NON-PROPRIETARY CALCULATIONS

Book 7 of 8

Attachments to PG&E Letter DIL-01-004
Dated December 21, 2001

NUCLEAR POWER GENERATION
CF3.ID4
ATTACHMENT 7.2

Index No. 402
Binder No.

TITLE: CALCULATION COVER SHEET

Unit(s): 1 & 2 File No.: 52.27

Responsible Group: Civil Calculation No.: 52.27.100.732

No. of Pages 3 pages + Index (4 pages) + 2 Attachments (169 pages) Design Calculation YES [x] NO [ ]

System No. 42C Quality Classification Q (Safety-Related)

Structure, System or Component: Independent Spent Fuel Storage Facility

Subject: Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site (GEO.DCPP.01.22, Rev. 1)

Electronic calculation YES [ ] NO [x]

Computer Model	Computer ID	Program Location	Date of Last Change

Registered Engineer Stamp: Complete A or B

A. Insert PE Stamp or Seal Below	B. Insert stamp directing to the PE stamp or seal
Expiration Date:	*REGISTERED ENGINEERS' STAMPS AND EXPIRATION DATES ARE SHOWN ON DWG 063618*

NOTE 1: Update DCI promptly after approval.
NOTE 2: Forward electronic calculation file to CCTG for uploading to EDMS.

TITLE: CALCULATION COVER SHEET

CALC No. 52.27.100.732, R0

RECORD OF REVISIONS

Rev No.	Status	Reason for Revision / Remarks	Prepared By: Initials/ LAN ID/ Date	LBIE Screen Yes/ No/ NA	LBIE Yes/ No/ NA	Check Method*	LBIE Approval PSRC Mtg. No.	LBIE Approval PSRC Mtg. Date	Checked Initials/ LAN ID/ Date	Supervisor Initials/ LAN ID/ Date	Registered Engineer Signature/ LAN ID/ Date
0	F	Acceptance of Geosciences Calc. No. GEO.DCPP.01.22, Rev. 0. Calc. supports current edition of 10CFR72 DCPP License Application to be reviewed by NRC prior to implementation. Prepared per CF3.ID17.	AFT2 AT 12/15/01	[ ] Yes [ ] No [x] NA	[ ] Yes [ ] No [x] NA	[ ] A [ ] B [x] C	N/A	N/A	N/A	[signature] LJS2 12/17/01	[signature] LJS2 12/17/01
				[ ] Yes [ ] No [ ] NA	[ ] Yes [ ] No [ ] NA	[ ] A [ ] B [ ] C					
				[ ] Yes [ ] No [ ] NA	[ ] Yes [ ] No [ ] NA	[ ] A [ ] B [ ] C					

*Check Method: A: Detailed Check, B: Alternate Method (note added pages), C: Critical Point Check

SUBJECT Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site

MADE BY A. Tafoya AT DATE 12/15/01 CHECKED BY N/A DATE

Table of Contents:

1- This table cross references between Geosciences calculation numbers and DCPP (Civil Group's) calculation numbers. This section is For Information Only.

Cross-Index
(For Information Only)

Item No.	Geosciences Calc. No.	Title	PG&E Calc. No.	Comments
1	GEO.DCPP.01.01	Development of Young's Modulus and Poisson's Ratios for DCPP ISFSI Based on Field Data	52.27.100.711	
2	GEO.DCPP.01.02	Determination of Probabilistically Reduced Peak Bedrock Accelerations for DCPP ISFSI Transporter Analyses	52.27.100.712	
3	GEO.DCPP.01.03	Development of Allowable Bearing Capacity for DCPP ISFSI Pad and CTF Stability Analyses	52.27.100.713	
4	GEO.DCPP.01.04	Methodology for Determining Sliding Resistance Along Base of DCPP ISFSI Pads	52.27.100.714	
5	GEO.DCPP.01.05	Determination of Pseudostatic Acceleration Coefficient for Use in DCPP ISFSI Cutslope Stability Analyses	52.27.100.715	
6	GEO.DCPP.01.06	Development of Lateral Bearing Capacity for DCPP CTF Stability Analyses	52.27.100.716	
7	GEO.DCPP.01.07	Development of Coefficient of Subgrade Reaction for DCPP ISFSI Pad Stability Checks	52.27.100.717	
8	GEO.DCPP.01.08	Determination of Rock Anchor Design Parameters for DCPP ISFSI Cutslope	52.27.100.718	
9	GEO.DCPP.01.09	Determination of Applicability of Rock Elastic	52.27.100.719	Calculation to be replaced by letter

Cross-Index
(For Information Only)

Item No.	Geosciences Calc. No.	Title	PG&E Calc. No.	Comments
		Applicability of Rock Elastic Stress-Strain Values to Calculated Strains Under DCPP ISFSI Pad		replaced by letter
10	GEO.DCPP.01.10	Determination of SSER 34 Long Period Spectral Values	52.27.100.720	
11	GEO.DCPP.01.11	Development of ISFSI Spectra	52.27.100.721	
12	GEO.DCPP.01.12	Development of Fling Model for Diablo Canyon ISFSI	52.27.100.722	
13	GEO.DCPP.01.13	Development of Spectrum Compatible Time Histories	52.27.100.723	
14	GEO.DCPP.01.14	Development of Time Histories with Fling	52.27.100.724	
15	GEO.DCPP.01.15	Development of Young's Modulus and Poisson's Ratio Values for DCPP ISFSI Based on Laboratory Data	52.27.100.725	
16	GEO.DCPP.01.16	Development of Strength Envelopes for Non-jointed Rock at DCPP ISFSI Based on Laboratory Data	52.27.100.726	
17	GEO.DCPP.01.17	Determination of Mean and Standard Deviation of Unconfined Compression Strengths for Hard Rock at DCPP ISFSI Based on Laboratory Tests	52.27.100.727	
18	GEO.DCPP.01.18	Determination of Basic Friction Angle Along Rock Discontinuities at DCPP ISFSI Based on Laboratory	52.27.100.728	

Cross-Index
(For Information Only)

Item No.	Geosciences Calc. No.	Title	PG&E Calc. No.	Comments
		Hoek-Brown Equations		
20	GEO.DCPP.01.20	Development of Strength Envelopes for Shallow Discontinuities at DCPP ISFSI Using Barton Equations	52.27.100.730	
21	GEO.DCPP.01.21	Analysis of Bedrock Stratigraphy and Geologic Structure at the DCPP ISFSI Site	52.27.100.731	
22	GEO.DCPP.01.22	Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site	52.27.100.732	
23	GEO.DCPP.01.23	Pseudostatic Wedge Analyses of DCPP ISFSI Cutslopes (SWEDGE Analysis)	52.27.100.733	
24	GEO.DCPP.01.24	Stability and Yield Acceleration Analysis of Cross-Section I-I'	52.27.100.734	
25	GEO.DCPP.01.25	Determination of Seismic Coefficient Time Histories for Potential Siding Masses Along Cut Slope Behind ISFSI Pad	52.27.100.735	
26	GEO.DCPP.01.26	Determination of Earthquake-Induced Displacements of Potential Sliding Masses on ISFSI Slope	52.27.100.736	
27	GEO.DCPP.01.27	Cold Machine Shop Retaining Wall Stability	52.27.100.737	
28	GEO.DCPP.01.28	Stability and Yield Acceleration Analysis of Potential Sliding Masses Along DCPP ISFSI Transport Route	52.27.100.738	

Pacific Gas and Electric Company
Engineering - Calculation Sheet
Project: Diablo Canyon Unit ( )1 ( ) 2 (x) 1&2

69-392(10/92)
Engineering

CALC. NO. 52.27.100.732
REV. NO. 0
SHEET NO. 1-4 of 4

SUBJECT Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site

MADE BY A. Tafoya DATE 12/15/01 CHECKED BY N/A DATE

Cross-Index
(For Information Only)

Item No.	Geosciences Calc. No.	Title	PG&E Calc. No.	Comments
		Retaining Wall Stability		
28	GEO.DCPP.01.28	Stability and Yield Acceleration Analysis of Potential Sliding Masses Along DCPP ISFSI Transport Route	52.27.100.738	
29	GEO.DCPP.01.29	Determination of Seismic Coefficient Time Histories for Potential Sliding Masses on DCPP ISFSI Transport Route	52.27.100.739	
30	GEO.DCPP.01.30	Determination of Potential Earthquake-Induced Displacements of Potential Sliding Masses Along DCPP ISFSI Transport Route	52.27.100.740	
31	GEO.DCPP.01.31	Development of Strength Envelopes for Clay Beds at DCPP ISFSI	52.27.100.741	
32	GEO.DCPP.01.32	Verification of Computer Program SPCTLR.EXE	52.27.100.742	
33	GEO.DCPP.01.33	Verification of Program UTEXAS3	52.27.100.743	
34	GEO.DCPP.01.34	Verification of Computer Code - QUAD4M	52.27.100.744	
35	GEO.DCPP.01.35	Verification of Computer Program DEFORMP	52.27.100.745	
36	GEO.DCPP.01.36	Reserved	52.27.100.746	
37	GEO.DCPP.01.37	Development of Freefield Ground Motion Storage Cask Spectra and Time Histories for the Used Fuel Storage Project	52.27.100.747	

PG&E
Geosciences Department
Departmental Calculation Procedure

Page: 1 of 1

Title: Calculation Cover Sheet

PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number:	GEO.DCPP.01.22
Revision:	1
Date:	December 14, 2001
No. of Calc Pages:	167
Verification Method:	A
No. of Verification Pages:	3

TITLE Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site

PREPARED BY	[signatures]	DATE	12/14/01
	Charles M. Brankman/ Jeff Bachhuber		William Lettis & Associates, Inc.
	Printed Name		Organization
VERIFIED BY	[signature]	DATE	12/14/01
	Scott C. Lindvall		William Lettis & Associates, Inc.
	Printed Name		Organization
APPROVED BY	[signature]	DATE	12/15/01
	Lloyd S. Cluff		PG&E Geosciences
	Printed Name		Organization

REGISTERED GEOLOGIST
JEFF BACHHUBER
EG 1534
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

REGISTERED GEOLOGIST
LLOYD S. CLUFF
No. EG567
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA
Exp. 12/31/02

PG&E
Geosciences Department
Departmental Calculation Procedure

Page: 1 of 1

Title: Calculation Cover Sheet

PACIFIC GAS AND ELECTRIC COMPANY
GEOSCIENCES DEPARTMENT
CALCULATION DOCUMENT

Calc Number:	GEO.DCPP.01.22
Revision:	1
Date:	December 14, 2001
No. of Calc Pages:	167
Verification Method:	A
No. of Verification Pages:	3

TITLE Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site

PREPARED BY	[signatures]	DATE	12/14/01
	Charles M. Brankman/ Jeff Bachhuber		William Lettis & Associates, Inc.
	Printed Name		Organization
VERIFIED BY	[signature]	DATE	12/14/01
	Scott C. Lindvall		William Lettis & Associates, Inc.
	Printed Name		Organization
APPROVED BY		DATE	
	Lloyd S. Cluff		PG&E Geosciences
	Printed Name		Organization

REGISTERED GEOLOGIST
JEFF BACHHUBER
EG 1534
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

PG&E
Geosciences Department
Departmental Calculation Procedure

Page: 1 of 1

Title: Record of Revision

Calc Number: GEO.DCPP.01.22, Revision 1

Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site

Rev. No.	Reason for Revision	Revision Date
0	Initial issue; incorporate A. Tafoya/Geosciences review comments	11/6/01
1	Incorporate additional review comments by A. Tafoya/ Geosciences	12/14/01

DCPP ISFSI

CALCULATION PACKAGE GEO.DCPP.01.22

Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site

DCPP ISFSI

CALCULATION PACKAGE GEO.DCPP.01.22

Kinematic Stability Analysis for Cutslopes at DCPP ISFSI Site

Table of Contents

List of Tables

List of Figures

List of Attachments

2.0 BACKGROUND

Stereographic projections of fracture data are tools commonly used to predict the types of discontinuity-controlled rock slope failures that are possible for given cutslope configurations and rock friction angles. Kinematic analyses of discontinuity data allow for the recognition of potential rock slope stability failures by examining the geometric relationships between discontinuity surfaces and the rock face. The technique is simple and easily performed, and the effects of various rock friction angles and different rock cutslope configurations are readily seen.

