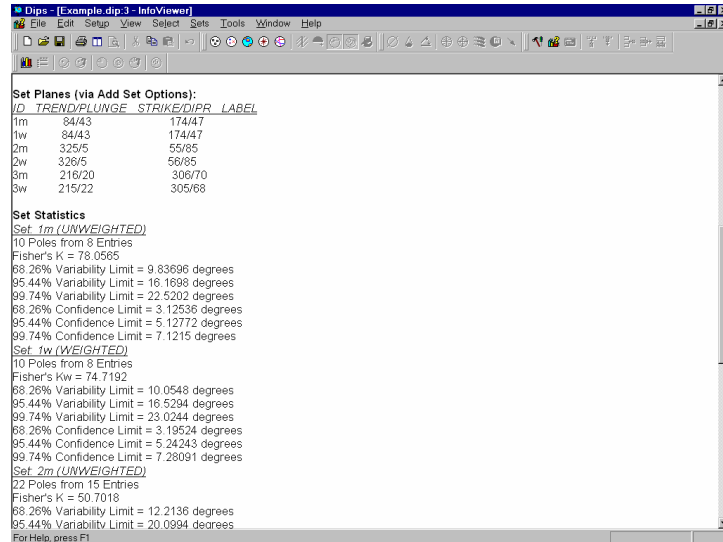


Figure 2-13: Info Viewer display of Set information.

As you scroll through the Info Viewer, you will see:

- your DIPS file setup information,
- Global mean vector orientation (ie. the mean vector of all poles in the file), and
- a list of Added Planes, if any exist (you should see the single plane listed, which we added earlier in this tutorial).

If Sets have been created, you will then see:

1. A listing of Unweighted and Weighted MEAN plane orientations for each Set, in both Pole Vector (Trend / Plunge) and Plane Vector format.
2. A listing of Set Statistics (Fisher coefficient, and Confidence and Variability Limits at one, two and three standard deviations).
3. The Set Window limits (ie. the two corners defining each Set Window, in Trend / Plunge format).

Confidence and Variability cones can be displayed on stereonet plots, as discussed in Tutorial 3.

The Info Viewer listing can be printed, copied to the clipboard, etc. The Info Viewer behaves like any other view in DIPS (ie. it can be tiled, minimized, maximized, etc.), and is automatically updated whenever new information is added to the current document (eg. when a new Set is created). When you are finished examining the Info Viewer, close the view by selecting the × button in the upper right corner.

Major Planes Plot

The Major Planes Plot option in DIPS allows the user to view PLANES ONLY on a clean stereonet, without poles or contours. In addition, a listing of plane orientations is displayed in the legend, in the format governed by the current Convention (Trend / Plunge or Plane Vector).



Select: View → Major Planes

The following PLANES are displayed on a Major Planes Plot:

- All ADDED planes created with the Add Plane option
- All MEAN planes for Sets created with the Add Set Window option

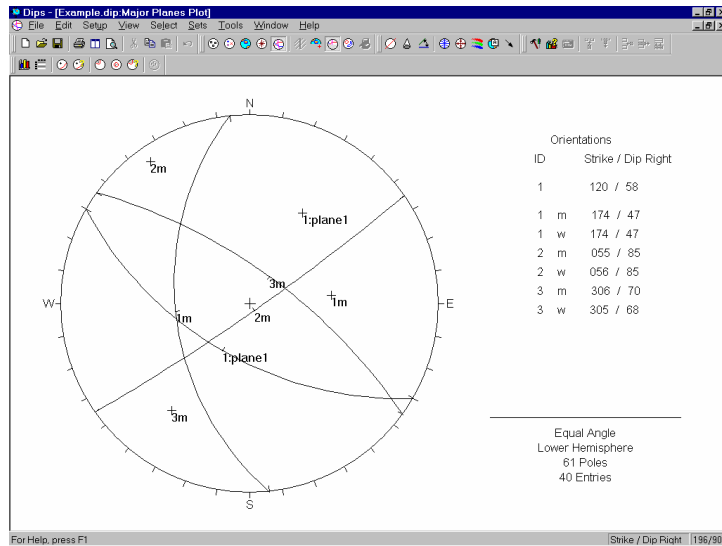


Figure 2-14: Major Planes Plot.

Only planes / poles toggled for Visibility in the Edit Planes and Edit Sets dialogs, will be displayed on the Major Planes Plot.

In Figure 2-14 we have toggled off the display of Set Windows. This is done with the Show Windows option in the Sets menu, which toggles the visibility of the Set Windows on a per view basis. Let's do that now.



Select: Sets → Show Windows

Major Planes Legend

The Major Planes legend displays the orientations of planes in the format governed by the Convention (Trend / Plunge or Plane Vector). Remember that the Convention can be toggled at any time in the Status Bar, and will automatically update the planes Legend. Also note:

- The letter “m” beside a plane ID indicates an UNWEIGHTED MEAN PLANE for a Set
- The letter “w” beside a plane ID indicates a WEIGHTED MEAN PLANE for a Set
- A Plane ID with NO letter indicates an ADDED plane created with the Add Plane option.

For our current example, we have one ADDED plane (Added Planes are always listed first in the legend), followed by the MEAN planes for the three Sets.

Plane Colours

The default colours used for planes in DIPS are:

- GREEN for all ADDED planes
- RED for all MEAN planes

The user can customize ADDED plane colours in the Edit Planes dialog, and MEAN plane colours in the Edit Sets dialog. This is left as an optional exercise. NOTE that unlike most other display options in DIPS, changes to the Plane Colours (or the Plane Visibility settings) affect ALL views for the current document, and are NOT customizable on a per view basis.

Working with Multiple Views

New stereonet plot views can be generated at any time, by selecting the New Plot View option in the Window menu. Let's generate two new plot views, so that we can view different plots at the same time.

Select: Window → New Plot View

By default, a Pole Plot is always displayed when a new plot view is generated in this manner. Generate one more view.

Select: Window → New Plot View

Now tile the views.



Select: Window → Tile Vertically

Your screen should now display:

- Two Pole Plot views
- A Major Planes Plot view
- The Grid View.

Click on one of the Pole Plot views, to make it the active view, and display a Rosette Plot.



Select: View → Rosette Plot

Click on the Major Planes Plot, to make it the active view, and display a Contour Plot.



Select: View → Contour Plot

Your screen should now look something like the following figure:

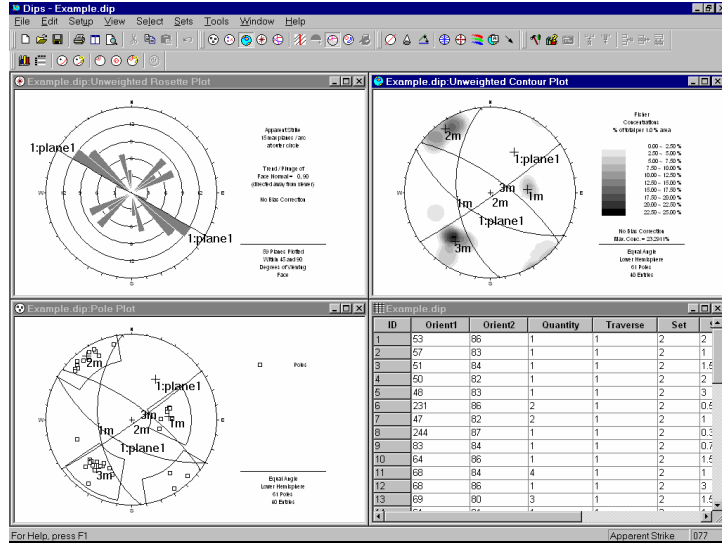


Figure 2-15: Tiled display of four views, EXAMPLE.DIP file.

We will now briefly demonstrate how display options in DIPS are customizable on a per view basis.

Customizing Views

First we will hide the planes and Set Windows on the Pole Plot View.

Show Planes

The Show Planes option can be used to Show or Hide planes on a PER VIEW basis.

Click the mouse in the Pole Plot view, to make it the active view. Now select Show Planes.



Select: Select → Show Planes

Notice that ALL planes on the Pole Plot view are now hidden. However, the Set Windows are still displayed.

Show Windows



To hide the Set Windows:

Select: Sets → Show Windows

The Set Windows on the Pole Plot view are now hidden.

(As an optional step, click in the Contour Plot view and select Show Windows, to re-display the Set Windows in this view).

This demonstrates how planes and Set Windows can be shown or hidden on a PER VIEW basis.

Display Options

Now let's look at the Display Options dialog. Right-click on the Pole Plot view, and select Display Options.

- In the Display Options dialog, change the Stereonet colour to WHITE, and select OK.

Right-click on the Rosette Plot and select Display Options.

- In the Display Options dialog, change the Background colour to BLACK and change the Legend Text colour to WHITE. Select OK.

This demonstrates how colours can be customized on a PER VIEW basis.

NOTE that favourite viewing options (all Display Options, Stereonet Options, and Contour Options), can be saved by the user with Auto Options in the Setup menu. Saved options can be re-applied to individual views at a later time, or saved as the program defaults, allowing the user to create their own customized version of DIPS.

Symbolic Pole Plot

We will now demonstrate how feature attribute analysis can be carried out using the Symbolic Pole Plot and Chart options in DIPS.

First, maximize the Pole Plot view.

1. Right-click on the Pole Plot and select Symbolic Pole Plot (Symbolic Pole Plot is also available in the View menu).
2. In the Symbolic Pole Plot dialog, change the Plot Style to Symbolic Pole Plot.
3. In the drop-down list, select the column you would like to plot. For example, select TYPE.

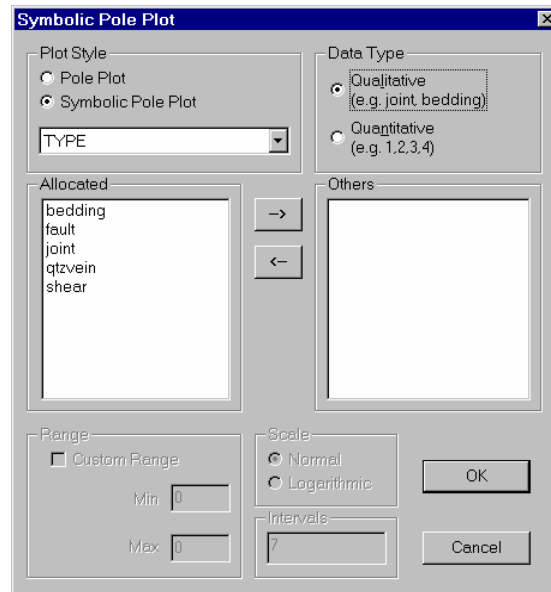


Figure 2-16: Symbolic Pole Plot dialog.

4. The data in the TYPE column is Qualitative, therefore we do not have to change the Data Type (if the data were Quantitative, ie. numeric, then we would have to select the Quantitative Data Type option).
5. Notice that a list of all entries in the TYPE column appears in the Allocated list area.
6. Select OK, and a Symbolic Pole Plot will be generated, displaying symbols corresponding to the entries in the TYPE column.

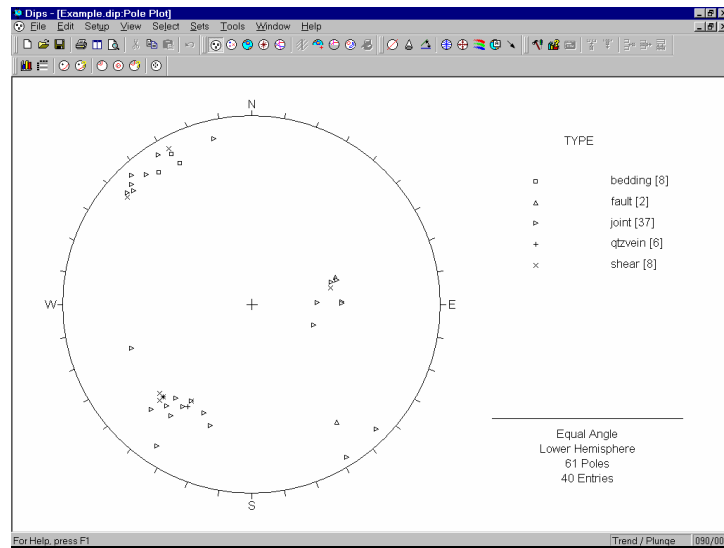


Figure 2-17: Symbolic Pole Plot of data in the TYPE column.