Kinematic analyses consider three primary failure modes: (1) topple failure of rock blocks and slabs, (2) planar sliding of rock on a single discontinuity or single discontinuity set, and (3) wedge sliding of rock along the intersection of two discontinuities. Other modes of slope failure, such as rotational slump failures, are not considered. Topple failures occur as blocks or slabs, which are bounded by discontinuities that dip steeply into the face at angles such that the center of mass falls outside the toe of the block and causes outward rotation and topple out of the cut face. Planar sliding failures occur when a rock mass slides along a single, optimally-oriented surface that dips out of the slope face. Wedge failures involve block sliding along two favorably oriented intersecting fractures in the direction of the plunge of the intersection line. Each of these failure scenarios is examined through a separate kinematic analysis.

In general, several conditions must be met for kinematic instability. For toppling-type failures, discontinuities must be subparallel to, and dip steeply into, the rock face. For sliding-mode failures (planar and wedge sliding), two conditions must be met. First, the discontinuity surface (or intersection line between discontinuities) must daylight in the cutslope, i.e. the discontinuities must dip in the direction of the cutslope and be less steep than the cutslope angle. Second, the discontinuities (or discontinuity intersections) must dip at greater than the rock friction angle (Wyllie, 1992). If these criteria are not met, failure of the rock slope by sliding along discontinuities is resisted by adjacent rock blocks, and thus is not kinematically possible.

3.0 INPUTS

Discontinuity data (joints, faults, and bedding) collected from rock outcrops, exploratory trenches, roadcuts, and boreholes were used as the basis for the kinematic stability analyses. These data are presented in William Lettis & Associates, Inc. (2001), Diablo Canyon ISFSI Data Reports B, E, and F. Every discontinuity measurement from the test trenches at the ISFSI site was used in the kinematic analyses. Discontinuity data from boreholes were taken from the geophysical image logs; however, only the discontinuities that were confirmed by at least two geologists in order to verify the presence and type of discontinuity and the accuracy of the orientation were included. The input files containing the discontinuity data used in each analysis are included in Attachment 1. The joint and fault data are identical to those shown in Table 21-7, which were used to create the rose diagrams in Calculation Package GEO.DCPP.01.21. For the kinematic analyses, bedding data was included with the joint and fault data.

Friction angles used for the kinematic analyses were obtained from direct shear testing of fractures and bedding planes; these data are presented in William Lettis & Associates, Inc. (2001), Diablo Canyon ISFSI Data Report I, and in Calculation Package GEO.DCPP.01.20. The geometry of the ISFSI excavation and cutslopes is taken from drawing PGE-009-SK-001, transmitted to Geosciences on September 27, 2001 (Page, 2001). The analyses use a 70° angle for the cutslope walls, as shown in the drawing.

4.0 ASSUMPTIONS

The following assumptions were made for the kinematic analyses:

1. The potential shallow rock slope failures are controlled primarily by laterally persistent discontinuities that bound intact rock blocks. Discontinuities in the ISFSI study area are observed generally to be continuous over 1 to 3 feet and, in places, up to about 14 feet, and intersect to form discrete rock blocks of similar dimensions (William Lettis & Associates, Inc. (2001), Diablo Canyon ISFSI Data Report F). Therefore this assumption is realistic for these dimensions.

2. The shear strength of the fractured rock mass is controlled only by the basal rock friction angle of the discontinuities. This is a conservative assumption because other factors that may impact shear strength, such as cohesion, asperity interlocking, or the presence of intact rock bridges across discontinuities, are not considered in this analysis.

3. Rock friction angle is assumed to be 28°. This value is based on direct shear laboratory testing of joints (William Lettis & Associates, Inc. (2001), Diablo Canyon ISFSI Data Report I) and the Barton criterion analyses (see Calculation Package GEO.DCPP.01.20). The value chosen is considered a conservative value, because it is the near lower-bound of the straight line fits to the mean Barton envelopes for all discontinuity types.

4. Only the geometric relationships between the discontinuities and the cutslope are used in the analyses. The kinematic analyses assume no rock reinforcement to the slope. External forces, such as seismic loads and hydrostatic pressures, are not considered in the kinematic analyses. These factors increase the risk of slope failure identified in the kinematic analyses, but do not affect the analysis. These factors are considered in Calculation Package GEO.DCPP.01.23.

5.0 METHOD

The step-by-step methodology used for the kinematic analyses for each of the three cutslopes (Eastcut, Backcut, and Westcut) and the existing road cuts on the transport route along Reservoir Road is listed below:

1. Compilation of discontinuity data from road cuts, trenches and borings near the slope being analyzed;

2. Development of stereographic projections of discontinuity data using the computer program DIPS (Rocscience, 1999), and identification of major discontinuity sets; and

3. Analyses of topple, planar sliding, and wedge sliding hazards.

Step 1

Discontinuity data were collected from road cuts, exploratory trenches and boreholes throughout the ISFSI study area. Details on the collection of these data are presented in William Lettis & Associates, Inc. (2001), Diablo Canyon ISFSI Data Reports B, E and F. For each wall of the proposed cut and for the roadcut, the data set from nearby trenches, borings, and roadcut were compiled to form distinct data sets for the analyses (Figures 22-1 and 22-2). The cutslope-specific data sets enable the evaluation to focus on local differences in discontinuity geometry, and identification of potential failure modes specific to each cutslope wall. Each discontinuity was classified in the field as either a joint, fault, or bedding surface, and this classification was carried into the DIPS input file. The DIPS input files are included in Attachment 1.

Step 2

For each cutslope and road cut segment, the discontinuity data from the appropriate trenches, boreholes, and outcrops are plotted on an equal angle stereonet. As described above, the plot shows discontinuities defined by discontinuity type (joint, fault, bedding).

After plotting the data, sets of discontinuities were defined based on contouring and clustering of similar orientations. Only fracture groups that show well-defined clustering, on the basis of the scatter plots and the contour plots of the data, are grouped as discontinuity sets. Attributes of each defined discontinuity set, such as average orientation and variability to two standard deviations, are calculated by the DIPS software.

Step 3

After defining the discontinuity sets, analyses for each mode of potential failure was performed. The procedure for each analysis is briefly described below.

Topple failure – Topple failure of rock blocks is possible when discontinuities strike within about 30° of the cutslope, and dip steeply into the slope. On the stereographic projection, the pole to the discontinuity must fall within 30° to the dip direction of the cutslope, and must plot above a line inclined at an angle equivalent to the friction angle above the cutslope to be considered to have a potential of topple failure (blue-shaded area in Figure 22-3A) (Rocscience, 1999).

Planar sliding failure – In order for planar sliding to occur, discontinuities must be present that strike within about 20° of the cutslope, and which dip at a shallower angle than the cutslope but steeper than the rock friction angle (Wyllie, 1992). On the stereographic projection, the pole to the discontinuity must fall within the daylight envelope of the cutslope but outside the rock friction cone to be considered to have a potential for planar sliding (blue-shaded area in Figure 22-3B).

Wedge sliding failure – Wedge sliding of rock blocks occurs when the intersection line between two discontinuities plunges in the direction of the cut face at an angle steeper than the rock friction angle but less steep than the angle of the cutslope (Wyllie, 1992). On the stereographic projection, the line of intersection between two discontinuities sets plots as a point. This point must fall outside the cutslope great circle but within the rock friction cone to be considered to have the potential for wedge sliding (blue-shaded area in Figure 22-3C). Note that the rock friction cone in this analysis is counted in from the edge of the stereonet instead of out from the center, which is the reverse of the analysis for planar sliding; this is done because this analysis uses the great circles instead of the poles to assess the hazard (Rocscience, 1999).

6.0 SOFTWARE

Fracture data visualization and kinematic analyses were performed using DIPS, v. 5.041 (Rocscience, 1999) on a DELL Dimension model XPS desktop computer running the Microsoft Windows 98 operating system. The software was purchased by and is licensed to William Lettis & Associates, Inc. (WLA), and all analyses were performed by WLA. The program has not been modified from the version purchased from Rocscience. Data tabulation, visualization, and kinematic analyses were performed using standard DIPS functions.

The following program items were also identified as part of the verification process:

a) program name: DIPS
b) program version: 5.041
c) program revision: not applicable
d) computer platform compatibility: Windows 98
e) program capabilities and limitations: The program performs kinematic stability analyses by plotting discontinuity data on stereonets, then analyzing if the data meet the requirements for stability in three failure modes: toppling, planar sliding, and wedge sliding.
f) program test cases: described in Attachment 2.
g) instructions for use: input orientations of discontinuity planes (joints, faults, bedding), a slope face, and friction angles as described in Rocscience (1999).
h) program owner: Rocscience.
i) identification of individual responsible for controlling the software or executables: Geosciences QA Coordinator.

j) change control: The software used in this calculation is stored on a CD filed with the calculation file. Only use this software version when re-running or revising this calculation. Contact the Geosciences QA Coordinator for access to this software.

k) verification methods used: Verification method 1 (comparison with well documented examples in software manuals) was used for verification of the accuracy of the DIPS software analysis capabilities, and is shown in Attachment 2. Verification method 3 (comparison of outputs from alternate independent methods such as by hand calculation) was used to verify that the software correctly plots discontinuity data on stereonets, and is shown in Attachment 3.

7.0 ANALYSIS

Separate analyses were performed for each of the three cutslopes in the ISFSI excavation and the two reaches of the transport route on Reservoir Road. Only data from nearby road cuts, trenches and borings were used in the analyses for each cutslope. Trenches, borings, and roadcuts used in each analysis are shown in Figure 22-1. Discontinuity data used in the analyses are shown in the input files presented in Attachment 1. Summaries of the discontinuity sets are included in Table 22-1.

Westcut

Data from trenches T-11 and T-18, borings 01-A, 01-B, 01-H, and discontinuity survey DS-1 were included in the analyses for the Westcut. A total of 211 discontinuity measurements were included in this data set (Attachment 1). The stereographic plots show clustering of discontinuities into four sets (Figure 22-4): (1) a WNW striking, steeply dipping set; (2) a NNW striking, steeply SSW dipping set; (3) a WNW to W striking, steeply N dipping set; and (4) a NW striking, shallowly dipping set. The remainder of the discontinuities are distributed throughout the stereonet without clear clustering, representing fractures with orientations not corresponding to a well-defined set.

Backcut

Data from trenches T-3, T-4, T-5, T-6, T-11, T-12, T-18, and T-20, discontinuity survey DS-1 and borings 00BA-2, 01-F, and 01-H were included in the analyses for the Backcut. A total of 421 discontinuity measurements were included in this data set (Attachment 1). The data show clustering of discontinuities into four groups (Figure 22-5): (1) a N to NNW striking, steeply dipping set; (2) a NW striking, moderately steeply SW dipping set; (3) a WNW striking, steeply dipping set; and (4) a NW striking, shallowly SW dipping to flat set. The remainder of the discontinuities are distributed throughout the stereonet without clear clustering, representing fractures with orientations not corresponding to a well-defined set.

Eastcut

Data from trenches T-3, T-4, T-20, and T-21, and borings 00BA-2, 01-E, and 01-G were included in the analyses for the Eastcut. A total of 167 discontinuities were included in this data set (Attachment 1). The data show discontinuities grouping into four clusters: (1) a NNE striking, steeply dipping set (Figure 22-6); (2) a NW striking, moderately steeply SW dipping set; (3) a NW striking, shallowly dipping to flat set; and (4) a W striking, steeply N dipping set. The remainder of the discontinuities are distributed throughout the stereonet without clear clustering, representing fractures with orientations not corresponding to a well-defined set.

Transport Route Cutslopes

Data from road cuts along Reservoir Road were included for the analyses of rock slopes along the Transport Route. A total of 37 discontinuity measurements were collected and included in this data set (Attachment 1). Two portions of the transport route were considered: the north-trending portion (stations 43+00 to 46+00), which is inclined at 50°, and the northwest-trending portion (stations 35+00 to 43+00), which is inclined at 30°. Each transport route analysis was performed using the entire discontinuity data set from the roadcut (37 measurements). The data show discontinuities grouping into three clusters (Figures 22-7 and 22-8): (1) a NW striking, steeply dipping set; (2) a NE striking, moderately S dipping set; and (3) a ENE striking, moderately N dipping set.

8.0 RESULTS

Figures 22-4 through 22-6 show the output of the kinematic analyses for each wall of the proposed ISFSI cutslope. Figures 22-7 and 22-8 show the analyses for the transport route along Reservoir Road.

Westcut

Analyses of the Westcut are shown in Figure 22-4. The Westcut shows a high potential for topple failure. The majority of discontinuity set 2, as well as some fractures from set 1, plot within the zone of potential failure for toppling. However, analyses of planar and wedge sliding failures show low to very low potential, respectively, for these modes of failure in the western slope, as very few discontinuities (and none belonging to any of the defined sets) fall within the failure envelope for planar sliding, and none of the discontinuity intersections fall within the failure envelope for wedge sliding failure. Thus the only identified significant failure mode for the southwestern cutslope is topple failure. It should be noted that a portion of the southwestern cutslope will be infill, and, as such, the failure mode identified above is not applicable in these fill slopes.

Backcut

Kinematic analyses of the Backcut are shown in Figure 22-5. The slope shows low potential for toppling failure, as only a few random discontinuities plot within this failure envelope. Planar sliding failure represents a low- to moderate-potential, as a few discontinuities from sets 1 and 2, as well as a number of random discontinuities, plot within the planar sliding failure envelope. Potential exists for wedge sliding along the intersection line of discontinuity sets 2 and 3, while another intersection (1 and 3) plots outside but relatively close to the failure envelope and should be considered a potential hazard, given that these lines represent the average orientation of the set and that there is a scatter of orientations around this mean. Thus, there is a high potential for wedge failure and minor planar sliding failure on the Backcut.

Eastcut

Kinematic analyses of the Eastcut are shown in Figure 22-6. The slope shows low potential for toppling failure, as only a few random discontinuities plot within this failure envelope. There is a moderate to high potential for planar sliding failure, as numerous discontinuities from discontinuity set 2 as well as some random discontinuities plot within the planar sliding failure envelope. Potential also exists for wedge sliding along the intersection lines between discontinuity sets 1 and 2 and between sets 2 and 4; though these intersections plot very close to the failure envelope, these lines represent the average orientation of the set and there is a scatter of orientations around this mean. Thus, there is a moderate to high potential for planar sliding and a moderate to high potential for wedge sliding failures along the Eastcut.

Transport Route Cutslopes

Kinematic analyses of the transport route cutslopes are shown in Figure 22-7 and 22-8. The north-trending slope shows moderate potential for toppling failure, as a large portion of set 1 plot within this failure envelope. There is low potential of planar sliding failure, and very low potential for wedge sliding failure. The northwest-trending slope shows low potential for all three failure modes. This is because of the very low inclination of this slope. Thus, the only the potentially significant failure mode is for topple failures along the transport route cutslopes.

9.0 CONCLUSIONS

Stereographic kinematic analyses of discontinuity-controlled shallow rock slope failures in the proposed ISFSI excavation cutslopes show that each of the three cutslopes are prone to potential shallow rock stability hazards, but failure modes and potential for failure vary between slopes. The results are summarized in Table 22-2. The Westcut will primarily be prone to toppling failure of rock blocks into the cut along steeply dipping discontinuities. The Backcut has a high potential of wedge failures along two discontinuity sets, a minor potential of planar sliding, and low potential of topple failure. The Eastcut is prone primarily to planar wedge sliding, with little topple failure hazard.

The transport route exhibits a low potential for rock topple, planar slide, and wedge sliding. These results will be used in the psuedostatic stability analyses of potential wedge failures (Calculation Package GEO.DCPP.01.23). Specific engineering measures will be required to mitigate the hazards associated with these potential failures.

10.0 REFERENCES

Rocscience, 1999, DIPS: Plotting, analysis, and presentation of structural data using spherical projection techniques, version 5.041, Toronto, 86 pp.

William Lettis & Associates, Inc., 2001, Letter to Robert White, PG&E Geosciences from Robert C. Witter, November 5, 2001, Completion of Data Reports transmitting Data Reports A through K to PG&E Geosciences Department;

Diablo Canyon ISFSI Data Report A - Geologic Mapping in the Plant Site Area and ISFSI Study Area, Rev. 1, November 5, 2001, prepared by W. Lettis, 42 p.

Diablo Canyon ISFSI Data Report B - Borings in ISFSI Study Area, Rev. 1, November 5, 2001, prepared by J. Bachhuber, 244 p.

Diablo Canyon ISFSI Data Report E, - Borehole Geophysical Data (NORCAL Geophysical Consultants, Inc.), Rev. 1, November 5, 2001, prepared by C. Brankman and J. Bachhuber, 350 p.

Diablo Canyon ISFSI Data Report F - Field Discontinuity Measurements, Rev. 1, November 5, 2001, prepared by C. Brankman and J. Bachhuber, 85 p.

Diablo Canyon ISFSI Data Report I - Rock Laboratory Test Data (GeoTest Unlimited), Rev. 1, November 5, 2001, prepared by J. Sun, 203 p.

Wyllie, D.C., 1992, Foundations on rock, Chapman & Hall, London, 331 pages, pp. 27-39.

Geosciences Calculation Packages

GEO.DCPP.01.08 Determination of rock anchor design parameters for DCPP ISFSI cutslope

GEO.DCPP.01.20 Development of strength envelopes for shallow discontinuities at DCPP ISFSI using Barton equations

GEO.DCPP.01.22 Kinematic stability analysis for cutslopes at DCPP ISFSI site

GEO.DCPP.01.23 Pseudostatic wedge analysis of DCPP ISFSI cutslope (SWEDGE analysis)

GEO.DCPP.01.24 Stability and yield acceleration analysis of cross section I'-I'

GEO.DCPP.01.28 Stability and yield acceleration analysis of potential sliding masses along DCPP ISFSI transport route

PG&E Memorandums and Design Drawing

Page, W.D., October 12, 2001, Transmittal of requested drawings, DCPP used fuel storage projects, for Calculation Package GEO.DCPP.01.21, Analysis of bedrock stratigraphy and geologic structure at the DCPP ISFSI site, including PG&E/Enercon Drawing PGE-009-SK-001, 9/27/01.

Table 22-1. Summary of discontinuity sets identified by kinematic analyses.

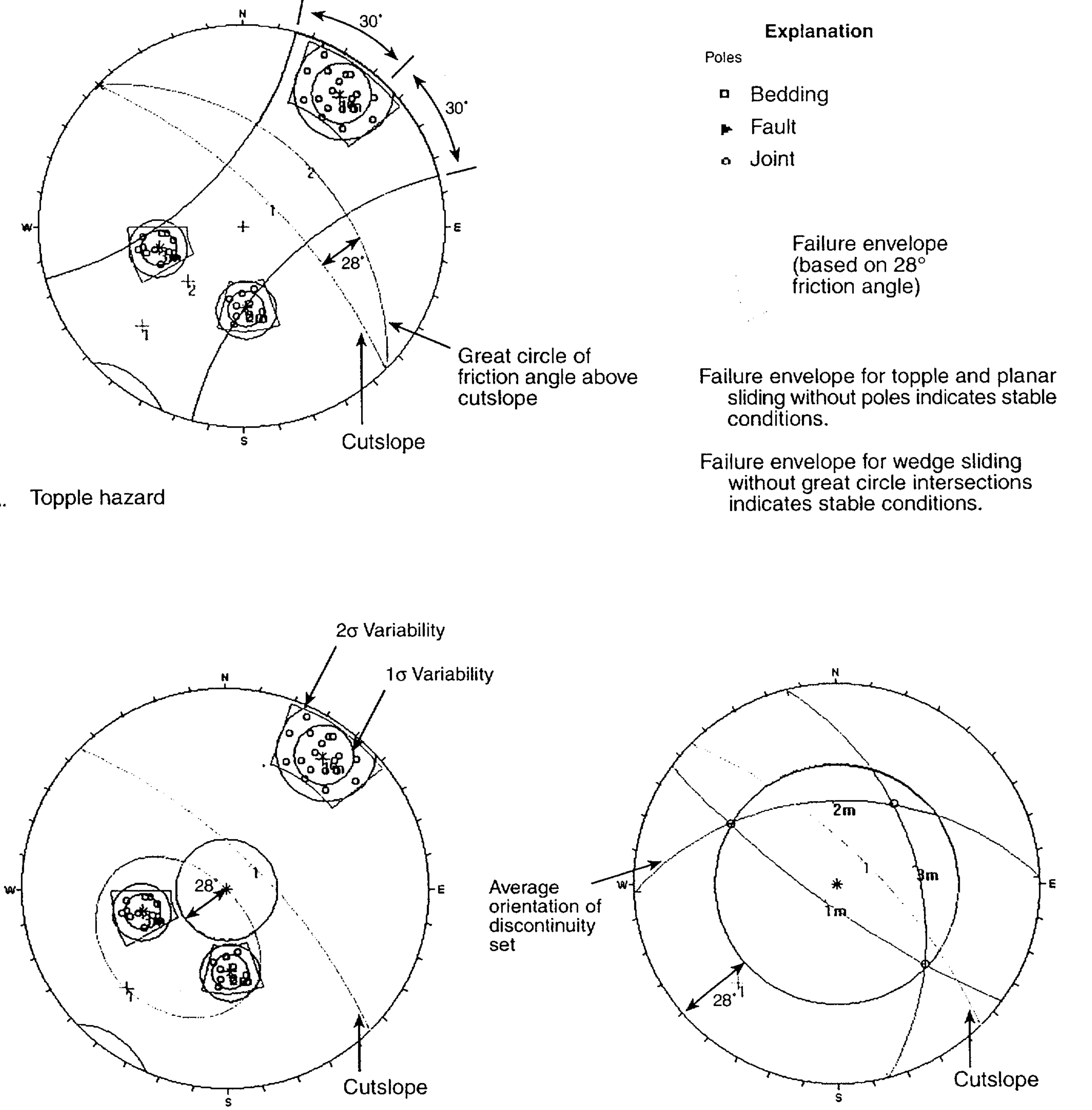
Area	Set	Dip (degrees)(1)	Dip Direction (azimuth degrees)(1)
Westcut	1	84	204
	2	73	249
	3	78	009
	4	28	239
Backcut	1	77	261
	2	69	220
	3	88	012
	4	24	232
Eastcut	1	88	098
	2	67	239
	3	9	229
	4	70	007
Transport Route Cutslopes	1	88	063
	2	45	150
	3	51	350

(1) Average dip and dip direction of discontinuity sets, as determined from stereographic plots of discontinuity data.

Table 22-2. Summary of stability hazards identified by kinematic analyses.

Area of Analysis	Type of Stability Hazard		
	Topple	**Planar Sliding**	**Wedge Sliding**
Westcut	High	Low	Very Low
Backcut	Low	Low – Moderate	High
Eastcut	Low	Moderate – High	Moderate - High
North Transport Route	Moderate	Low	Very Low
Northwest Transport Route	Low	Very Low	Very Low

Security-Related Information – Withhold Under 10 CFR 2.390.



A. Topple hazard

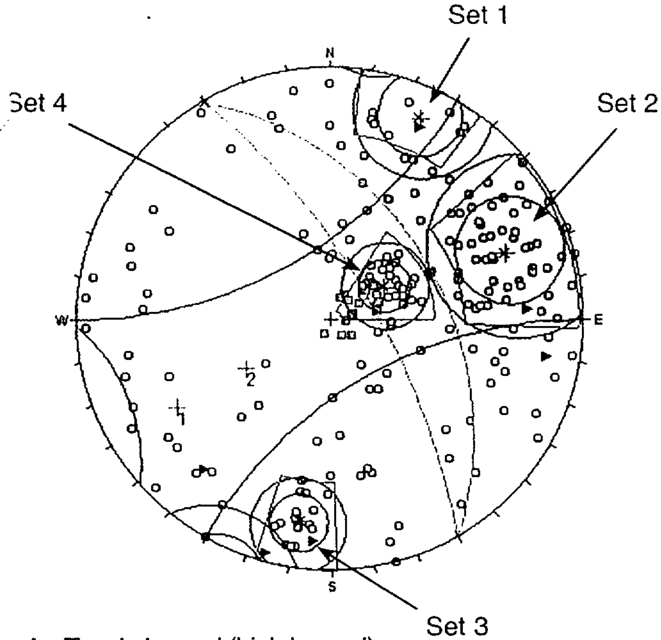
B. Planar sliding hazard

C. Wedge sliding hazard

Notes
Analysis performed using computer program DIPS, v. 5.041 (Rocscience, 1999).