Symbolic Pole Plot Legend

In the Symbolic Pole Plot legend, you will notice a number in square brackets beside each label being plotted. This refers to the TOTAL number of poles with that label (ie. it accounts for the Quantity Column values). If you add the numbers in the square brackets, you will find that the total is equal to the number of Poles listed at the bottom of the legend, in this case, 61.

Creating a Chart from a Symbolic Plot

Now let's create a corresponding Histogram, based on our Symbolic Pole Plot.

1. Right-click on the Symbolic Pole Plot and select Create Corresponding Chart.
2. A new chart view will automatically be generated, using the same data and settings selected for the Symbolic Pole Plot.

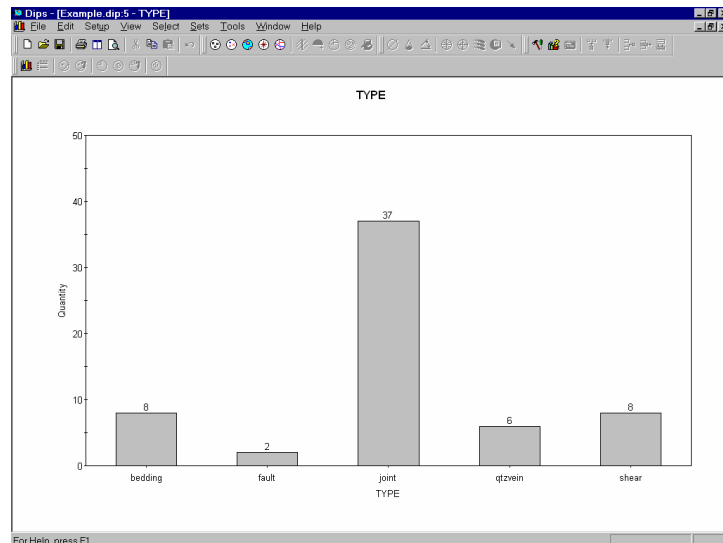


Figure 2-18: Histogram corresponding to Symbolic Pole Plot.

The Chart can then be customized, if necessary, by right-clicking on the Chart and selecting Chart Properties (eg. the Histogram can be converted to a Pie Chart or a Line graph).

Of course, Charts can be generated directly using the Chart option in the Select menu, the above procedure is simply a shortcut for generating a chart from an existing Symbolic Pole Plot.

Query Data

To wrap up this Quick Tour, we will demonstrate how to quickly and easily create subset files from a DIPS file, using the Query Data option.



Select: Select → Query Data

You will see the Query Data dialog.

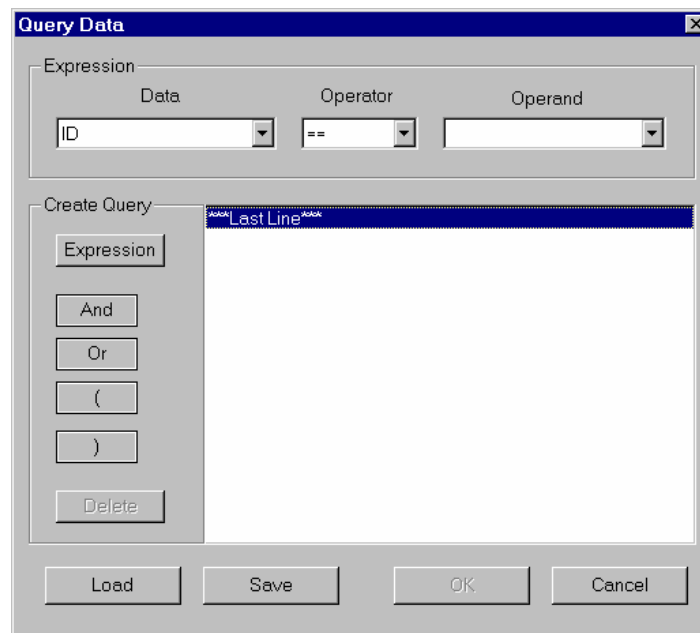


Figure 2-19: Query Data dialog.

Query Data allows the user to create any sort of logical expression to query the information in any column, or any combination of columns, of your DIPS file.

Let's first create a simple query which searches for all JOINTS with a ROUGH surface, ie.:

TYPE == joint && SURFACE Includes rough

Query Example 1

The first step in creating a query, is to create an Expression. As you can see at the top of the Query Data dialog, an Expression consists of Data, Operator and Operand.

1. In the Query Data dialog, click in the Data box at the left of the Expression area, and select TYPE from the drop-down list.
2. Click in the Operand box, and select "joint" from the drop-down list.
3. The Expression area should now display TYPE == joint.

To create the query, use the buttons at the left of the Create Query area to enter the desired expression(s) in the area to the right of the buttons.

4. Select the Expression button in the Create Query area. This will enter the expression TYPE == joint in the Create Query area.
5. Select the AND button to enter the logical && operator.
6. Now create the Expression SURFACE Includes rough.

7. Select the Expression button.
8. Select OK.

A new DIPS file should immediately be generated, and a new Grid view will display the selected data. For the EXAMPLE.DIP file, this query should create a new file with 13 rows.

Note that:

- All entries in the TYPE column are “joint”.
- All entries in the SURFACE column “include” the string “rough” – “sl.rough”, “rough” and “v.rough”.

This example also demonstrates the use of the “Includes” operator, which finds all entries “including” the substring entered as Operand in the Expression.

The New File

The new file created after a query is also a DIPS file, with all of the same Job Control and Traverse information as the original file.

You can immediately start working with this file. For example:



Select: View → Pole Plot

to generate a Pole Plot of the new subset. *Any DIPS option can now be carried out on the new file, including another query.*

If you want to preserve the new file, it is recommended that you save the file with an appropriate name, before proceeding with further analysis.

What About the Set Column?

Earlier in this tutorial, we created Sets with the Add Set Window option. When Sets are created in DIPS, a Set Column is automatically added to the Grid. You will notice in the new file created after a Query, that the Set column is preserved.

However, note that the Set Column in the new file merely preserves the Set ID information. *ALL OTHER SET INFORMATION (ie. MEAN PLANES, WINDOW LIMITS, SET STATISTICS etc.) IS NOT TRANSFERRED TO THE NEW FILE. SETS, AS DEFINED IN DIPS, DO NOT EXIST IN THE NEW FILE CREATED AFTER A QUERY.*

Query Example 2

If you followed through Query Example 1, then first click in any view of the original EXAMPLE.DIP file, so that you can create another query using this file.

As a final step in this Quick Tour of DIPS, we will demonstrate how to create a new file from a Set, using Query Data.

Since the Set Column records the Set ID of data belonging to Sets, this is simply a matter of querying the Set Column for the desired ID(s).



Select: Select → Query Data

1. In the Query Data dialog, create the Expression Set == 1.
2. Select the Expression button.
3. Select OK.

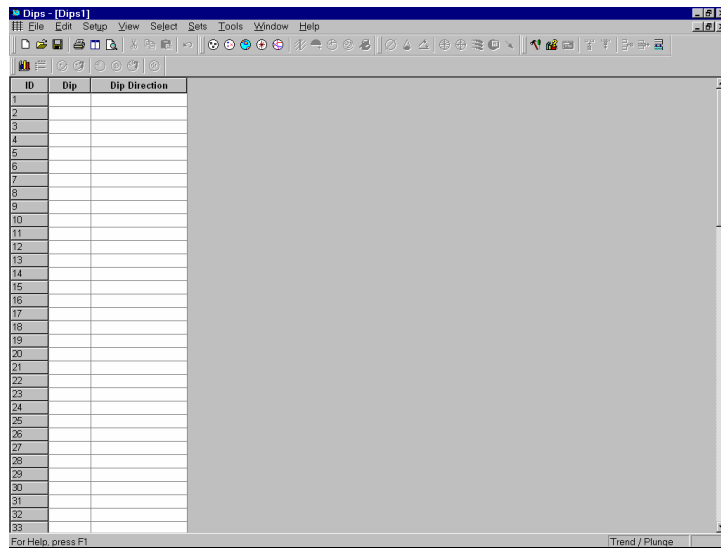
You should now be looking at a new Grid view, containing only the data in Set 1. Notice that all of the data in the SET Column of the new file = 1, as we would expect.

This demonstrates how easily new files can be created from Sets in DIPS using Query Data.

Verify that the new Grid contains the Set 1 data, by creating a Pole Plot, and comparing with the Sets you created in the EXAMPLE.DIP file. The poles in the new file should correspond to the poles within the Set Window for Set 1.

More Query examples can be found in the DIPS Help System. That concludes this Quick Tour of DIPS.

Creating a DIPS File



In this tutorial we outline the steps necessary to create the EXAMPLE.DIP file, which you will be familiar with if you followed the Quick Tour of DIPS in the previous chapter.

If you have not already done so, run DIPS by double-clicking on the DIPS icon in your installation folder. Or from the Start menu, select Programs → Rocscience → Dips → Dips.

If the DIPS application window is not already maximized, maximize it now, so that the full screen is available for viewing the data.

EXAMPLE.DIP File

Since we will be re-creating the EXAMPLE.DIP file, let's first examine this file.

If you have already taken the Quick Tour of DIPS in the previous chapter, then proceed on to the next section (New File).

If you have NOT taken the Quick Tour, then open the EXAMPLE.DIP file, which you will find in the Examples folder in your DIPS installation folder.

A DIPS file is always opened by displaying a Grid View (spreadsheet) of the data. Maximize the Grid View.

ID	Orient1	Orient2	Quantity	Traverse	SPACING, M	TYPE	SURFACE
1	53	86	1	1	2	joint	smooth
2	57	83	1	1	1	joint	smooth
3	51	84	1	1	1.5	joint	smooth
4	50	82	1	1	2	joint	sl.rough
5	48	83	1	1	3	joint	rough
6	231	86	2	1	0.5	joint	rough
7	47	82	2	1	1	shear	slickens
8	244	87	1	1	0.3	joint	v.rough
9	83	84	1	1	0.75	joint	rough
10	64	86	1	1	1.5	joint	smooth
11	68	84	4	1	1	bedding	sl.rough
12	68	86	1	1	3	shear	slickens
13	69	80	3	1	1.5	bedding	sl.rough
14	61	81	1	1	1	bedding	sl.rough
15	300	64	3	1	0.2	joint	v.rough
16	295	68	1	1	0.5	joint	rough
17	320	75	1	1	0.5	joint	sl.rough
18	316	70	1	1	1	joint	smooth
19	315	65	2	1	1	joint	smooth
20	320	68	1	1	2	shear	slickens
21	312	72	2	2	0.4	joint	smooth
22	346	68	3	2	0.7	joint	rough
23	308	65	1	2	1	qtzvein	sealed
24	310	66	1	2	1.5	joint	smooth
25	310	84	4	2	0.3	joint	sl.rough
26	308	62	1	2	1	shear	slickens
27	308	62	1	2	1	joint	smooth
28	170	47	1	2	1.5	joint	smooth
29	320	68	3	2	0.25	qtzvein	sealed
30	322	68	1	2	1	shear	slickens
31	320	68	2	2	0.3	qtzvein	sealed
32	168	50	1	2	5	fault	gouge
33	174	46	1	2	1	shear	slickens

Figure 3-1: Grid View of EXAMPLE.DIP file.

Notice that this file contains the following columns:

- Two Orientation Columns
- A Quantity Column
- A Traverse Column
- Three Extra Columns

When you have finished examining the EXAMPLE.DIP data, close the file, and we will discuss how to re-create this file from scratch.

New File



To begin creating a new DIPS file, select New from the File menu or the Standard toolbar.