DIABLO CANYON ISFSI
FIGURE 22-3 EXAMPLES OF KINEMATIC ANALYSES

GEO.DCPP.01.22 REV 1 December, 2001



A. Topple hazard (high hazard)

Explanation

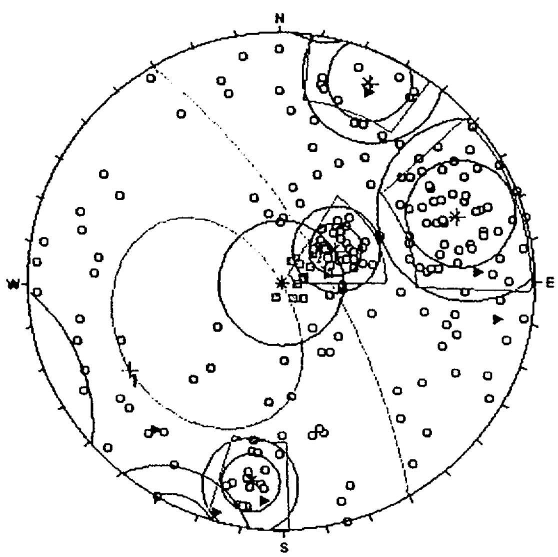
Poles

- Bedding
- Fault
- Joint

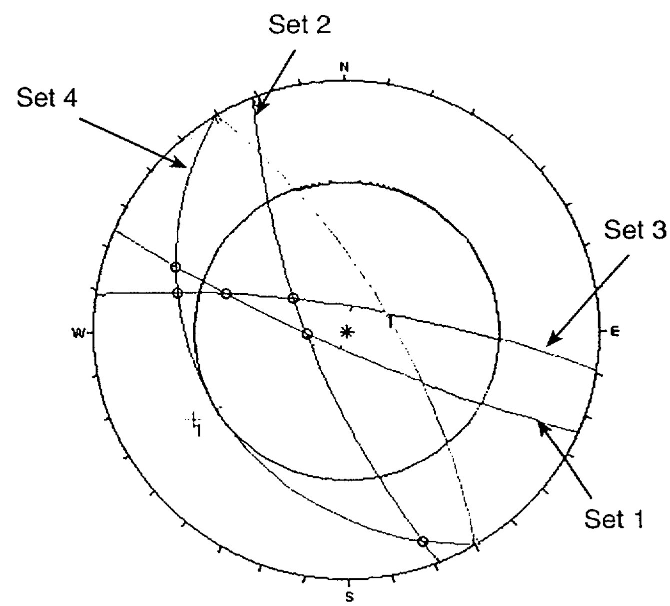
Failure envelope (based on 28° friction angle)

Failure envelope for topple and planar sliding without poles indicates stable conditions.

Failure envelope for wedge sliding without great circle intersections indicates stable conditions.



B. Planar sliding hazard (low hazard)



C. Wedge sliding hazard (very low hazard)

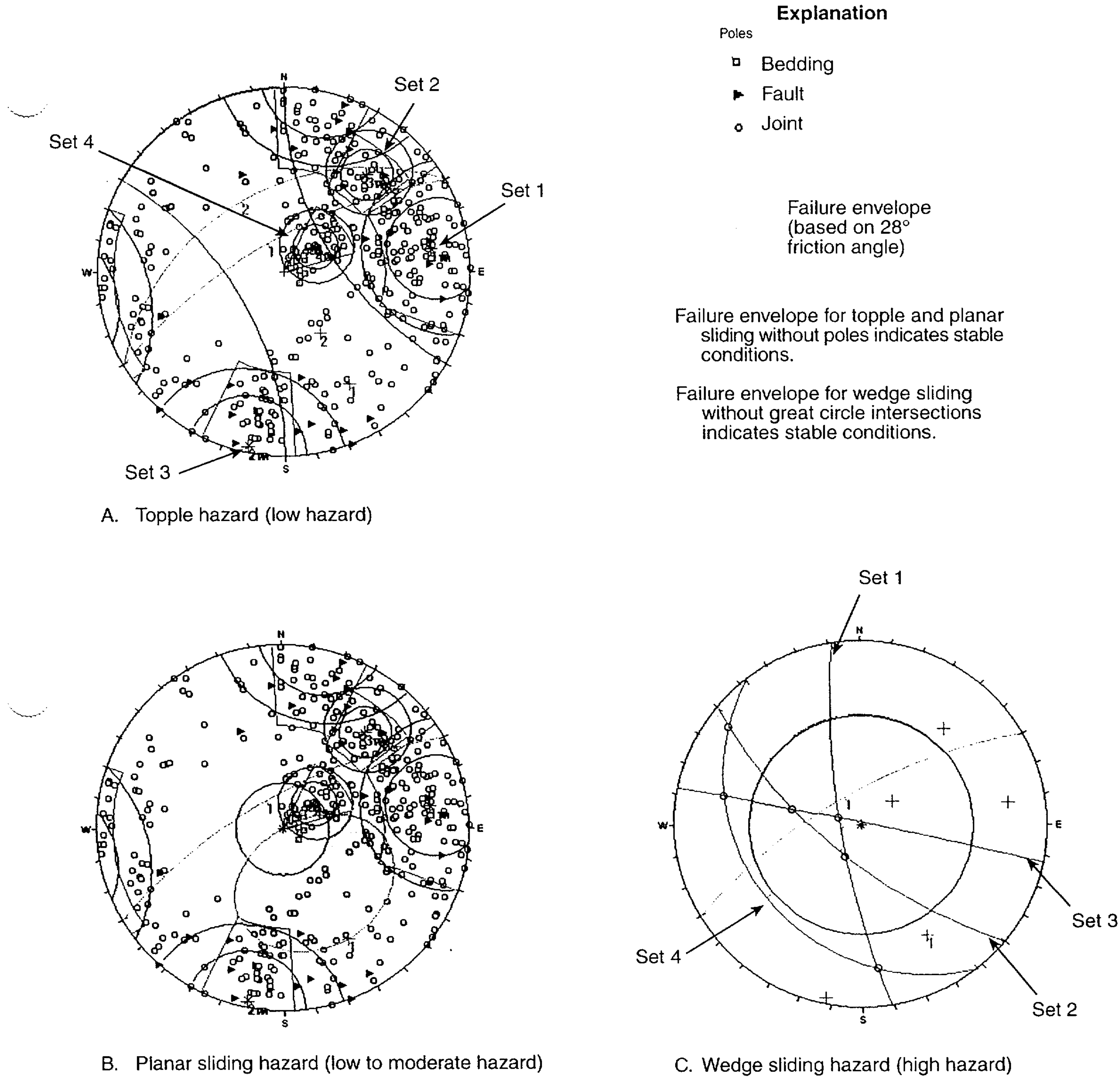
Notes

Analysis performed using computer program DIPS, v. 5.041 (Rocscience, 1999).

Data for westcut analyses taken from trenches T-11 and T-18, borings 01-A, 01-B, 01-H, and discontinuity survey DS-1.

DIABLO CANYON ISFSI
FIGURE 22-4 **KINEMATIC ANALYSES OF WESTCUT ISFSI CUTSLOPE**

GEO.DCPP.01.22 REV 1 December, 2001



Notes

Analysis performed using computer program DIPS, v. 5.041 (Rocscience, 1999).

Data for backcut analyses taken from trenches T-3, T-4, T-5, T-6, T-11, T-12, T-18, and T-20, discontinuity survey DS-1 and borings 00BA-2, 01-F, and 01-H.

DIABLO CANYON ISFSI

FIGURE 22-5
KINEMATIC ANALYSES OF BACKCUT ISFSI CUTSLOPE

GEO.DCPP.01.22 REV 1 December, 2001

Explanation

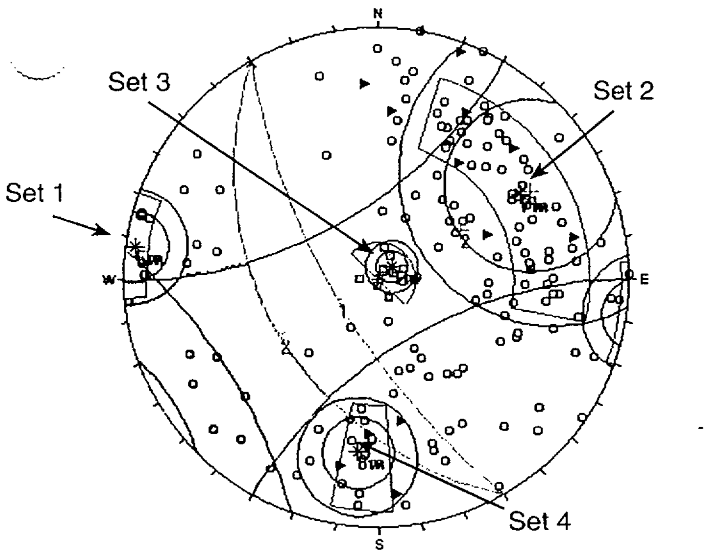
Poles

- ◘ Bedding
- ▶ Fault
- o Joint

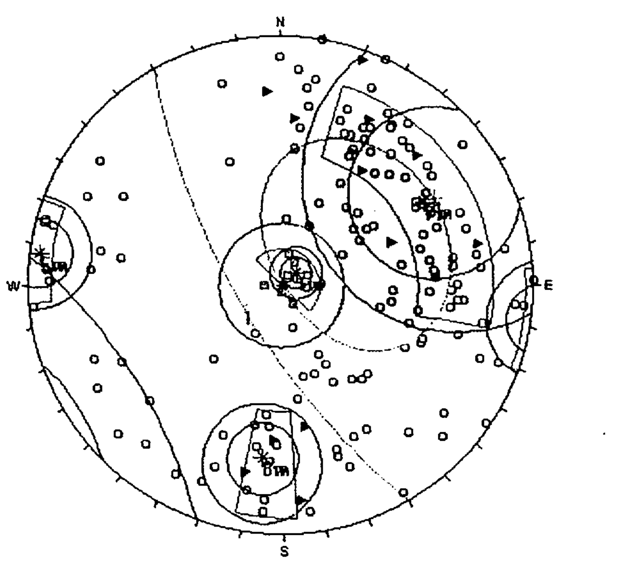
Failure envelope (based on 28° friction angle)

Failure envelope for topple and planar sliding without poles indicates stable conditions.

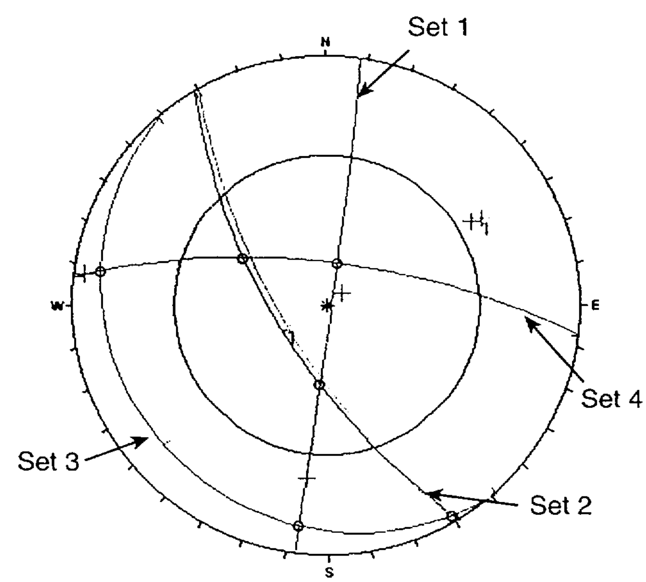
Failure envelope for wedge sliding without great circle intersections indicates stable conditions.



A. Topple hazard (low hazard)



B. Planar sliding hazard (moderate to high hazard)



C. Wedge sliding hazard (moderate to high hazard)

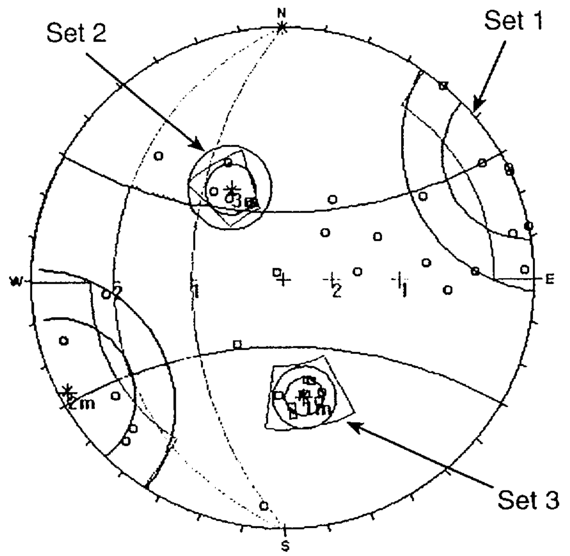
Notes

Analysis performed using computer program DIPS, v. 5.041 (Rocscience, 1999).