Select: File → New

You will see the following blank DIPS spreadsheet, which contains:

- Two Orientation Columns
- 100 rows

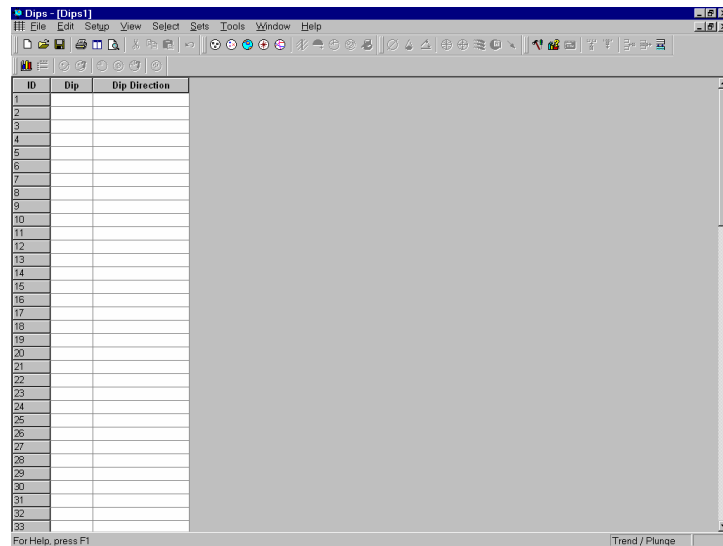


Figure 3-2: Grid View of New File.

If you have not already, maximize the Grid View.

As you can see from the titles of the two Orientation Columns, the default Global Orientation Format for a New file is DIP/DIPDIRECTION. For this example, we need to change this to STRIKE/DIP (right hand rule). This is done through the Job Control option.

Job Control

When creating a new DIPS file, you will generally need to use the Job Control option before proceeding to enter data.



Select: Setup → Job Control

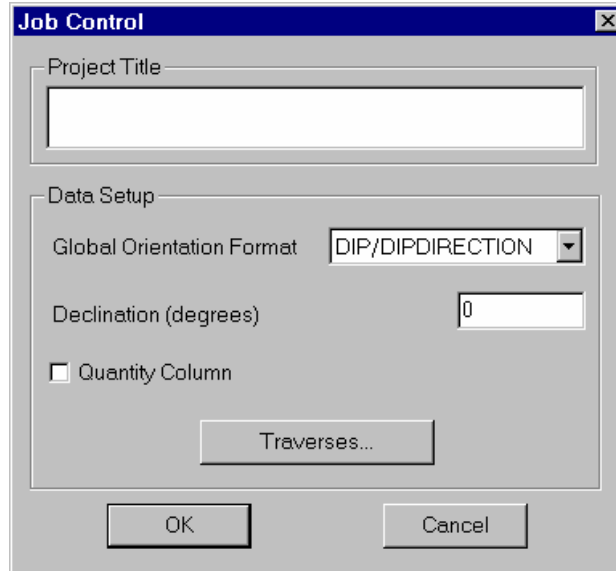


Figure 3-3: Job Control dialog.

For this example, we need to configure the:

- Global Orientation Format
- Declination
- Quantity Column

Global Orientation Format

The Global Orientation Format in the Job Control dialog determines how DIPS will interpret the data in the two Orientation Columns.

Mixed orientation formats can be combined in the same DIPS file by using the Traverse Orientation Format.

For this example, most of our data is in STRIKE/DIP (right hand rule) format, so change the Global Orientation Format to STRIKE/DIPR.

NOTE: Mixed orientation formats CAN BE COMBINED IN THE SAME DIPS FILE by using the optional Traverse Orientation Format, described later in this tutorial.

Declination

Enter a Declination of -5.5 .

The Declination is typically used to correct for magnetic declination, but can be used to adjust to grid north.

Note that the declination is ADDED to all azimuth values, therefore a POSITIVE value corrects for EAST declination, and a NEGATIVE value corrects for WEST declination (which is the case in this example).

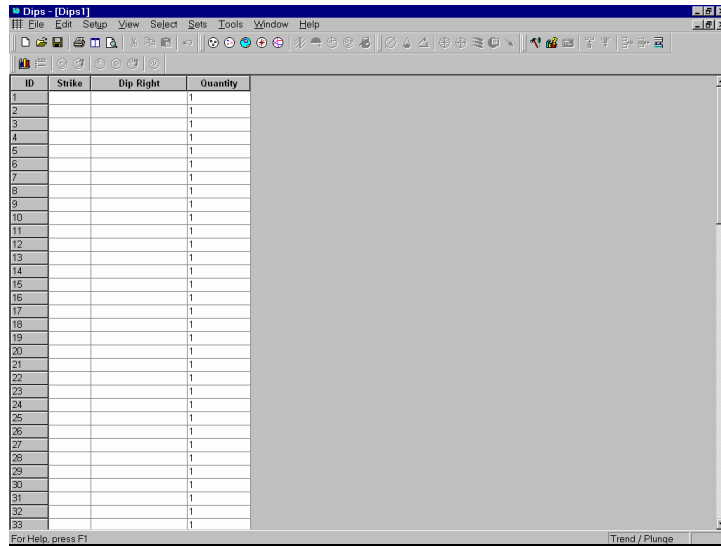
Quantity Column

A Quantity Column in a DIPS file allows the user to record single data entries which refer to multiple identical features having the same orientation.

Select the Quantity Column checkbox in the Job Control dialog.

We are now done with the Job Control dialog. Select OK, and note the following changes to the spreadsheet:

- The titles of the two Orientation Columns are now Strike (Right) and Dip.
- A Quantity Column has been added to the spreadsheet. For convenience, the Quantity Column values are initially set to 1 when the column is created. The user can enter higher values as necessary (eg. 2, 3, 4...)



ID	Strike	Dip Right	Quantity
1			1
2			1
3			1
4			1
5			1
6			1
7			1
8			1
9			1
10			1
11			1
12			1
13			1
14			1
15			1
16			1
17			1
18			1
19			1
20			1
21			1
22			1
23			1
24			1
25			1
26			1
27			1
28			1
29			1
30			1
31			1
32			1
33			1

Figure 3-4: Quantity Column added to spreadsheet.

Traverses

Traverses are used to group data units, and are also used by DIPS to weight the data to correct for measurement bias. To define Traverses:

Select: Setup → Traverses

You will see the Traverse Information dialog. The EXAMPLE.DIP file uses four Traverses, so select the Add button four times.

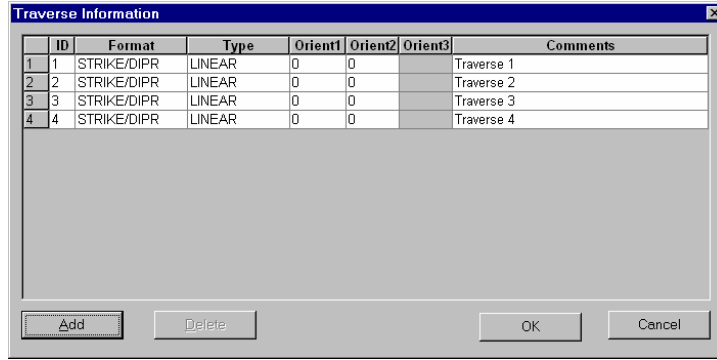


Figure 3-5: Traverse Information dialog.

Enter the following information for the four Traverses.

ID	Format	Type	Or1	Or2	Or3	Comment
1	STRIKE/ DIPR	LINEAR	120	30		Traverse 1
2	STRIKE/ DIPR	PLANAR	100	10		Traverse 2
3		BORE HOLE	20	145	120	Traverse 3
4	DIP/ DIPDIRECTION	PLANAR	10	190		Traverse 4

Table 3-1: Traverse Information for EXAMPLE.DIP file.

Traverse ID

The Traverse ID can be any integer value greater than 0. Each Traverse must have its own unique ID.

Traverse Orientation Format

The Traverse Orientation Format is very important, because it allows the user to combine mixed orientation formats in the same DIPS file.

Whenever the Traverse Orientation Format is different from the Global Orientation Format, DIPS will interpret the orientation data for the Traverse according to the Traverse Orientation Format.

In this example:

- Traverses 1 and 2 have the same data format as the Global Orientation Format (STRIKE/DIPR).
- Traverse 3 is a BOREHOLE traverse. The Traverse Orientation Format is not applicable, since data is measured in terms of alpha and beta angles on the oriented core. See the DIPS Help system for detailed discussion of BOREHOLE traverses.
- Traverse 4 uses a different orientation format from the Global Orientation Format. In this case, the data on Traverse 4 is in DIP/DIPDIRECTION format.

Traverse Type

Four Traverse Types are available in DIPS:

- LINEAR
- PLANAR
- BOREHOLE
- CLINORULE

Traverse Orientation

The orientations required to define the Traverse Orientation depend on the Traverse Type, and may also depend on the Traverse Orientation Format.

- Traverse 1 is a LINEAR traverse. For a LINEAR traverse, the Orient 1 and Orient 2 values are always in TREND/PLUNGE format.

- Traverse 2 is a PLANAR traverse. For a PLANAR traverse, the Orient 1 and Orient 2 values correspond to the Traverse Orientation Format, in this case STRIKE/DIPR.
- Traverse 3 is a BOREHOLE traverse, which requires THREE orientations to define. See the DIPS Help system for details.
- Traverse 4 is a PLANAR traverse. In this case, the Traverse Orientation Format is DIP/DIPDIRECTION, therefore the Orient 1 and Orient 2 values are in DIP/DIPDIRECTION format.

Traverse Comment

An optional Traverse Comment can be added for each Traverse, to further identify / describe each traverse.

You may inspect the original EXAMPLE.DIP file to view the comments added for these four traverses.

Traverse Column

When you are finished entering the Traverse Information, select OK, and you will see that a Traverse Column has been added to the spreadsheet, after the Quantity Column.

The Traverse Column is for recording the Traverse ID of each data unit. In this case, 1, 2, 3 and 4.

Also notice that the titles of the two Orientation Columns are now Orient 1 and Orient 2, instead of StrikeR and Dip. Since there are mixed orientation formats in this data file (remember that the Traverse Orientation Format for Traverse 4 is DIP/DIPDIRECTION while the Global Orientation Format is STRIKE/DIPR), the titles of the Orientation Columns are simply Orient 1 and Orient 2, to avoid misinterpretation of the data.

ID	Orient1	Orient2	Quantity	Traverse
1			1	
2			1	
3			1	
4			1	
5			1	
6			1	
7			1	
8			1	
9			1	
10			1	
11			1	
12			1	
13			1	
14			1	
15			1	
16			1	
17			1	
18			1	
19			1	
20			1	
21			1	
22			1	
23			1	
24			1	
25			1	
26			1	
27			1	
28			1	
29			1	
30			1	
31			1	
32			1	
33			1	

Figure 3-6: Traverse Column added to spreadsheet.

Extra Columns

In DIPS, any columns AFTER the two mandatory Orientation Columns, and the optional Quantity and Traverse Columns (if present), are referred to as Extra Columns.

Extra Columns can be used to store any other QUANTITATIVE or QUALITATIVE data that the user wishes to record.

Recall that the EXAMPLE.DIP file used three Extra Columns:

- SPACING
- TYPE
- SURFACE

Extra Columns are added to the DIPS spreadsheet with the Add Column option in the Edit menu.

Add Column

Since Extra Columns can only be added AFTER the Orientation, Quantity and Traverse Columns, the current highlighted spreadsheet cell must be either:

- IN AN EXISTING EXTRA COLUMN, or
- IN THE LAST OF THE ORIENTATION, QUANTITY, OR TRAVERSE COLUMNS, AS APPLICABLE,

in order for the Add Column option to be enabled.

In this case, since no Extra Columns currently exist, click the mouse in the Traverse Column. The Add Column option will be enabled.



Select: Edit → Add Column

You will see the Add Column dialog, allowing you to enter the column name. Enter the name SPACING,M:

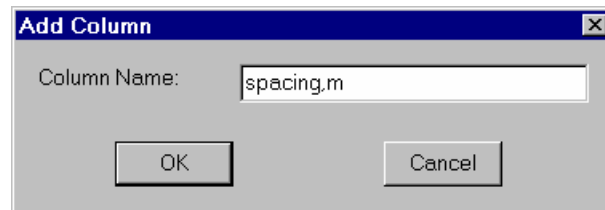


Figure 3-7: Add Column dialog.

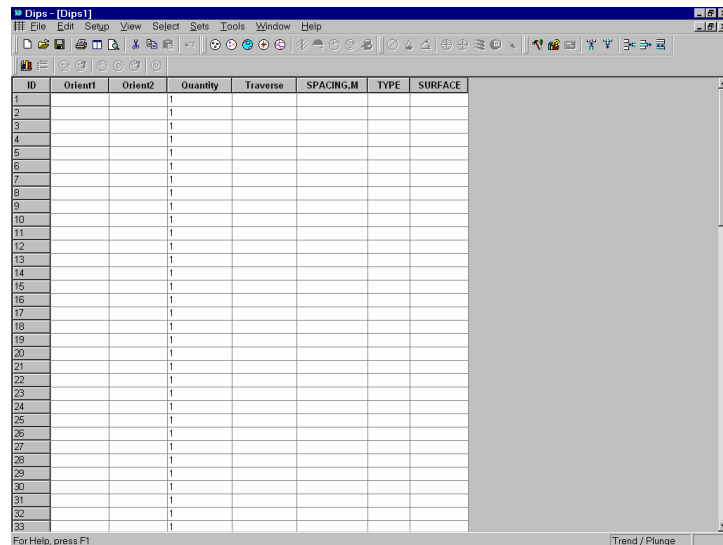
The title of Extra Columns is always displayed in UPPERCASE.

Select OK to add the Extra Column. Notice that the title of Extra Columns is always displayed in UPPERCASE, regardless of how the name was actually entered in the Add Column dialog.

Now let's add the TYPE and SURFACE Extra Columns. An alternative way to add an Extra Column, is to RIGHT-CLICK on the title of an existing Extra Column, or the LAST of the Orientation, Quantity or Traverse columns, as applicable. For example:

1. Right-click the mouse on the title of the SPACING,M column which you just created.
2. Select Add Column from the right-click menu.
3. Enter the name TYPE in the Add Column dialog, and select OK, and the TYPE Extra Column will be added to the spreadsheet.
4. Now right-click the mouse on the title of the TYPE column.
5. Select Add Column from the right-click menu.
6. Enter the name SURFACE in the Add Column dialog, and select OK, and the SURFACE Extra Column will be added to the spreadsheet.

Congratulations! You have now re-created all of the columns of the EXAMPLE.DIP file. You are now ready to start entering data.



ID	Orient	Orient2	Quantity	Traverse	SPACING,M	TYPE	SURFACE
1			1				
2			1				
3			1				
4			1				
5			1				
6			1				
7			1				
8			1				
9			1				
10			1				
11			1				
12			1				
13			1				
14			1				
15			1				
16			1				
17			1				
18			1				
19			1				
20			1				
21			1				
22			1				
23			1				
24			1				
25			1				
26			1				
27			1				
28			1				
29			1				
30			1				
31			1				
32			1				
33			1				

Figure 3-8: Three Extra Columns added to spreadsheet.

Entering Data

To conclude this tutorial, we will:

- Open the EXAMPLE.DIP file, and copy the data into our new file.
- Generate Pole Plots for both files, and hopefully they will be identical!



Select: File → Open

Navigate to the Examples folder in your DIPS installation folder, and open the EXAMPLE.DIP file. Tile the two views.

Select: Window → Tile Horizontally

1. In the EXAMPLE.DIP spreadsheet, click on the ID button at the upper left corner, to select the entire spreadsheet.
2. Right-click the mouse anywhere in the EXAMPLE.DIP spreadsheet and select Copy.
3. Now left-click the mouse in the FIRST cell of the new spreadsheet (ie. the Row 1 , Orient 1 cell).
4. Right-click the mouse anywhere in the new file spreadsheet, and select Paste.
5. The data from the EXAMPLE.DIP file should now be pasted into the new file.
6. Let's verify that we have correctly re-created the EXAMPLE.DIP file.



Select: View → Pole Plot

7. This will generate a Pole Plot of the data in the new file.
8. Now click the mouse anywhere in the EXAMPLE.DIP spreadsheet, to make it the active view.



Select: View → Pole Plot

9. This will generate a Pole Plot of the EXAMPLE.DIP file.

10. Tile the views.



Select: Window → Tile Vertically

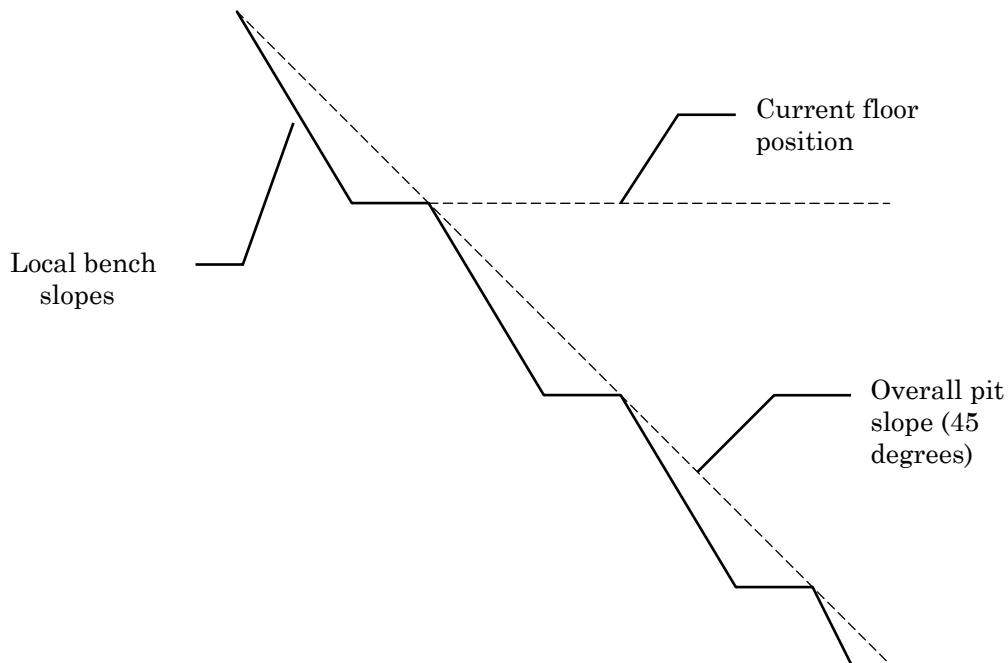
11. Compare the two Pole Plots. They should be identical. If not, then examine the Job Control and Traverse dialogs of the new file, and make sure they are the same as the EXAMPLE.DIP file. Also check that the data in the new file ends at the fortieth row, since the EXAMPLE.DIP file contained forty rows.

That concludes this tutorial. If you wish you can save the new file, and then read it back in again. Notice that the blank rows after the fortieth row are no longer present after saving the file.

Toppling, Planar Sliding, Wedge Sliding

This advanced DIPS tutorial uses the example file EXAMPPIT.DIP, which you should find in the Examples folder of your DIPS Installation folder.

The data has been collected by a geologist working on a single rock face above the first bench in a young open pit mine.



The rock face above the current floor of the existing pit has a dip of 45 degrees and a dip direction of 135 degrees. The current plan is to extend the pit down at an overall angle of 45 degrees. This will require a steepening of the local bench slopes, as indicated in the figure above.

The local benches are to be separated by an up-dip distance of 16m. The bench roadways are 4m wide.

EXAMPPIT.DIP File

First open the EXAMPPIT.DIP file.



Select: File → Open

Navigate to the Examples folder in your DIPS installation folder, and open the EXAMPPIT.DIP file. Maximize the view.

ID	Orient1	Orient2	Traverse	SPACING(M)	LENGTH(M)	TYPE	SHAPE	SURFACE
1	77	322	1	3	14	joint	planar	rough
2	68	80	1	1.3	7	joint	undulate	v.rough
3	39	136	1	1.6	22	bedding	planar	smooth
4	79	319	1	3.8	10	joint	planar	polished
5	74	85	1	0.7	6	joint	planar	smooth
6	70	134	1	1.6	17	joint	planar	smooth
7	73	319	1	4.8	14	joint	undulate	rough
8	83	319	1	1.0	6	joint	undulate	rough
9	65	310	1	2.6	12	joint	planar	smooth
10	68	288	1	2.3	10	joint	stepped	rough
11	30	265	1	2.1	6	joint	planar	smooth
12	76	231	1	1.8	8	joint	planar	smooth
13	49	306	1	3.8	21	joint	undulate	rough
14	55	294	1	1.0	8	joint	undulate	smooth
15	76	88	1	2.0	8	joint	undulate	rough
16	86	91	1	0.9	6	joint	undulate	smooth
17	62	76	1	1.3	7	joint	planar	rough
18	69	258	1	1.5	8	joint	planar	smooth
19	66	9	1	2.1	7	joint	planar	rough
20	69	325	1	2.2	14	joint	planar	polished
21	71	246	1	1.8	8	joint	planar	rough
22	65	53	1	8.0	26	shear	planar	slick
23	37	250	1	2.4	16	joint	planar	rough
24	78	79	1	3.4	10	joint	undulate	rough
25	61	125	1	1.3	17	bedding	planar	smooth
26	31	223	1	1.9	15	joint	planar	v.rough
27	64	249	1	7.0	20	shear	planar	slick
28	64	40	1	1.0	10	joint	stepped	smooth
29	66	130	1	1.4	16	joint	stepped	smooth
30	55	122	1	1.6	19	bedding	planar	smooth
31	74	78	1	3.3	10	joint	planar	smooth
32	67	183	1	0.9	7	joint	planar	rough
33	69	181	1	0.5	6	joint	planar	rough

Figure 4-1: EXAMPPIT.DIP data.

The EXAMPPIT.DIP file contains 303 rows, and the following columns:

- The two mandatory Orientation Columns
- A Traverse Column
- 5 Extra Columns

Let's examine the Job Control information for this file.



Job Control

Select: Setup → Job Control

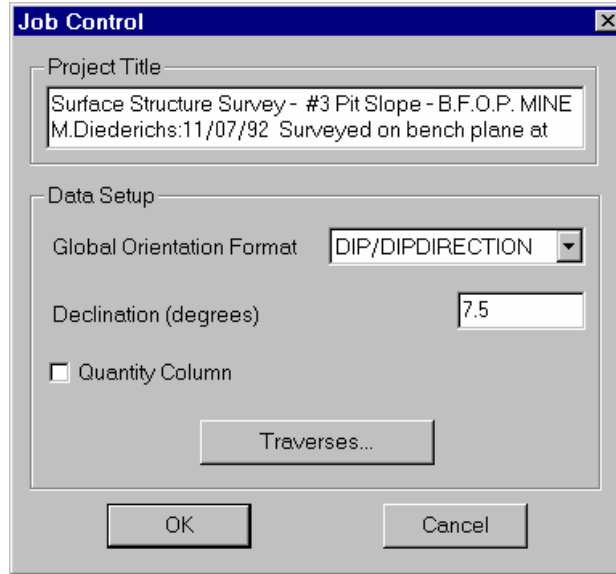


Figure 4-2: Job Control information for EXAMPPIT.DIP file.

Note the following:

- the Global Orientation Format is DIP/DIPDIRECTION
- The Declination is 7.5 degrees, indicating that 7.5 degrees will be added to the dip direction of the data, to correct for magnetic declination
- The Quantity Column is NOT used in this file, so each row of the file represents an individual measurement.

Traverses

Let's inspect the Traverse Information. You can select the Traverses button in the Job Control dialog (the Traverses dialog is also available directly in the Setup menu).

As you can see in the Traverse Information dialog, this file uses only a single traverse:

- The Traverse is a PLANAR traverse, with a DIP of 45 degrees and a DIP DIRECTION of 135 degrees (ie. the face above the survey bench, as you can read in the Traverse Comment).
- Note that the Traverse Orientation Format is the same as the Global Orientation Format (DIP/DIPDIRECTION), as we would expect for a file with only a single traverse defined.