Data for eastcut analyses taken from trenches T-3, T-4, T-20 and T-21, and borings 00BA-2, 01-E and 01-G.

DIABLO CANYON ISFSI
FIGURE 22-6 **KINEMATIC ANALYSES OF EASTCUT ISFSI CUTSLOPE**

GEO.DCPP.01.22 REV 1 December, 2001



A. Topple hazard (moderate hazard)

Explanation

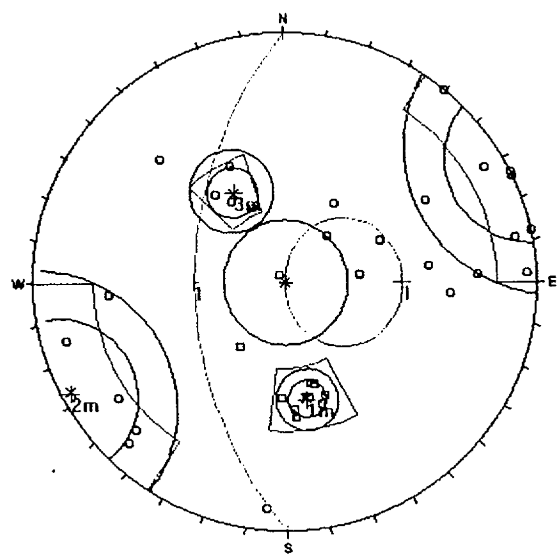
Poles

- Joint
- Bedding

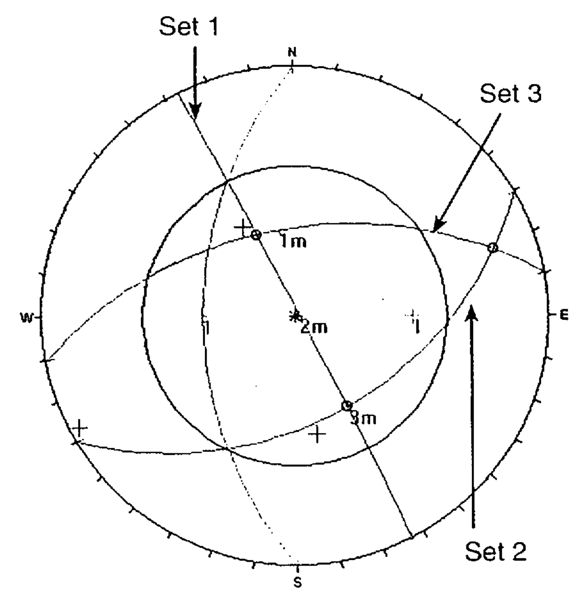
Failure envelope (based on 28° friction angle)

Failure envelope for topple and planar sliding without poles indicates stable conditions.

Failure envelope for wedge sliding without great circle intersections indicates stable conditions.



B. Planar sliding hazard (low hazard)



C. Wedge sliding hazard (very low hazard)

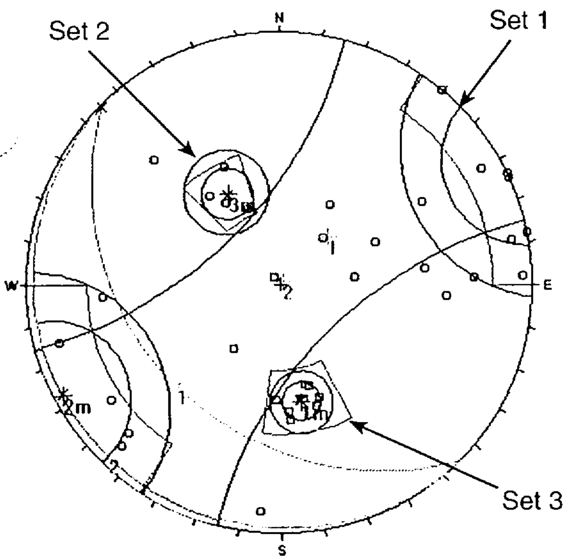
Notes

Analysis performed using computer program DIPS, v. 5.041 (Rocscience, 1999).

Fracture data from stations 38+00 to 45+00 applied to north-trending cut slope above Reservoir Road from stations 43+00 to 46+00.

DIABLO CANYON ISFSI
FIGURE 22-7 KINEMATIC ANALYSES OF NORTH-TRENDING CUTSLOPE OF TRANSPORT ROUTE (STATIONS 43+00 TO 46+00)

GEO.DCPP.01.22 REV 1 — December, 2001



A. Topple hazard (low hazard)

Explanation

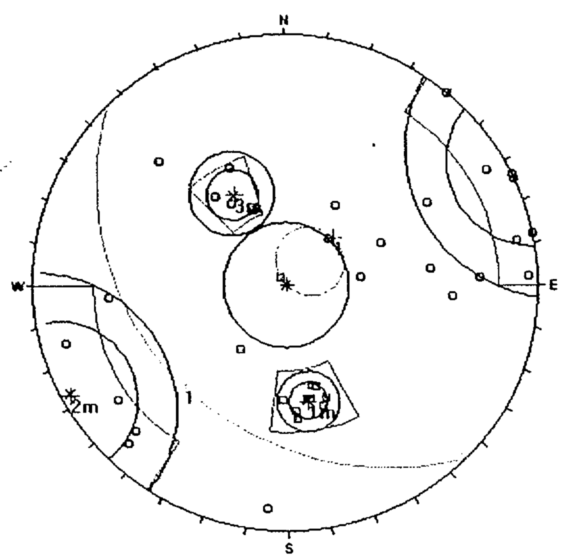
Poles

- o Joint
- ◻ Bedding

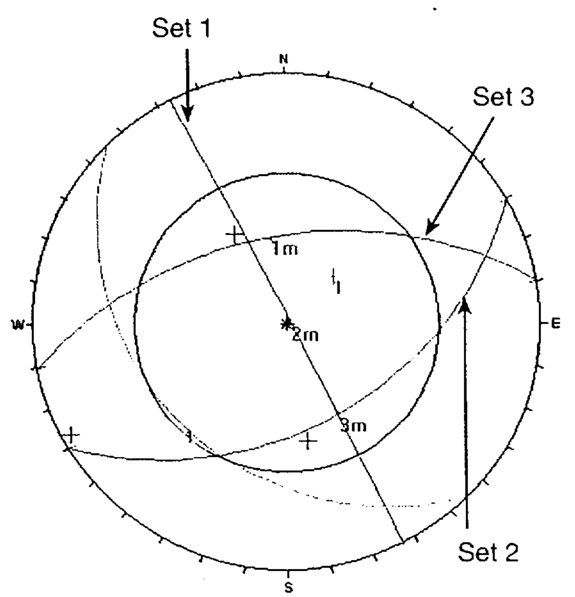
Failure envelope (based on 28° friction angle)

Failure envelope for topple and planar sliding without poles indicates stable conditions.

Failure envelope for wedge sliding without great circle intersections indicates stable conditions.



B. Planar sliding hazard (very low hazard)



C. Wedge sliding hazard (very low hazard)

Notes

Analysis performed using computer program DIPS, v. 5.041 (Rocscience, 1999).

Fracture data from stations 38+00 to 45+00 applied to northwest-trending cutslope above Reservoir Road from stations 35+00 to 43+00

DIABLO CANYON ISFSI
FIGURE 22-8 KINEMATIC ANALYSES OF NORTHWEST-TRENDING CUTSLOPE OF TRANSPORT ROUTE (STATION 35+00 TO 43+00)

GEO.DCPP.01.22 REV 1 December, 2001

ATTACHMENT 1

Dips Program Input Files

DIPS input file for Westcut - SouthWestCut.dip

```
* This file is generated by Dips for Windows
*The following 2 lines are the Title of this file
 Default Title Line 2
 Default Title Line 2

Number of Traverses: 0

* Global Orientation is:
DIP/DIPDIRECTION

0      (Declination)

NO QUANTITY

Number of extra columns are: 3

ID;    Dip;   Dip Direction     DEPTH;       TYPE; TRENCH/BORING;

1      70     264    69.083           joint        01-A
2      61     240    68.545           joint        01-A
3      76     235    68.24            joint        01-A
4      64     265    57.922           joint        01-A
5      49     199    57.577           joint        01-A
6      37     257    56.422           joint        01-A
7      35     358    53.227           joint        01-A
8      69     184    52.954           joint        01-A
9      67     249    51.988           joint        01-A
10     64     248    51.772           joint        01-A
11     29     182    51.682           joint        01-A
12     58     194    51.196           joint        01-A
13     34     55     50.081           joint        01-A
14     48     39     44.392           joint        01-A
15     35     225    42.265           joint        01-A
16     31     251    41.065           joint        01-A
17     24     243    40.711           joint        01-A
18     73     93     39.856           joint        01-A
19     35     229    37.372           joint        01-A
20     23     284    36.913           joint        01-A
21     26     224    36.724           joint        01-A
22     34     240    34.384           joint        01-A
23     78     192    33.245           joint        01-A
24     67     192    32.682           joint        01-A
25     76     150    31.869           joint        01-A
26     71     243    30.474           joint        01-A
27     56     223    23.229           joint        01-A
28     77     54     21.08            joint        01-A
29     67     231    19.973           joint        01-A
30     81     30     16.441           joint        01-A
31     31     171    15.275           joint        01-A
32     36     330    8.838            joint        01-A
33     77     50     7.758            joint        01-A
34     42     188    6.3              joint        01-A
35     20     230    37.8             bedding      01-A
```

36	23	251	42.1	bedding	01-A
37	7	21	54.9	bedding	01-A
38	23	226	55.8	bedding	01-A
39	22	259	58.8	bedding	01-A
40	11	256	64	bedding	01-A
41	71	215	68.043	joint	01-B
42	41	245	66.291	joint	01-B
43	69	250	65.902	joint	01-B
44	59	237	64.885	joint	01-B
45	36	194	47.241	joint	01-B
46	62	214	37.695	joint	01-B
47	60	266	33.099	joint	01-B
48	28	277	27.706	joint	01-B
49	83	257	26.796	joint	01-B
50	41	259	26.506	joint	01-B
51	39	163	22.992	joint	01-B
52	75	243	21.277	joint	01-B
53	27	180	20.117	joint	01-B
54	25	326	18.984	joint	01-B
55	28	273	16.33	joint	01-B
56	65	229	11.573	joint	01-B
57	9	325	26	bedding	01-B
58	10	260	32.5	bedding	01-B
59	7	276	37.7	bedding	01-B
60	42	289	91.717	joint	01-H
61	69	306	91.21	joint	01-H
62	75	259	82.788	joint	01-H
63	69	249	77.589	joint	01-H
64	69	242	75.574	joint	01-H
65	33	259	66.793	joint	01-H
66	34	253	66.625	joint	01-H
67	55	42	28.355	joint	01-H
68	51	275	24.063	joint	01-H
69	58	264	22.203	joint	01-H
70	35	230	16.238	joint	01-H
71	72	119	14.676	joint	01-H
72	79	256	11.53	joint	01-H
73	33	235	9.324	joint	01-H
74	25	231	7.332	joint	01-H
75	34	244	7.207	joint	01-H
76	56	253	6.52	joint	01-H
77	37	223	5.819	joint	01-H
78	52	6	4.867	joint	01-H
79	35	247	4.466	joint	01-H
80	41	227	4.297	joint	01-H
81	15	240	39.4	bedding	01-H
82	13	211	58.7	bedding	01-H
83	12	225	82.3	bedding	01-H
84	11	203	89.6	bedding	01-H
85	21	232	94.5	bedding	01-H
86	78	10		joint	DS-1
87	75	260		joint	DS-1
88	70	10		joint	DS-1
89	85	345		joint	DS-1
90	77	246		joint	DS-1
91	66	10		joint	DS-1
92	56	206		joint	DS-1