Select Cancel in the Traverse Information dialog.

Select Cancel in the Job Control dialog.

Pole Plot



Now generate a Pole Plot of the data.

Select: View → Pole Plot

Feature attribute analysis can be carried out on a Pole Plot with the Symbolic Pole Plot option. Let's create a Symbolic Pole Plot based on the discontinuity type (ie. the data in the TYPE column).

Right-click on the Pole Plot and select Symbolic Pole Plot. In the Symbolic Pole Plot dialog:

1. Change the Plot Style to Symbolic Pole Plot, and select TYPE from the pull-down list of column names.
2. The Data Type for this column is Qualitative, which is the default selection, so just select OK to generate the Symbolic Pole Plot.

Look closely at the data clustering and the data TYPE. Note the clustering of bedding features and the two clusters of shear features. These may behave very differently from similarly oriented joints or extension fractures, and should be considered separately.

Observe the clustering of **joint, bedding and shear** features on a Symbolic Pole Plot.

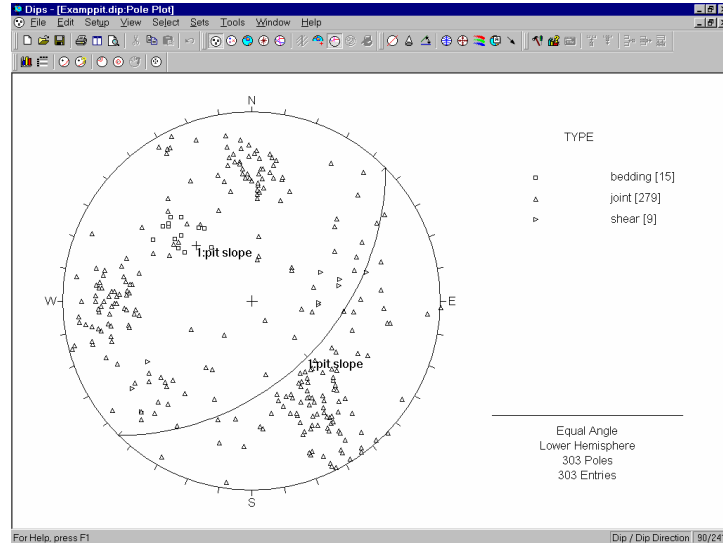


Figure 4-3: Symbolic Pole Plot of discontinuity TYPE. Great circle representing the pit slope has also been added.

In the above figure, you will notice that a great circle has been added to the plot, representing the pit slope.

Planes are added to stereonet plots with the Add Plane option, as described below.

Add Plane

Use Add Plane to add a great circle representing the **pit slope** on the stereonet.

Before we add the plane, let's change the Convention. In DIPS, orientation coordinates can be displayed in either Pole Vector (Trend/Plunge) format, or Plane Vector format. Right now we want to use the Plane Vector Convention, which for this file is DIP/DIPDIRECTION, since this is the Global Orientation Format.

To change the Convention, click the left mouse button on the box at the lower right of the Status Bar, which should currently display Trend/Plunge. It should then display Dip / DipDirection. The Convention can be toggled at any time in this manner.

Now let's add the plane.



Select: Select → Add Plane

1. On the Pole Plot, move the cursor to APPROXIMATELY the coordinates 45 / 135 (Dip / DipDirection). Remember that the cursor coordinates are displayed in the Status Bar.
2. Click the LEFT mouse button, and you will see the Add Plane dialog.



Figure 4-4: Add Plane dialog.

3. If you did not click at exactly 45 / 135 , don't worry, you can now enter the exact coordinates in the Add Plane dialog.
4. You can also enter an optional descriptive label, for example, "pit slope". If you wish, you can clear the ID checkbox, so that only the label "pit slope" appears.
5. Select OK, and the plane (great circle) representing the overall pit slope, will be added to the plot.

Contour Plot

Now let's view the contoured data.



Select: View → Contour Plot

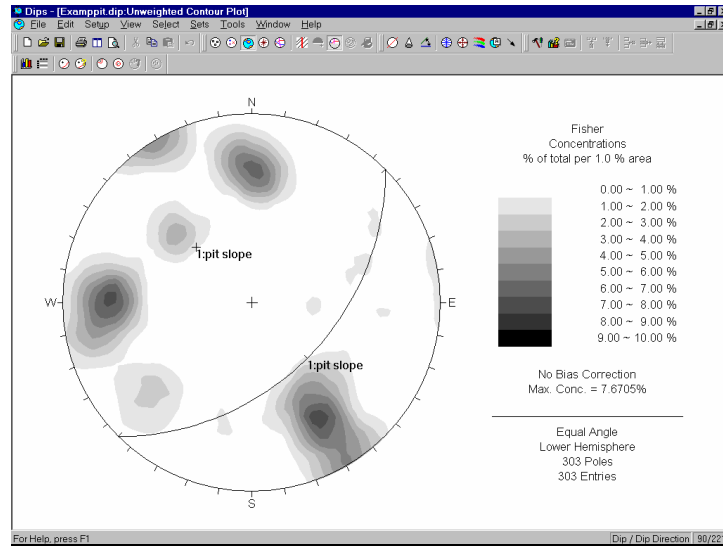


Figure 4-5: Unweighted Contour Plot of EXAMPPIT.DIP data.

A useful rule of thumb is that any cluster with a maximum concentration of greater than 6% is very significant. 4-6% represents a marginally significant cluster. Less than 4% should be regarded with suspicion unless the overall quantity of data is very high (several hundreds of poles). Rock mechanics texts give more rigorous rules for statistical analysis of data.

Now let's apply the Terzaghi Weighting to the data, to account for bias correction due to data collection on the (planar) traverse.



Select: View → Terzaghi Weighting

Observe the change in adjusted concentration for the set nearly parallel to the mapping face (the “bedding plane” joint set).

Observe the effect of bias correction on the bedding plane joint set in particular.

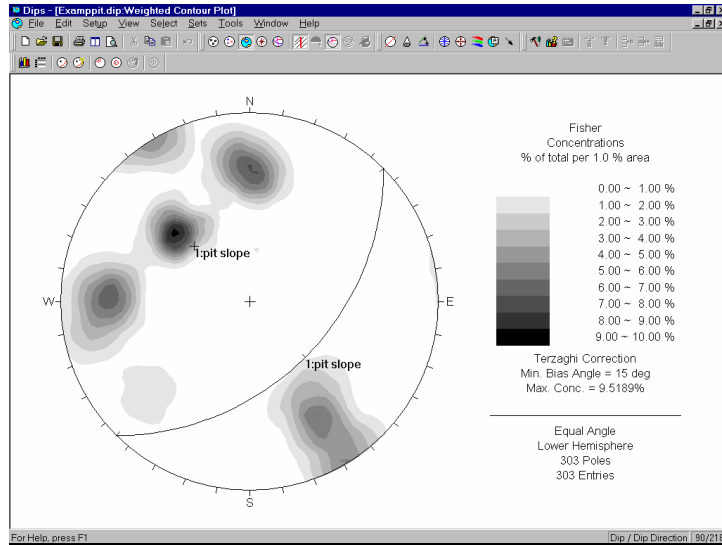


Figure 4-6: WEIGHTED Contour Plot of EXAMPPIT.DIP data.

See the DIPS Help system for more information about the Terzaghi Weighting procedure used in DIPS.

The Terzaghi Weighting option works as a toggle, so re-select the option to restore the original unweighted Contour Plot.



Select: View → Terzaghi Weighting

Contours can be overlaid on a Pole Plot with the Overlay Contours option. Let's do that now.

Overlay of Contours and Poles

To overlay contours, let's first view the Pole Plot again.



Select: View → Pole Plot

Note that the Symbolic Pole Plot is still in effect, and does NOT get reset when you switch to viewing other plot types (eg. the Contour Plot). To overlay contours:



Select: View → Overlay Contours

Let's change the Contour Mode to Lines, so that the Poles are easier to see.

Select: Setup → Contour Options

In the Contour Options dialog, set the Mode to Lines and select OK.

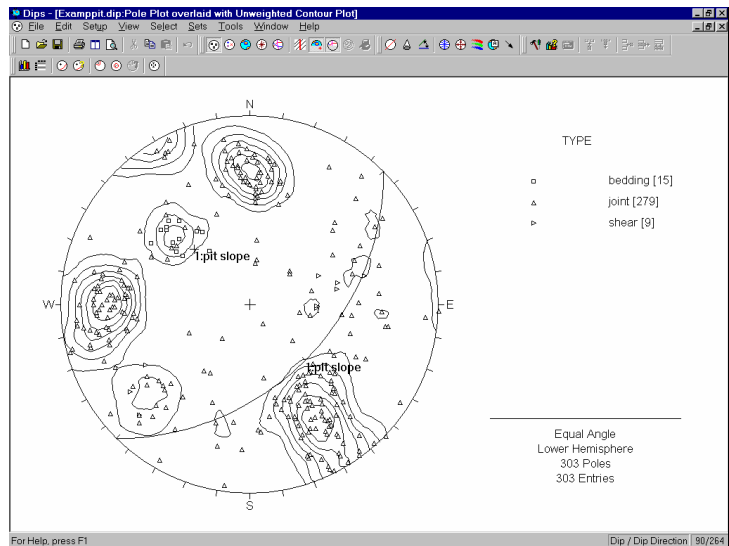


Figure 4-7: Overlaid Contours on Pole Plot.

Although the SHEARS are not numerous enough to be represented in the contours, they may have a dominating influence on stability due to low friction angles and inherent persistence.

Notice that the Shears in this example are not represented in the contours. This is because the number of mapped shears is small. However, due to the low friction angle and inherent persistence, the shear features may have a dominating influence on stability. It is always important to look beyond mere orientations and densities when analyzing structural data.

Creating Sets

Now use the Add Set Window option to delineate the joint contours, and create four Sets from the four major data concentrations on the stereonet.



Select: Sets → Add Set Window

See the Quick Tour of DIPS, the first tutorial in this manual, for instructions on how to create Sets. Also see the DIPS Help system for detailed information.

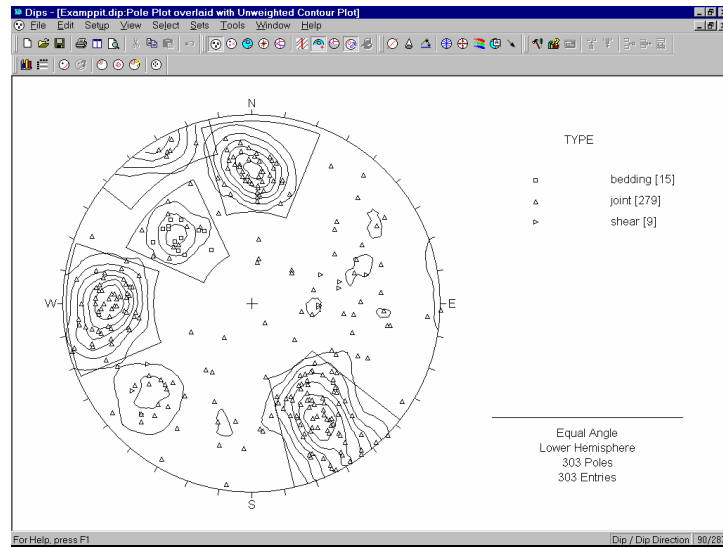


Figure 4-8: Set Windows formed around the four principal joint sets, using the Add Set Window option.

Note that in Figure 4-8, the display of the planes was hidden using the Show Planes option. Show Planes can be used at any time to show or hide the planes on any given view.

FAILURE MODES

Surface Condition

For stability analysis it will be necessary to assume a value for friction angle on the joint surfaces.

For the purpose of estimating a friction angle, we will create a Chart of the data in the SURFACE column of the EXAMPPIT.DIP file.



Select: Select → Chart

In the Chart dialog, select SURFACE from the pull-down list of columns.

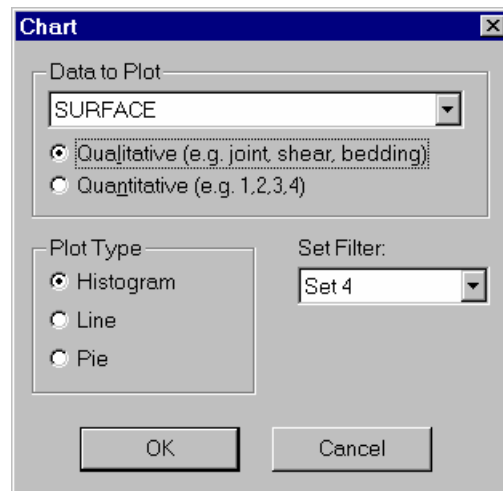


Figure 4-9: Chart dialog.

Also, for the purpose of our first analysis, which will be a toppling analysis, we are concerned primarily with the joint set at the lower right of the stereonet. Use the Set Filter option in the Chart dialog, to select this Set (in this example, Set ID = 4, yours may be different, depending on the order in which you created the Sets).

Select OK, and the Chart will be created.

View the SURFACE properties and estimate a friction angle.

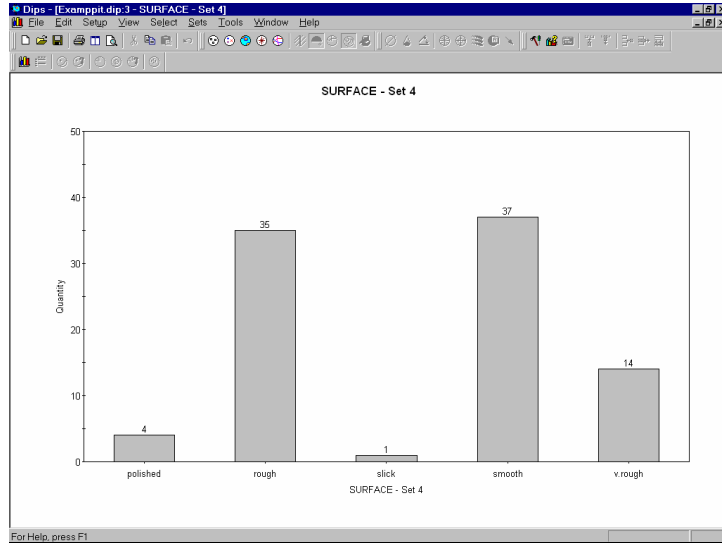


Figure 4-10: Histogram of SURFACE properties for joint set 4.

The joint set illustrated above is predominantly rough (considering both “rough” and “v.rough” features), and so a friction angle of 35 – 40 degrees (a conservative estimate) will be used.

We are finished with the Chart, so close the Chart view and we will return to the stereonet.

Statistical Info

We will now add some statistical information to the Pole Plot, by displaying Variability cones around the mean Set orientations. (The shears will be considered separately where appropriate).

If you are still viewing the overlaid Contours on the Pole Plot, toggle this off by re-selecting Overlay Contours.



Select: View → Overlay Contours

Variability Cones

Variability cones are displayed through the Edit Sets dialog.



Select: Sets → Edit Sets

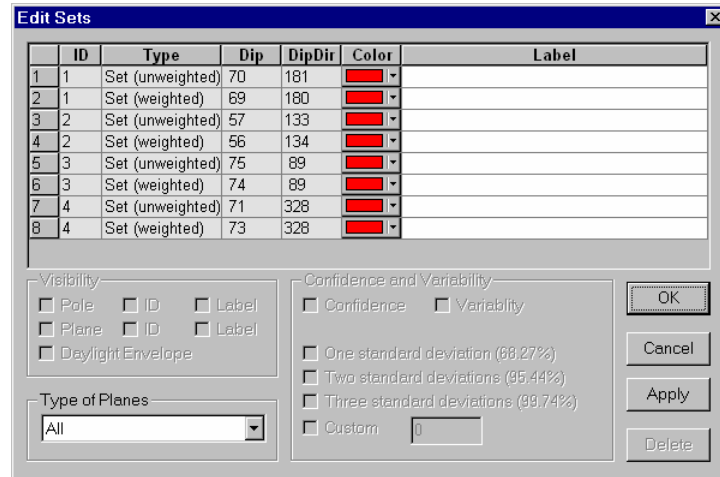


Figure 4-11: Edit Sets dialog.

For the remainder of this tutorial we will be dealing with WEIGHTED Set information, so select Weighted planes in the Type of Planes pull-down in the Edit Sets dialog.

1. Notice that only the WEIGHTED planes are now listed in the dialog.
2. Select all four planes by selecting the row ID buttons at the left of the dialog. You can click and drag with the mouse, or use the Shift and / or Ctrl keys in conjunction with the mouse, to make multiple selections.
3. Select the Variability checkbox.

4. Select the One Standard Deviation and Two Standard Deviation checkboxes.
5. Select OK.

You now have variability cones representing one and two standard deviations of orientation uncertainty centered on the calculated means.

If you previously toggled the display of planes OFF with the Show Planes option, toggle the display back ON again, by re-selecting Show Planes, since we want to view the Added Plane representing the pit slope.



Select: Select → Show Planes

However, we do not currently want to display the MEAN planes, so let's toggle their visibility OFF for now. We'll revisit the Edit Sets dialog.



Select: Sets → Edit Sets

1. Select ALL planes.
2. Clear ALL Visibility checkboxes (ie. Pole, Plane, ID and Label).
3. Select OK.

Your screen should look like Figure 4-12.

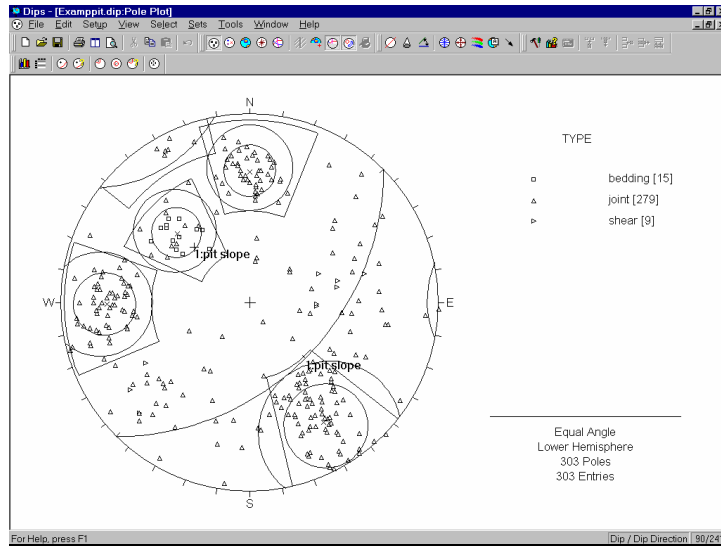


Figure 4-12: Variability cones displayed on Pole Plot.

A TOPPLING ANALYSIS using stereonets is based on:

- 1) Variability cones indicating the extent of the joint set population.
- 2) A Slip Limit based on the joint friction angle and pit slope.
- 3) Kinematic considerations.



Toppling

(The following analysis is based on Goodman 1980. See the reference at the end of this tutorial).

Using the variability cones generated above, proceed with a toppling analysis. Assume a friction angle of 35 degrees, based on the surface condition of the joints (see Figure 4-10).

Planes cannot topple if they cannot slide with respect to one another. Add a second plane representing a “slip limit” to the stereonet with the Add Plane option.

Select: Select → Add Plane

Position the cursor at APPROXIMATELY 10 / 135 (Dip / DipDirection) and click the left mouse button.

In the Add Plane dialog, if your graphically entered coordinates are not exactly 10 / 135, then enter these exact coordinates and select OK.

NOTE: the DIP angle for this plane is derived from the $\text{PIT SLOPE ANGLE} - \text{FRICTION ANGLE} = 45 - 35 = 10$ degrees. The DIP DIRECTION is equal to that of the face (135 degrees). Goodman states that for slip to occur, the bedding normal must be inclined less steeply than a line inclined at an angle equivalent to the friction angle above the slope.

Next, use the Add Cone option to place kinematic bounds on the plot. When specifying cone angles, remember that the angle is measured from the cone axis.



Select: Tools → Add Cone

Click the mouse anywhere in the stereonet, and you will see the Add Cone dialog. Enter the following values:

These values are derived as follows:

- The Trend is equal to the DIP DIRECTION of the face plus 90 degrees ($135 + 90 = 225$).
- The 60 degree cone angle will place two limits plus / minus 30 degrees with respect to the face DIP DIRECTION as suggested by Goodman – planes must be within 30 degrees of parallel to a cut slope to topple. An earlier 15 degree limit proposed by Goodman was found to be too small.

Select OK on the Add Cone dialog.

The zone bounded by these new curves (outlined in Figure 4-13 below) is the toppling region. Any Poles plotting within this region indicate a toppling risk. Remember that a near horizontal pole represents a near vertical plane.

The zone outlined in Figure 4-13 is the **toppling region**. Any **POLES** plotting within this region indicate a toppling risk.

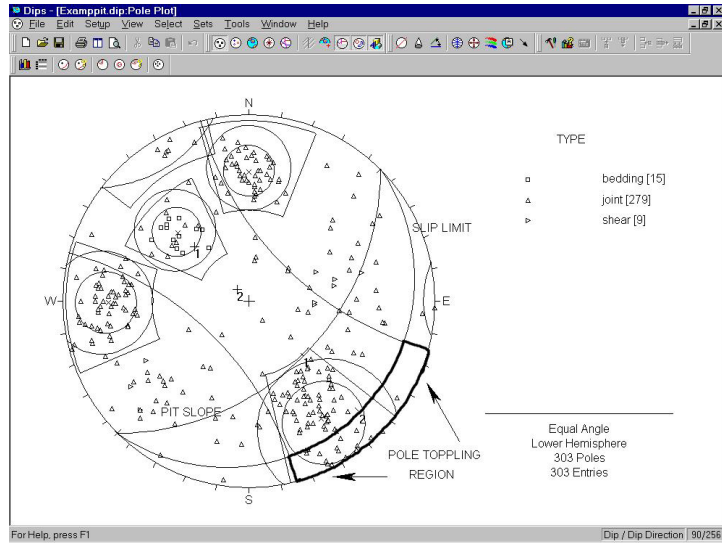


Figure 4-13: Toppling risk is indicated by the relative number of poles within joint set which fall within the outlined pole toppling region. Visual estimate indicates about 25 – 30% toppling risk for joint set 4, based on the 95% variability cone.

The two variability cones give a statistical estimate of the toppling risk for the joint set in question. A visual estimate indicates that 25 – 30% of the theoretical population of joint set 4 falls within the toppling zone. It could be said that, ignoring variability in the friction angle, there is an approximate toppling risk of 30%. Frictional variability could be introduced by overlaying additional slip limits corresponding to say 30 and 40 degrees.

A PLANAR SLIDING analysis uses Variability Cones, a Friction cone, and a Daylight Envelope, to test for combined **frictional** and **kinematic** possibility of planar sliding.



Planar Sliding

Before we proceed with the Planar Sliding analysis, let's first delete the cone added for the Toppling analysis.

Select: Tools → Delete → Delete All

This will delete the cone, and also any Added Text and Arrows which you may have added to the view.

Now, in the Edit Planes dialog, we will:

- delete the “slip limit” plane that we added for the Toppling analysis, and
- display a Daylight Envelope for the pit slope plane.

Select: Select → Edit Planes



Figure 4-14: Edit Planes dialog.

1. Select the second Added Plane and select Delete.
2. Select the first Added Plane (the Pit Slope), and select the Daylight Envelope checkbox.

3. Select OK.

A Daylight Envelope for the Pit Slope plane should be visible on the stereonet.

A Daylight Envelope allows us to test for kinematics (ie. a rock slab must have somewhere to slide into – free space). Any pole falling within this envelope is kinematically free to slide if frictionally unstable.

Finally, let's place a POLE friction cone at the center of the stereonet.



Select: Tools → Add Cone

Click the mouse anywhere in the stereonet, and enter the following values in the Add Cone dialog:

Select OK.

Note that the friction angle is equal to our friction estimate of 35 degrees, determined earlier in this tutorial.