93	90	255	joint	DS-1
94	80	14	joint	DS-1
95	80	235	joint	DS-1
96	85	9	joint	DS-1
97	90	30	joint	DS-1
98	85	11	joint	DS-1
99	65	242	joint	DS-1
100	82	342	joint	DS-1
101	90	345	joint	DS-1
102	75	180	joint	DS-1
103	75	38	joint	DS-1
104	71	260	joint	DS-1
105	85	200	joint	DS-1
106	80	74	joint	DS-1
107	80	9	joint	DS-1
108	65	345	joint	DS-1
109	85	235	joint	DS-1
110	70	8	joint	DS-1
111	79	122	joint	T11
112	63	346	joint	T11
113	80	317	joint	T11
114	81	15	joint	T11
115	65	349	joint	T11
116	78	41	joint	T11
117	65	314	joint	T11
118	70	238	joint	T11
119	70	1	joint	T11
120	85	285	joint	T11
121	84	295	joint	T11
122	75	198	joint	T11
123	50	355	joint	T11
124	55	260	joint	T11
125	86	180	joint	T11
126	87	255	joint	T11
127	85	10	joint	T11
128	70	281	joint	T11
129	35	314	joint	T11
130	90	249	joint	T11
131	82	264	joint	T11
132	65	260	joint	T11
133	85	171	joint	T11
134	71	208	joint	T11
135	89	242	joint	T11
136	12	305	bedding	T11
137	90	255	joint	T11
138	64	0	joint	T11
139	68	70	joint	T11
140	72	221	joint	T11
141	84	61	joint	T11
142	80	164	joint	T11
143	76	267	fault	T11
144	81	66	joint	T11
145	79	6	joint	T11
146	79	229	joint	T11
147	77	193	joint	T11
148	76	165	joint	T18
149	47	245	joint	T18

150	80	240	joint	T18
151	88	148	joint	T18
152	70	237	joint	T18
153	26	235	joint	T18
154	87	300	joint	T18
155	73	228	joint	T18
156	25	230	joint	T18
157	71	232	joint	T18
158	30	218	joint	T18
159	21	225	joint	T18
160	89	231	joint	T18
161	39	247	joint	T18
162	38	230	joint	T18
163	32	227	joint	T18
164	84	215	joint	T18
165	87	210	joint	T18
166	78	105	joint	T18
167	80	192	joint	T18
168	72	98	joint	T18
169	84	270	joint	T18
170	84	325	joint	T18
171	80	268	joint	T18
172	25	234	joint	T18
173	87	210	joint	T18
174	82	275	joint	T18
175	72	320	joint	T18
176	76	40	fault	T18
177	78	245	joint	T18
178	88	88	joint	T18
179	79	257	joint	T18
180	87	100	joint	T18
181	88	95	joint	T18
182	82	280	fault	T18
183	80	250	joint	T18
184	62	265	joint	T18
185	82	250	joint	T18
186	72	273	joint	T18
187	80	5	joint	T18
188	88	262	joint	T18
189	75	5	joint	T18
190	76	298	joint	T18
191	88	46	joint	T18
192	57	250	joint	T18
193	79	250	joint	T18
194	86	215	joint	T18
195	28	250	joint	T18
196	88	279	joint	T18
197	84	240	joint	T18
198	69	292	joint	T18
199	70	205	joint	T18
200	68	285	joint	T18
201	87	210	joint	T18
202	72	287	joint	T18
203	67	257	joint	T18
204	80	205	fault	T18
205	38	325	joint	T18
206	78	80	joint	T18

207	76	10	joint	T18
208	80	110	joint	T18
209	83	5	fault	T18
210	88	16	fault	T18
211	60	282	joint	T18

* End of File!
-1

DIPS input file for Backcut - SouthEastCut.dip

* This file is generated by Dips for Windows
*The following 2 lines are the Title of this file
Default Title Line 2
Default Title Line 2

Number of Traverses: 0

* Global Orientation is:
DIP/DIPDIRECTION

0 (Declination)

NO QUANTITY

Number of extra columns are: 3

ID;	Dip;	Dip Direction;	DEPTH;	TYPE;	TRENCH/BORING;
1	40	205	53.453	joint	00BA-2
2	18	267	50.147	joint	00BA-2
3	74	223	48.521	joint	00BA-2
4	48	237	40.597	joint	00BA-2
5	67	205	39.467	joint	00BA-2
6	66	214	39.208	joint	00BA-2
7	41	232	39.113	joint	00BA-2
8	40	240	38.731	joint	00BA-2
9	44	282	35.604	joint	00BA-2
10	48	272	34.321	joint	00BA-2
11	72	101	27.219	joint	00BA-2
12	71	120	26.263	joint	00BA-2
13	64	224	9.438	joint	00BA-2
14	68	264	127.137	joint	01-F
15	42	224	120.021	joint	01-F
16	79	45	87.824	joint	01-F
17	61	197	82.255	joint	01-F
18	57	213	82.036	joint	01-F
19	60	215	81.472	joint	01-F
20	62	228	81.159	joint	01-F
21	66	231	80.287	joint	01-F
22	48	238	71.965	joint	01-F
23	66	218	69.88	joint	01-F
24	66	190	69.665	joint	01-F
25	72	194	68.299	joint	01-F
26	65	223	64.732	joint	01-F
27	70	17	63.379	joint	01-F
28	53	178	61.017	joint	01-F
29	38	317	58.766	joint	01-F
30	29	200	53.569	joint	01-F
31	65	2	51.178	joint	01-F
32	40	182	50.897	joint	01-F
33	43	194	49.677	joint	01-F
34	71	230	46.728	joint	01-F
35	31	185	43.719	joint	01-F

36	32	188	41.198	joint	01-F
37	34	193	26.194	joint	01-F
38	53	211	4.924	joint	01-F
39	9	200	6.8	joint	01-F
40	14	180	94.3	joint	01-F
41	9	200	117	joint	01-F
42	42	289	91.717	joint	01-H
43	69	306	91.21	joint	01-H
44	75	259	82.788	joint	01-H
45	69	249	77.589	joint	01-H
46	69	242	75.574	joint	01-H
47	33	259	66.793	joint	01-H
48	34	253	66.625	joint	01-H
49	55	42	28.355	joint	01-H
50	51	275	24.063	joint	01-H
51	58	264	22.203	joint	01-H
52	35	230	16.238	joint	01-H
53	72	119	14.676	joint	01-H
54	79	256	11.53	joint	01-H
55	33	235	9.324	joint	01-H
56	25	231	7.332	joint	01-H
57	34	244	7.207	joint	01-H
58	56	253	6.52	joint	01-H
59	37	223	5.819	joint	01-H
60	52	6	4.867	joint	01-H
61	35	247	4.466	joint	01-H
62	41	227	4.297	joint	01-H
63	15	240	39.4	bedding	01-H
64	13	211	58.7	bedding	01-H
65	12	225	82.3	bedding	01-H
66	11	203	89.6	bedding	01-H
67	21	232	94.5	bedding	01-H
68	78	10	0.1	joint	DS-1
69	75	260	0.3	joint	DS-1
70	70	10	0.3	joint	DS-1
71	85	345	0.5	joint	DS-1
72	77	246	0.7	joint	DS-1
73	66	10	0.9	joint	DS-1
74	56	206	0.9	joint	DS-1
75	90	255	1	joint	DS-1
76	80	14	1	joint	DS-1
77	80	235	1.5	joint	DS-1
78	85	9	1.5	joint	DS-1
79	90	30	1.8	joint	DS-1
80	85	11	3	joint	DS-1
81	65	242	3.8	joint	DS-1
82	82	342	3.8	joint	DS-1
83	90	345	4.1	joint	DS-1
84	75	180	4.1	joint	DS-1
85	75	38	4.8	joint	DS-1
86	71	260	4.8	joint	DS-1
87	85	200	5	joint	DS-1
88	80	74	5.2	joint	DS-1
89	80	9	5.2	joint	DS-1
90	65	345	5.5	joint	DS-1
91	85	235	5.8	joint	DS-1
92	70	8	5.8	joint	DS-1

93	79	122	joint	T-11
94	63	346	joint	T-11
95	80	317	joint	T-11
96	81	15	joint	T-11
97	65	349	joint	T-11
98	78	41	joint	T-11
99	65	314	joint	T-11
100	70	238	joint	T-11
101	70	1	joint	T-11
102	85	285	joint	T-11
103	84	295	joint	T-11
104	75	198	joint	T-11
105	50	355	joint	T-11
106	55	260	joint	T-11
107	86	180	joint	T-11
108	87	255	joint	T-11
109	85	10	joint	T-11
110	70	281	joint	T-11
111	35	314	joint	T-11
112	90	249	joint	T-11
113	82	264	joint	T-11
114	65	260	joint	T-11
115	85	171	joint	T-11
116	71	208	joint	T-11
117	89	242	joint	T-11
118	12	305	bedding	T-11
119	90	255	joint	T-11
120	64	0	joint	T-11
121	68	70	joint	T-11
122	72	221	joint	T-11
123	84	61	joint	T-11
124	80	164	joint	T-11
125	76	267	fault	T-11
126	81	66	joint	T-11
127	79	6	joint	T-11
128	79	229	joint	T-11
129	77	193	joint	T-11
130	49	274	joint	T-12
131	83	236	joint	T-12
132	79	20	fault	T-12
133	77	180	joint	T-12
134	79	197	joint	T-12
135	85	1	joint	T-12
136	77	231	joint	T-12
137	55	258	joint	T-12
138	64	175	joint	T-12
139	73	226	joint	T-12
140	88	228	joint	T-12
141	45	213	joint	T-12
142	90	25	joint	T-12
143	67	221	joint	T-12
144	60	158	fault	T-12
145	80	350	fault	T-12
146	76	165	joint	T-18
147	47	245	joint	T-18
148	80	240	joint	T-18
149	88	148	joint	T-18

150	70	237	joint	T-18
151	26	235	joint	T-18
152	87	300	joint	T-18
153	73	228	joint	T-18
154	25	230	joint	T-18
155	71	232	joint	T-18
156	30	218	joint	T-18
157	21	225	joint	T-18
158	89	231	joint	T-18
159	39	247	joint	T-18
160	38	230	joint	T-18
161	32	227	joint	T-18
162	84	215	joint	T-18
163	87	210	joint	T-18
164	78	105	joint	T-18
165	80	192	joint	T-18
166	72	98	joint	T-18
167	84	270	joint	T-18
168	84	325	joint	T-18
169	80	268	joint	T-18
170	25	234	joint	T-18
171	87	210	joint	T-18
172	82	275	joint	T-18
173	72	320	joint	T-18
174	76	40	fault	T-18
175	78	245	joint	T-18
176	88	88	joint	T-18
177	79	257	joint	T-18
178	87	100	joint	T-18
179	88	95	joint	T-18
180	82	280	fault	T-18
181	80	250	joint	T-18
182	62	265	joint	T-18
183	82	250	joint	T-18
184	72	273	joint	T-18
185	80	5	joint	T-18
186	88	262	joint	T-18
187	75	5	joint	T-18
188	76	298	joint	T-18
189	88	46	joint	T-18
190	57	250	joint	T-18
191	79	250	joint	T-18
192	86	215	joint	T-18
193	28	250	joint	T-18
194	88	279	joint	T-18
195	84	240	joint	T-18
196	69	292	joint	T-18
197	70	205	joint	T-18
198	68	285	joint	T-18
199	87	210	joint	T-18
200	72	287	joint	T-18
201	67	257	joint	T-18
202	80	205	fault	T-18
203	38	325	joint	T-18
204	78	80	joint	T-18
205	76	10	joint	T-18
206	80	110	joint	T-18