Any pole falling outside of this cone represents a plane which could slide if kinematically possible.

The crescent shaped zone formed by the Daylight Envelope and the pole friction circle therefore encloses the region of planar sliding. Any poles in this region represent planes which can and will slide. See Figure 4-15.

Note that a **POLE friction cone angle** is measured from the **center of the stereonet**.

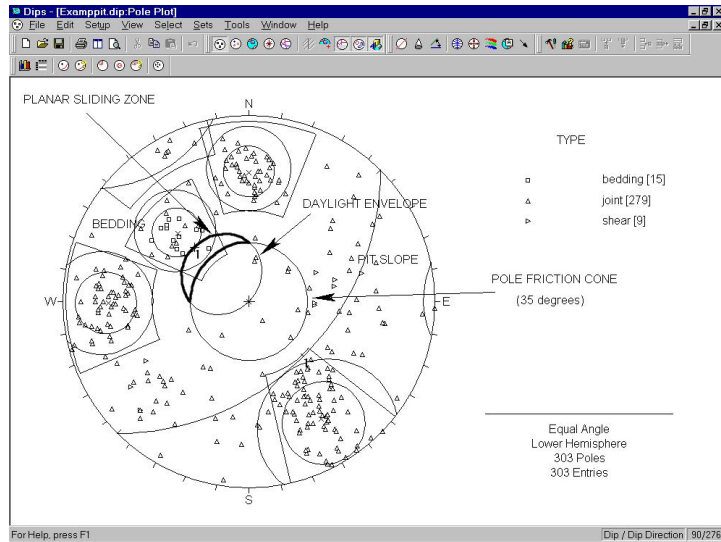


Figure 4-15: Planar sliding zone is represented by crescent shaped region. Only a small area overlaps the bedding joint set, therefore the risk of planar sliding is minimal.

Again, the variability cones give a statistical estimate of failure probability. Only a small percentage ($< 5\%$) of the bedding joint set falls within this zone.

Planar sliding is unlikely to be a problem.

NOTE: We have been using EQUAL ANGLE projection throughout this analysis. When making visual estimates of clusters and variabilities, it is actually more appropriate to use EQUAL AREA projection to reduce areal distortion and improve visual estimates.

Wedge Sliding

It has been shown that a sliding failure along any of the joint planes is unlikely. However, multiple joints can form wedges which can slide along the line of intersection between two planes.

For this analysis, let's switch to the Major Planes plot, which allows us to view planes only on the stereonet, without poles or contours.



Select: View → Major Planes

Before we proceed with the Wedge Sliding analysis, let's first delete the cone added for the Planar Sliding analysis.

Select: Tools → Delete → Delete All

This will delete the cone, and also any Added Text and Arrows which you may have added to the view.

Next, let's hide the Daylight Envelope for the pit slope, since we do not need it for this analysis.



Select: Select → Edit Planes

In the Edit Planes dialog, select the pit slope plane, and clear the Daylight Envelope checkbox. Select OK.

Next, in the Edit Sets dialog, we want to make the WEIGHTED MEAN planes visible (which we hid earlier in this tutorial), and also hide the Variability cones.

Select: Sets → Edit Sets

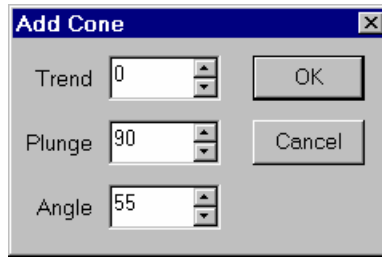
In the Edit Sets dialog, select the four WEIGHTED MEAN planes, and select the Plane visibility checkbox ONLY. Also, clear the Variability Cone and Standard Deviation checkboxes. Select OK.

Finally, let's add a PLANE friction cone to the stereonet.



Select: Tools → Add Cone

Click the mouse anywhere in the stereonet, and enter the following values in the Add Cone dialog:



Note that a PLANE friction cone angle is measured from the **perimeter** (equator) of the stereonet.

NOTE: this time we are not dealing with poles but an actual sliding surface or line, so that the friction angle (35 degrees) is taken from the EQUATOR of the stereonet, and NOT FROM THE CENTER as before. Therefore the angle we enter in the Add Cone dialog is $90 - 35 = 55$ degrees.

Select OK, and your plot should appear as follows:

WEDGE SLIDING may occur if the mean joint set orientation INTERSECTIONS fall within the zone defined by the friction cone and the pit slope.

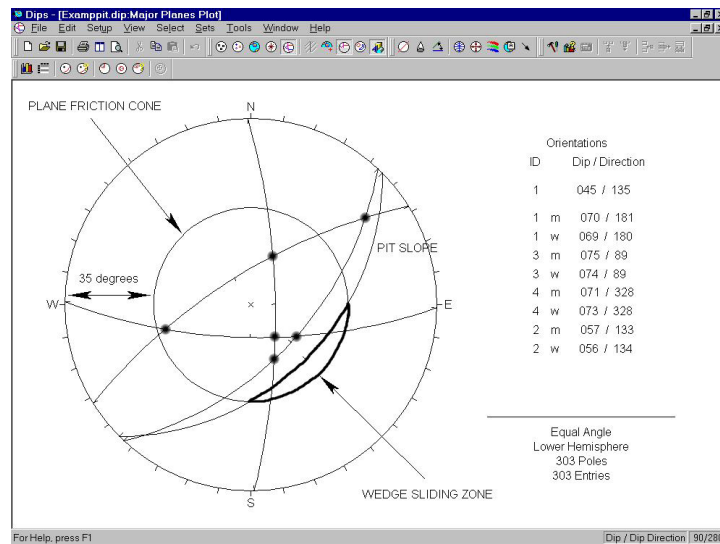


Figure 4-16: Major Planes Plot showing WEIGHTED MEAN planes, pit slope and friction cone. Wedge sliding zone is represented by crescent shaped region. Since no plane intersections (black dots) fall within this region, wedge sliding failure should not be a concern.

The zone OUTSIDE the pit slope but enclosed by the friction cone represents the zone of wedge (intersection) sliding. Any plane intersections (highlighted by black dots in Figure 4-16) which fall within this zone will be unstable. This is not the case in this example, therefore wedge sliding should not be a problem.

Discrete Structures

Finally, you should analyze the shear zones mentioned earlier. If these shears occur in proximity to one another they may interact to create local instability.

*Using the procedure described above for a wedge analysis, the stability of discrete combinations of **shear planes**, or of shear planes with the **mean joint orientations**, may be analyzed.*

Perform an analysis similar to the one above using discrete combinations of shear planes.

- Use the Add Plane option to add planes corresponding to the shear features.
- TIP – while using Add Plane, the Pole Snap option (available in the right-click menu) can be used to snap to the exact orientations of the shear poles.

You should find that the risk of wedge failure along the shear planes is low, for this pit slope configuration.

As a further exercise, determine whether the shears will interact with any of the mean joint set orientations to create an unstable wedge.

Increased Local Pit Slope

Repeat these analyses for steeper local slopes. If the overall slope is to be maintained at 45 degrees (see the first page of this tutorial), the local bench slope will have to be increased to accommodate the roadways. What is the critical local slope?

Examine the stability of other pit slope orientations.

Assume that the joint sets are consistent throughout the mine property, and perform the analyses described in this tutorial using 45 degree increments of dip direction around the pit wall.

Other Pit Orientations

Assume that the joint sets are consistent throughout the mine property. Are there any slope orientations that are more unstable than others? Examine slope dip directions in 45 degree increments around the pit wall.

HINT:

- you can import DIPS plots into AutoCAD using the Copy to Metafile option in the Edit menu. This will copy a metafile of the current view to the clipboard, which can then be pasted into AutoCAD.
- Pole or Contour plots showing mean planes and the selected pit slope orientation can be imported into a plan of the pit and placed in their appropriate orientations for quick reference.

References

Goodman, R.E. 1980. Introduction to Rock Mechanics (Chapter 8), Toronto: John Wiley, pp 254-287.

Oriented Core and Rockmass Classification

This advanced DIPS tutorial uses the example file EXAMPBHQ.DIP, which you should find in the Examples folder of your DIPS Installation folder.

EXAMPBHQ.DIP File

First open the EXAMPBHQ.DIP file.



Select: File → Open

Navigate to the Examples folder in your DIPS installation folder, and open the EXAMPBHQ.DIP file. Maximize the view.

ID	Orient1	Orient2	Traverse	CORE POSIT (m)	INTCT LNTH (m)	NGL-JA	NGL-JR
1	72	19	1	35.10	0.10	1	1.5
2	3	234	1	35.36	0.26	3	1
3	6	37	1	35.45	0.09	1	3
4	6	37	1	35.50	0.05	2	3
5	16	113	1	35.58	0.07	1	2
6	16	29	1	35.68	0.11	1	3
7	10	18	1	35.79	0.11	2	3
8	10	18	1	35.92	0.13	1	3
9	17	117	1	36.03	0.11	3	2
10	17	117	1	36.13	0.11	2	2
11	20	248	1	36.25	0.11	4	1
12	18	245	1	36.35	0.11	3	1
13	18	245	1	36.47	0.11	3	1
14	9	234	1	36.56	0.10	3	1
15	9	234	1	36.67	0.11	3	1
16	82	23	1	36.76	0.09	2	2
17	12	253	1	36.82	0.06	3	1
18	12	253	1	36.88	0.06	3	1
19	1	14	1	36.96	0.08	2	3
20	1	14	1	37.06	0.10	1	3
21	15	239	1	37.17	0.11	3	1
22	15	239	1	37.29	0.11	3	1
23	13	34	1	37.42	0.13	2	3
24	13	34	1	37.55	0.14	1	2
25	9	12	1	37.69	0.14	2	3
26	13	253	1	37.83	0.13	3	1
27	13	253	1	37.93	0.10	3	1
28	24	105	1	38.02	0.09	1	2
29	24	105	1	38.14	0.12	2	2
30	22	240	1	38.27	0.13	4	1
31	22	240	1	38.35	0.08	4	2
32	29	104	1	38.73	0.08	2	2
33	62	55	1	38.81	0.08	2	1.5

Figure 5-1: EXAMPBHQ.DIP data.

The file contains 650 measurements from 2 oriented borehole cores.

The file uses the following columns:

- The two mandatory Orientation Columns
- A Traverse Column
- 4 Extra Columns

Orientation Columns

The Orientation Columns, for borehole data, record **alpha** and **beta** core joint angles:

- The **alpha** angle, entered in the Orient 1 column, is measured with respect to the **core axis**.
- The **beta** angle, entered in the Orient 2 column, is measured with respect to the **core reference line**.

See the DIPS Help system for detailed information about recording borehole data.

Extra Columns

The four Extra Columns record the following information:

- core position from collar
- intact length (calculated in a spreadsheet from position or recorded directly) between adjacent joints
- JA
- JR

The latter measurements are qualitative indices of roughness and alteration taken from the Q Classification by Barton and can be quickly recorded during core logging. Consult any modern rock engineering text for a definition of these terms.

Let's examine the Job Control information for this file.

Job Control



Select: Setup → Job Control

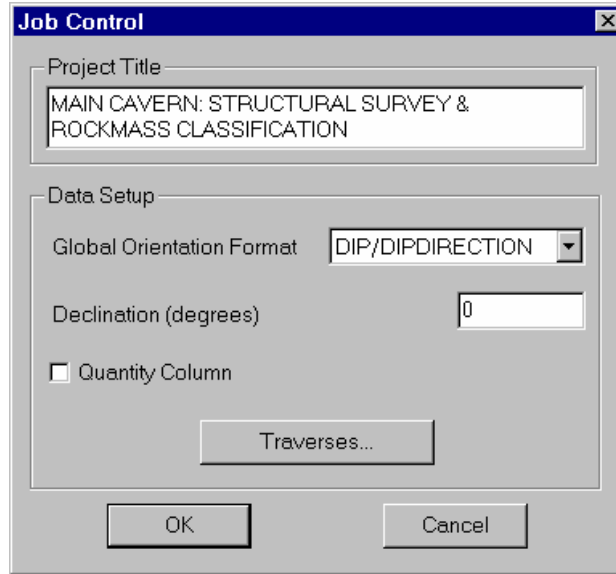


Figure 5-2: Job Control information for EXAMPBHQ.DIP file.

Note the following:

- The Global Orientation Format is DIP / DIPDIRECTION. For borehole data, the Global Orientation Format does NOT apply to the data in the Orientation Columns, but it does determine the Plane Vector Convention for coordinate listings in DIPS).
- The Declination is zero in this file. Declination would, if present, be applied to the borehole trends (azimuths).
- The Quantity Column is NOT used in this file, so each row of the file represents an individual measurement.

Traverses

Let's inspect the Traverse Information. You can select the Traverses button in the Job Control dialog (the Traverses dialog is also available directly in the Setup menu).

As you can see in the Traverse Information dialog, this file uses 2 borehole traverses:

- Both traverses have an Orient 1 value of 180. This denotes a reference line that is 180 degrees from the top of the core (ie. at the bottom of the core as it would be in situ).
- The Orient 2 value indicates the drilling angle from the vertical. Traverse 1 has an Orient 2 value of 135, indicating that the borehole was drilled at 135 degrees from the vertical, or with a plunge of 45 degrees. Traverse 2 was drilled at 160 degrees from the vertical, or a plunge of 70 degrees.
- The Orient 3 value indicates the azimuth (ie. CW angle from compass north) of the downhole direction of the borehole. Orient 3 is 40 degrees for Traverse 1 and 135 degrees for Traverse 2.

See the DIPS Help system for detailed illustration of the borehole orientation requirements for DIPS input.

See the DIPS Help system for detailed illustration of the borehole orientation requirements for DIPS input.

Select Cancel in the Traverse Information dialog.

Select Cancel in the Job Control dialog.

Rock Tunneling Quality Index – Q

The rock tunneling quality index Q is defined as:

$$Q = (RQD / JN) * (JR / JA) * (JW / SRF)$$

Consult any modern rock engineering text (see the references at the end of this tutorial) for more information if required.

Set the water parameter JW = 1 (dry) and stress reduction factor SRF = 1 (moderate confinement, no stress problems) for this example.

Determination of RQD

Using the intact lengths, RQD (Rock Quality Designation) can be calculated using a spreadsheet. RQD is taken as the:

Use a spreadsheet and the INTACT LENGTH extra data column to determine a value for RQD.

$$\frac{\text{Cumulative length of core pieces greater than 10 cm}}{100} \times \text{Total length of core}$$

Determination of JN

JN is the joint number. To obtain a value for this parameter, let's view a Contour Plot, to determine the number of (well) defined joint sets.



Select: View → Contour Plot

Apply the Terzaghi Weighting, so that we can view the weighted contours.



Select: View → Terzaghi Weighting

(Note that DIPS has automatically converted the borehole alpha and beta angles to dip and dip direction, using the borehole traverse orientations.)

View a **WEIGHTED Contour Plot** of the data.

The three well defined joint sets result in a Barton JN value = 9.

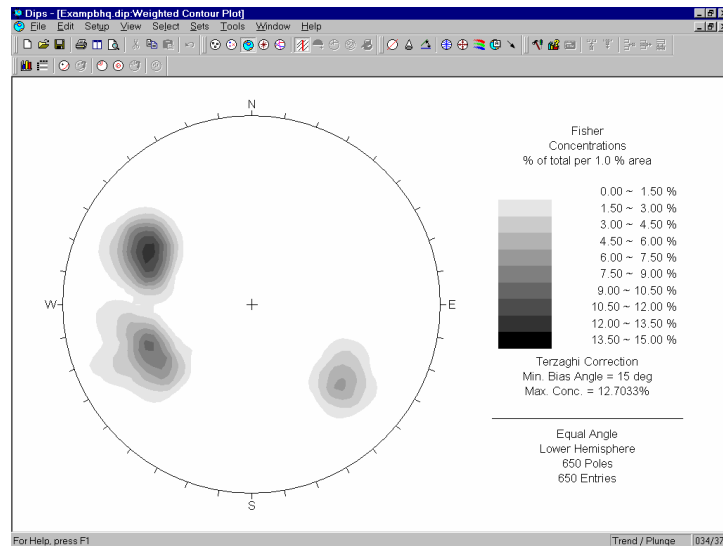


Figure 5-3: Weighted Contour Plot of combined borehole data, converted to global orientations. The 3 well defined joint sets result in Barton's JN = 9.

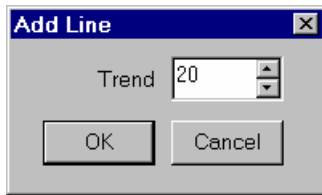
The three well defined joints sets result in Barton's JN = 9.

Now use Add Set Window to determine the mean orientations of the three joint sets. (See the Quick Tour of DIPS for details about creating Sets with the Add Set Window option.) NOTE: when you create the Sets, display the WEIGHTED mean planes, using the checkbox in the Add Set Window dialog.

Finally, let's add a LINE through the center of the stereonet, to represent a proposed tunnel axis. Assume a tunnel trend of 20 degrees.



Select: Tools → Add Line



1. Place the cursor at APPROXIMATELY Trend = 20 degrees, and click the left mouse button (remember that the cursor coordinates are visible in the Status Bar).
2. In the Add Line dialog, if your graphically entered orientation is not exactly 20 degrees, then enter 20 and select OK.

Let's view a Pole Plot.



Select: View → Pole Plot

*Superimpose the **tunnel axis** on the **mean joint planes** to judge the **critical joint set** for Q classification.*

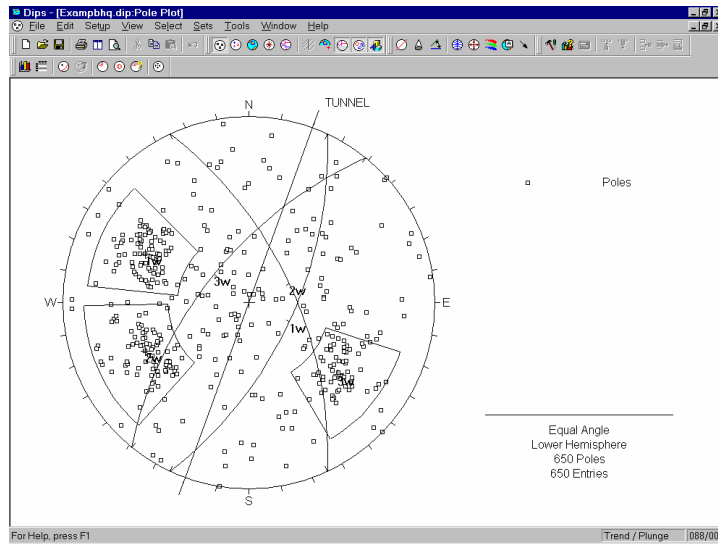


Figure 5-4: Mean planes with superimposed tunnel axis.

It is not immediately obvious which is the critical joint in this case. However, it can be shown that joint set 1 is most likely to prevent any development of tension in the roof and therefore will reduce the self-supporting nature of the tunnel roof. Let us then use this as the critical joint set for Q classification. Note the sliding wedge (closed triangle in the above plot formed by the three joint sets) which appears in the roof of the tunnel.

Estimation of JR and JA

The next step is to use the Chart option to look at JR and JA. These indices can be viewed as either QUALITATIVE or QUANTITATIVE. Quantitative analysis allows a mean calculation and so is preferred.



Select: Select → Chart

In the Chart dialog, select Data to Plot as NGI-JR, select the Quantitative button, and select Set 1 in the Set Filter. (NOTE that Set 1 in this example is the joint set at the upper left of the stereonet. If you used different Set IDs, then enter your Set ID for this Set). Select OK.

Create Quantitative Charts of the JR and JA Extra Columns, to estimate mean values of JR and JA for the critical joint set.

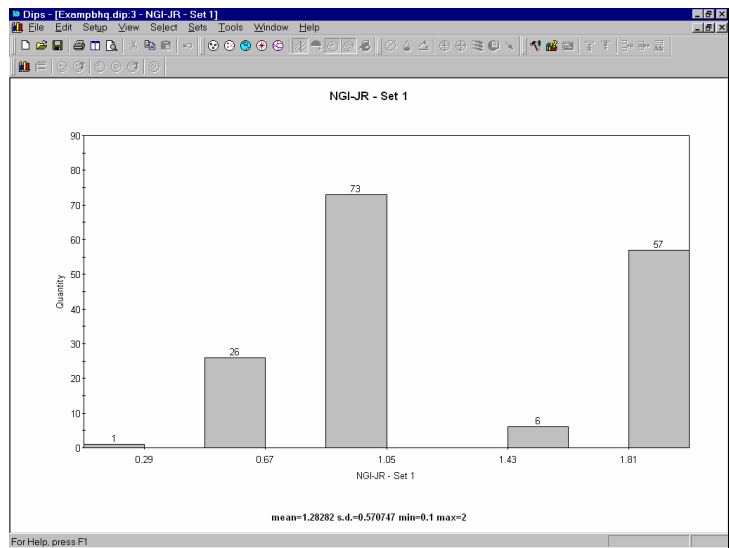


Figure 5-5: Joint Roughness, JR, for joint set 1. Mean = 1.28.

Notice the mean and standard deviation at the bottom of the Chart. The mean value of JR is approximately 1.28.

Now right-click on this chart, and select Chart Properties. Change the Data to Plot to NGI-JA, and select OK. The mean value of JA is approximately 3.2.

For the purposes of classification, a JR of 1 to 1.5 and a JA of 3 to 4 would be adequate in this example.

Calculation of Q Values

RQD, as calculated in the spreadsheet was 60%. Using the JN value of 9, and the upper and lower limits for JR and JA (see above), gives:

- A lower Q of $(60 / 9) * (1 / 4) * (1 / 1) = 1.7$
- An upper Q of $(60 / 9) * (1.5 / 3) * (1 / 1) = 3.3$

This range of values can now be used for further empirical support design according to Barton's design charts – see Figure 5-6. Real values for JW may be evaluated qualitatively from borehole inflow notes. SRF can be determined from the depth of the proposed excavation according to Barton.

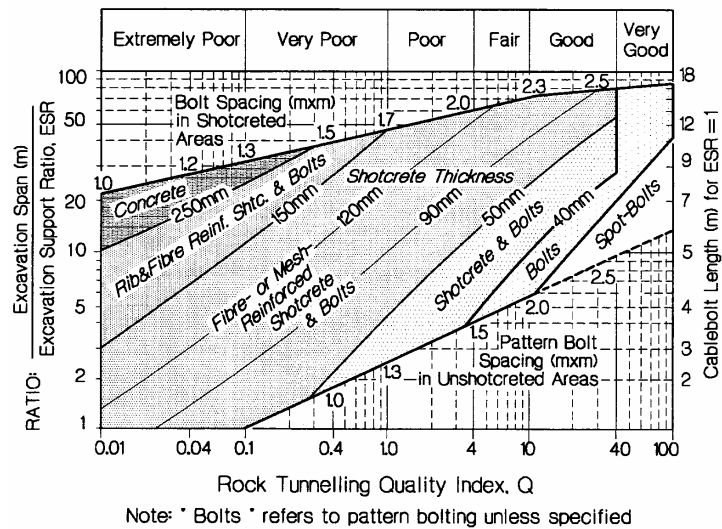


Figure 5-6: Tunneling support guidelines, based on the tunneling quality index Q (bolt lengths modified for cablebolting). Ref. 1, after original Ref. 3.

References

1. Hutchinson, D.J. and Diederichs, M. 1996. Cablebolting in Underground Mines, Vancouver: Bitech. 400 pp.
2. Hoek, E., Kaiser, P.K. and Bawden, W.F. 1995. Support of Underground Excavations in Hard Rock. Rotterdam: Balkema.
3. Grimstad, E. and Barton, N. 1993. Updating the Q-System for NMT. *Proc. int. symp. on sprayed concrete - modern use of wet mix sprayed concrete for underground support*, Fagernes, (eds Kompen, Opsahl and Berg). Oslo: Norwegian Concrete Assn.