207	83	5		fault	T-18	
208	88	16		fault	T-18	
209	60	282		joint	T-18	
210	63	208	26.5	fault	T20a	
211	75	11	26.7	fault	T20a	
212	68	242	-0.4	joint	T20b	
213	53	316	-0.05	joint	T20b	
214	72	189	0	joint	T20b	
215	69	264	0.1	joint	T20b	
216	83	47	0.35	joint	T20b	
217	84	261	0.7	joint	T20b	
218	82	29	2.3	joint		T20b
219	77	265	2.65	joint	T20b	
220	63	264	2.9	joint	T20b	
221	59	215	3.15	fault	T20b	
222	70	270	3.4	joint	T20b	
223	70	48	3.5	joint	T20b	
224	62	293	4.2	joint	T20b	
225	61	220	7	joint	T20b	
226	80	291	7.4	joint	T20b	
227	56	286	7.7	joint	T20b	
228	82	205	7.9	joint	T20b	
229	4	216	7.9	bedding	T20b	
230	74	231	7.9	joint	T20b	
231	5	208	0	bedding	T20c	
232	60	351	1.2	fault	T20c	
233	76	176	3.9	fault	T20c	
234	68	185	10.2	fault	T20c	
235	80	10	11	joint	T20c	
236	85	290	11	joint	T20c	
237	71	208	0.2	joint	T-3	
238	69	261	0.25	joint	T-3	
239	74	226	0.45	fault	T-3	
240	85	91	0.5	joint	T-3	
241	76	261	1.6	joint	T-3	
242	76	320	2.4	joint	T-3	
243	73	234	3.15	joint	T-3	
244	76	20	3.7	joint	T-3	
245	90	190	4.5	joint	T-3	
246	67	9	5.35	joint	T-3	
247	30	206	5.35	joint	T-3	
248	79	309	5.35	joint	T-3	
249	65	187	5.75	joint	T-3	
250	64	240	5.9	joint	T-3	
251	74	208	7	fault	T-3	
252	60	255	7.2	joint	T-3	
253	85	180	7.3	joint	T-3	
254	51	248	7.5	fault	T-3	
255	66	21	8.4	joint	T-3	
256	61	208	8.6	joint	T-3	
257	79	218	9	joint	T-3	
258	90	205	9.55	joint	T-3	
259	62	291	9.6	joint	T-3	
260	74	201	9.9	joint	T-3	
261	90	269	10	joint	T-3	
262	88	275	1.6	joint	T-4	
263	85	5	1.7	joint	T-4	

264	77	258	1.8	fault	T-4
265	75	248	2	joint	T-4
266	88	105	2.1	joint	T-4
267	60	11	2.15	joint	T-4
268	89	85	2.25	joint	T-4
269	58	186	2.45	joint	T-4
270	60	5	2.5	joint	T-4
271	86	94	2.6	joint	T-4
272	42	340	2.8	joint	T-4
273	65	100	2.92	joint	T-4
274	86	105	3.08	joint	T-4
275	88	106	3.28	joint	T-4
276	30	185	3.28	joint	T-4
277	56	158	3.4	joint	T-4
278	86	275	3.6	joint	T-4
279	74	220	3.78	joint	T-4
280	74	95	3.82	joint	T-4
281	50	352	3.94	joint	T-4
282	35	332	4.1	joint	T-4
283	66	240	4.2	joint	T-4
284	42	347	4.3	joint	T-4
285	62	250	4.5	joint	T-4
286	70	200	4.52	joint	T-4
287	82	355	4.68	fault	T-4
288	82	125	4.78	joint	T-4
289	88	330	4.8	joint	T-4
290	80	115	4.9	joint	T-4
291	12	275	4.9	joint	T-4
292	48	278	5.1	joint	T-4
293	68	335	5.48	joint	T-4
294	70	342	5.56	joint	T-4
295	82	5	5.62	joint	T-4
296	52	260	5.92	joint	T-4
297	80	164	6	joint	T-4
298	65	238	6.14	joint	T-4
299	75	215	6.3	joint	T-4
300	80	190	6.4	joint	T-4
301	45	220	6.6	joint	T-4
302	68	330	6.68	joint	T-4
303	68	272	7.02	joint	T-4
304	82	185	7.02	joint	T-4
305	80	60	7.28	joint	T-4
306	88	200	7.32	fault	T-4
307	58	280	7.42	joint	T-4
308	72	275	7.6	joint	T-4
309	8	250	8.02	joint	T-4
310	89	305	8.28	joint	T-4
311	70	275	8.6	joint	T-4
312	76	340	9.12	joint	T-4
313	62	260	9.3	joint	T-4
314	11	284	0.05	bedding	T-5
315	90	277	0.05	joint	T-5
316	10	266	1.2	bedding	T-5
317	90	307	2.5	joint	T-5
318	87	301	4	joint	T-5
319	90	283	5	joint	T-5
320	50	217	5.4	joint	T-5

321	83	198	5.5	joint	T-5
322	70	121	5.6	joint	T-5
323	90	201	6.7	joint	T-5
324	70	70	7.4	joint	T-5
325	85	330	8.4	fault	T-5
326	70	70	8.5	fault	T-5
327	76	76	8.7	joint	T-5
328	77	105	9.6	joint	T-5
329	64	291	9.9	joint	T-5
330	90	42	10.2	fault	T-5
331	87	294	10.7	joint	T-5
332	57	131	10.9	joint	T-5
333	55	265	11	joint	T-5
334	75	344	11.4	joint	T-5
335	50	254	11.75	joint	T-5
336	70	144	12	joint	T-5
337	65	249	12.2	joint	T-5
338	83	146	12.5	joint	T-5
339	5	244	12.7	bedding	T-5
340	84	55	12.8	joint	T-5
341	78	165	13	joint	T-5
342	63	250	13.05	fault	T-5
343	86	252	13.3	joint	T-5
344	74	345	13.6	joint	T-5
345	25	242	14.4	joint	T-5
346	75	264	14.4	joint	T-5
347	13	276	14.5	bedding	T-5
348	63	271	15.3	joint	T-5
349	78	249	15.55	joint	T-5
350	77	209	15.8	joint	T-5
351	70	270	16	joint	T-5
352	86	261	16.3	joint	T-5
353	76	204	16.4	joint	T-5
354	51	280	16.6	joint	T-5
355	70	252	16.8	joint	T-5
356	74	18	16.9	joint	T-5
357	75	258	17.6	joint	T-5
358	90	339	17.9	fault	T-5
359	85	340	18.4	fault	T-5
360	79	206	18.5	joint	T-5
361	78	71	19	joint	T-5
362	83	185	19	joint	T-5
363	84	289	19.1	joint	T-5
364	57	226	19.1	joint	T-5
365	61	243	19.7	joint	T-5
366	75	241	20	joint	T-5
367	10	230		bedding	T-5
368	70	0	0.64	joint	T-6
369	40	215	0.64	joint	T-6
370	48	10	2.53	joint	T-6
371	90	220	4.02	joint	T-6
372	78	70	4.4	joint	T-6
373	89	82	4.6	joint	T-6
374	71	92	4.98	joint	T-6
375	82	265	5.6	joint	T-6
376	68	25	5.72	fault	T-6
377	88	105	6.28	joint	T-6

378	82	52	7.26	joint	T-6
379	88	95	7.56	joint	T-6
380	90	310	7.88	joint	T-6
381	62	15	8.72	joint	T-6
382	15	240	8.84	joint	T-6
383	70	6	8.88	joint	T-6
384	88	85	9.4	joint	T-6
385	22	225	9.4	joint	T-6
386	80	255	9.64	joint	T-6
387	84	345	10.08	joint	T-6
388	18	230	10.08	joint	T-6
389	74	75	10.08	joint	T-6
390	72	238	10.36	joint	T-6
391	76	4	10.58	joint	T-6
392	86	190	10.8	joint	T-6
393	78	70	11.08	joint	T-6
394	82	200	11.1	fault	T-6
395	89	265	11.6	joint	T-6
396	78	255	11.8	joint	T-6
397	22	235	11.88	joint	T-6
398	89	180	11.9	joint	T-6
399	85	270	12.06	joint	T-6
400	85	145	12.28	joint	T-6
401	22	235	12.7	bedding	T-6
402	82	70	12.8	joint	T-6
403	80	255	13.76	joint	T-6
404	90	145	13.84	joint	T-6
405	86	46	13.84	joint	T-6
406	16	232	14.02	bedding	T-6
407	78	292	14.02	joint	T-6
408	76	333	14.4	joint	T-6
409	80	290	14.6	joint	T-6
410	78	185	14.8	joint	T-6
411	16	205	15.08	bedding	T-6
412	14	215	15.9	bedding	T-6
413	84	185	16.02	joint	T-6
414	74	245	16.24	joint	T-6
415	78	260	16.6	joint	T-6
416	86	215	16.82	joint	T-6
417	76	65	17.2	joint	T-6
418	15	204	17.5	bedding	T-6
419	75	250	18.14	joint	T-6
420	14	210	18.24	bedding	T-6
421	75	10	18.4	joint	T-6

* End of File!
-1

DIPS input file for Eastcup - NorthEastCut.dip

```
* This file is generated by Dips for Windows
*The following 2 lines are the Title of this file

 Default Title Line 2
 Default Title Line 2

Number of Traverses: 0

* Global Orientation is:
DIP/DIPDIRECTION

0     (Declination)

NO QUANTITY

Number of extra columns are: 3
```

ID;	Dip;	Dip Direction;	DEPTH;	TYPE;	BORING/TRENCH;
1	40	205	53.453	joint	00BA-2
2	18	267	50.147	joint	00BA-2
3	74	223	48.521	joint	00BA-2
4	48	237	40.597	joint	00BA-2
5	67	205	39.467	joint	00BA-2
6	66	214	39.208	joint	00BA-2
7	41	232	39.113	joint	00BA-2
8	40	240	38.731	joint	00BA-2
9	44	282	35.604	joint	00BA-2
10	48	272	34.321	joint	00BA-2
11	72	101	27.219	joint	00BA-2
12	71	120	26.263	joint	00BA-2
13	64	224	9.438	joint	00BA-2
14	51	210	79.228	joint	01-E
15	64	208	78.505	joint	01-E
16	72	210	75.4	joint	01-E
17	79	281	66.396	joint	01-E
18	75	253	59.959	joint	01-E
19	76	215	57.898	joint	01-E
20	67	229	54.626	joint	01-E
21	69	220	53.573	joint	01-E
22	85	232	51.698	joint	01-E
23	81	22	36.199	joint	01-E
24	63	267	35.461	joint	01-E
25	68	278	29.089	joint	01-E
26	45	236	25.673	joint	01-E
27	66	2	15.68	joint	01-E
28	72	342	13.177	joint	01-E
29	67	203	9.579	joint	01-E
30	8	90	47	bedding	01-E
31	10	330	48	bedding	01-E
32	3	0	48.8	bedding	01-E
33	78	212	71.79	joint	01-G
34	61	272	70.765	joint	01-G

35	46	227	65.647	joint	01-G
36	68	210	63.781	joint	01-G
37	70	64	61.594	joint	01-G
38	69	237	50.116	joint	01-G
39	67	244	49.801	joint	01-G
40	67	249	49.303	joint	01-G
41	78	281	31.327	joint	01-G
42	58	297	26.302	joint	01-G
43	31	243	14.083	joint	01-G
44	72	286	11.392	joint	01-G
45	63	265	7.867	joint	01-G
46	13	248	18.7	bedding	01-G
47	15	192	25.4	bedding	01-G
48	12	210	29.1	bedding	01-G
49	63	208	26.5	fault	T20a
50	75	11	26.7	fault	T20a
51	68	242	-0.4	joint	T20b
52	53	316	-0.05	joint	T20b
53	72	189	0	joint	T20b
54	69	264	0.1	joint	T20b
55	83	47	0.35	joint	T20b
56	84	261	0.7	joint	T20b
57	82	29	2.3	joint	T20b
58	77	265	2.65	joint	T20b
59	63	264	2.9	joint	T20b
60	59	215	3.15	fault	T20b
61	70	270	3.4	joint	T20b
62	70	48	3.5	joint	T20b
63	62	293	4.2	joint	T20b
64	61	220	7	joint	T20b
65	80	291	7.4	joint	T20b
66	56	286	7.7	joint	T20b
67	82	205	7.9	joint	T20b
68	4	216	7.9	bedding	T20b
69	74	231	7.9	joint	T20b
70	5	208	0	bedding	T20c
71	60	351	1.2	fault	T20c
72	76	176	3.9	fault	T20c
73	68	185	10.2	fault	T20c
74	80	10	11	joint	T20c
75	85	290	11	joint	T20c
76	71	208	0.2	joint	T-3
77	69	261	0.25	joint	T-3
78	74	226	0.45	fault	T-3
79	85	91	0.5	joint	T-3
80	76	261	1.6	joint	T-3
81	76	320	2.4	joint	T-3
82	73	234	3.15	joint	T-3
83	76	20	3.7	joint	T-3
84	90	190	4.5	joint	T-3
85	67	9	5.35	joint	T-3
86	30	206	5.35	joint	T-3
87	79	309	5.35	joint	T-3
88	65	187	5.75	joint	T-3
89	64	240	5.9	joint	T-3
90	74	208	7	fault	T-3
91	60	255	7.2	joint	T-3

92	85	180	7.3	joint	T-3
93	51	248	7.5	fault	T-3
94	66	21	8.4	joint	T-3
95	61	208	8.6	joint	T-3
96	79	218	9	joint	T-3
97	90	205	9.55	joint	T-3
98	62	291	9.6	joint	T-3
99	74	201	9.9	joint	T-3
100	90	269	10	joint	T-3
101	88	275	1.6	joint	T-4
102	85	5	1.7	joint	T-4
103	77	258	1.8	fault	T-4
104	75	248	2	joint	T-4
105	88	105	2.1	joint	T-4
106	60	11	2.15	joint	T-4
107	89	85	2.25	joint	T-4
108	58	186	2.45	joint	T-4
109	60	5	2.5	joint	T-4
110	86	94	2.6	joint	T-4
111	42	340	2.8	joint	T-4
112	65	100	2.92	joint	T-4
113	86	105	3.08	joint	T-4
114	88	106	3.28	joint	T-4
115	30	185	3.28	joint	T-4
116	56	158	3.4	joint	T-4
117	86	275	3.6	joint	T-4
118	74	220	3.78	joint	T-4
119	74	95	3.82	joint	T-4
120	50	352	3.94	joint	T-4
121	35	332	4.1	joint	T-4
122	66	240	4.2	joint	T-4
123	42	347	4.3	joint	T-4
124	62	250	4.5	joint	T-4
125	70	200	4.52	joint	T-4
126	82	355	4.68	fault	T-4
127	82	125	4.78	joint	T-4
128	88	330	4.8	joint	T-4
129	80	115	4.9	joint	T-4
130	12	275	4.9	joint	T-4
131	48	278	5.1	joint	T-4
132	68	335	5.48	joint	T-4
133	70	342	5.56	joint	T-4
134	82	5	5.62	joint	T-4
135	52	260	5.92	joint	T-4
136	80	164	6	joint	T-4
137	65	238	6.14	joint	T-4
138	75	215	6.3	joint	T-4
139	80	190	6.4	joint	T-4
140	45	220	6.6	joint	T-4
141	68	330	6.68	joint	T-4
142	68	272	7.02	joint	T-4
143	82	185	7.02	joint	T-4
144	80	60	7.28	joint	T-4
145	88	200	7.32	fault	T-4
146	58	280	7.42	joint	T-4
147	72	275	7.6	joint	T-4
148	8	250	8.02	joint	T-4

149	89	305	8.28	joint	T-4
150	70	275	8.6	joint	T-4
151	76	340	9.12	joint	T-4
152	62	260	9.3	joint	T-4
153	51	324		joint	T-21
154	85	353		joint	T-21
155	25	28		joint	T-21
156	44	42		joint	T-21
157	56	7		joint	T-21
158	77	68		joint	T-21
159	71	4		joint	T-21
160	40	331		joint	T-21
161	48	332		joint	T-21
162	20	344		joint	T-21
163	80	40		joint	T-21
164	53	320		joint	T-21
165	77	188		joint	T-21
166	83	314		joint	T-21
167	64	3		fault	T-21

* End of File!
-1

DIPS input file for Transport Route Road Cuts - AccessRoadFracs.dip

* This file is generated by Dips for Windows
*The following 2 lines are the Title of this file
Default Title Line 2
Default Title Line 2

Number of Traverses: 0

* Global Orientation is:
DIP/DIPDIRECTION

0 (Declination)

NO QUANTITY

Number of extra columns are: 3

ID;	Dip;	Dip Direction;	TYPE;	SURFACE;	STATION;
1	90	220	Joint	14	
2	84	44	Joint	6	
3	88	268	Joint	8	
4	67	274	Joint	13	
5	85	240	Joint	7	
6	85	5	Joint	9	
7	84	75	Joint	9	
8	50	2	Bedding	7	
9	80	45	Joint	11	
10	70	135	Joint	9	
11	33	265	Joint	8	
12	78	55	Joint	7	
13	54	344	Bedding	11	
14	4	140	Bedding		
15	35	35	Bedding		
16	45	346	Bedding	6	
17	90	245	Joint	5	
18	42	146	Joint	8	
19	90	244	Joint	8	
20	50	350	Bedding	7	
21	48	142	Joint	8	
22	45	246	Joint	13	
23	46	344	Bedding	6	
24	50	349	Bedding	5	
25	60	264	Joint	5	
26	75	268	Joint		7
27	28	223	Joint	6	
28	57	356	Bedding	6	
29	66	240	Joint	9	
30	54	155	Joint	8	
31	54	356	Bedding	6	
32	36	157	Joint	6	
33	70	86	Joint	7	
34	51	341	Bedding	4	
35	86	259	Joint	9	

```
36    41    212                 Joint     10
37    90    258                 Joint     8

* End of File!
-1
```

ATTACHMENT 2

DIPS Program Verification Runs

rocscience

Geomechanics Software & Research

User's Guide

Dips

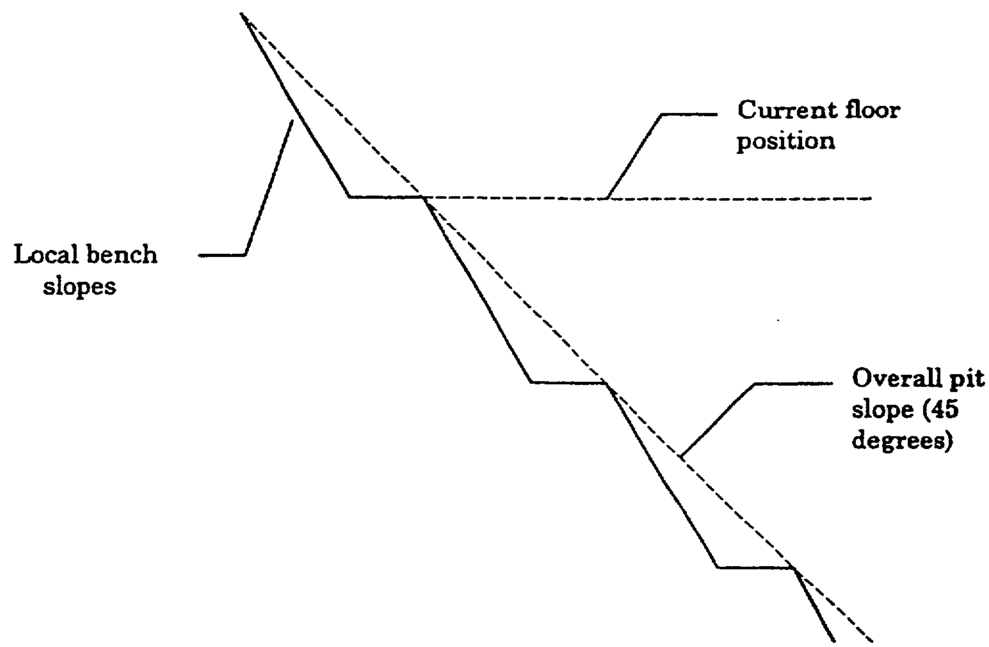
Plotting, analysis and presentation of structural data using spherical projection techniques

Designed for Windows 95/98/NT®

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.

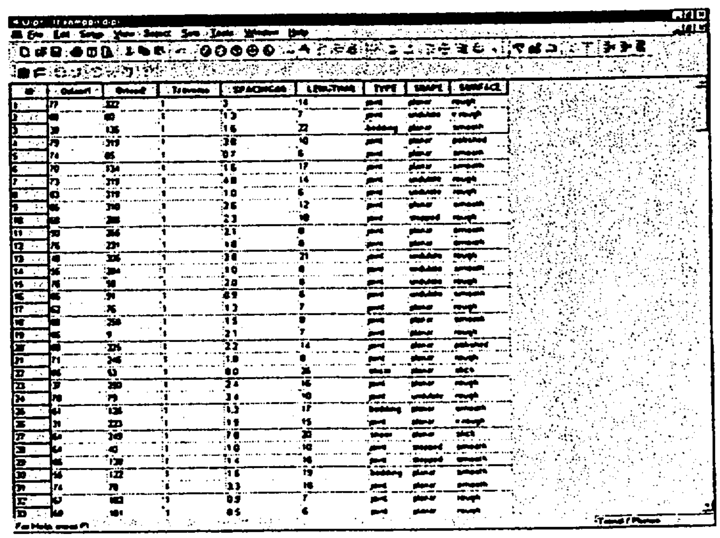


Figure 4-1: EXAMPPIT.DIP data.

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.

DIPS Example File · Examppit.dip

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	90	265	1	2.1	8	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	58	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
34	75	6	1	1.9	7	joint	undulate	smooth
35	77	88	1	0.9	6	joint	undulate	rough
36	78	169	1	1.2	7	joint	undulate	rough
37	85	76	1	2.1	8	joint	undulate	rough
38	64	219	1	1.7	9	joint	planar	rough
39	38	179	1	1.9	13	joint	undulate	smooth
40	59	176	1	0.5	6	joint	undulate	rough
41	77	81	1	1.2	7	joint	planar	smooth
42	64	334	1	3.8	17	joint	planar	smooth
43	51	249	1	6.0	20	shear	planar	slick
44	73	272	1	1.4	7	joint	undulate	v.rough
45	74	176	1	0.9	7	joint	planar	rough
46	66	87	1	1.1	7	joint	planar	smooth
47	50	316	1	3.8	21	joint	undulate	v.rough
48	64	324	1	4.3	13	joint	undulate	smooth
49	60	177	1	1.9	10	joint	planar	rough
50	69	323	1	1.6	11	joint	undulate	rough
51	26	32	1	2.7	8	joint	undulate	rough

ID	Orient1	Orient2	Traverse	SPACING(M)	LENGTH(M)	TYPE	SHAPE	SURFACE
52	71	309	1	3.4	17	joint	stepped	rough
53	53	321	1	1.0	9	joint	planar	smooth
54	89	317	1	3.8	10	joint	planar	rough
55	68	92	1	1.1	7	joint	planar	rough
56	54	232	1	2.1	12	joint	planar	rough
57	74	183	1	2.4	9	joint	undulate	rough
58	60	302	1	2.2	12	joint	planar	smooth
59	62	29	1	3.0	9	joint	planar	smooth
60	89	311	1	3.0	10	joint	planar	smooth
61	77	95	1	0.8	6	joint	undulate	rough
62	69	331	1	5.3	18	joint	planar	smooth
63	84	328	1	2.2	10	joint	planar	rough
64	90	307	1	1.6	7	joint	planar	rough
65	73	87	1	0.7	6	joint	planar	smooth
66	70	320	1	2.2	10	joint	planar	smooth
67	72	36	1	3.8	10	joint	planar	smooth
68	88	316	1	3.4	11	joint	undulate	smooth
69	79	89	1	3.8	11	joint	planar	rough
70	67	187	1	1.6	10	joint	planar	smooth
71	55	323	1	4.3	22	joint	planar	smooth
72	54	126	1	1.6	19	bedding	planar	smooth
73	62	126	1	1.9	19	bedding	planar	smooth
74	80	203	1	2.3	9	joint	planar	rough
75	73	166	1	0.5	6	joint	undulate	rough
76	70	312	1	3.0	16	joint	planar	smooth
77	57	338	1	1.9	13	joint	undulate	smooth
78	89	68	1	1.5	7	joint	undulate	rough
79	82	68	1	0.7	6	joint	planar	smooth
80	73	328	1	2.6	10	joint	planar	rough
81	62	240	1	1.6	9	joint	undulate	rough
82	66	331	1	1.0	9	joint	stepped	smooth
83	49	319	1	1.3	11	joint	planar	rough
84	63	79	1	3.0	11	joint	planar	smooth
85	43	240	1	10.0	23	shear	planar	slick
86	68	171	1	1.2	8	joint	planar	rough
87	67	86	1	0.9	7	joint	planar	rough
88	76	180	1	0.8	7	joint	planar	rough
89	64	316	1	3.4	15	joint	planar	smooth
90	66	317	1	2.6	12	joint	planar	rough
91	87	23	1	2.9	8	joint	planar	rough
92	75	181	1	0.8	6	joint	undulate	smooth
93	88	147	1	3.0	9	joint	planar	rough
94	72	163	1	0.6	6	joint	planar	rough
95	72	182	1	0.6	6	joint	planar	smooth
96	65	91	1	1.9	9	joint	planar	polished
97	80	95	1	0.9	6	joint	planar	rough
98	63	192	1	2.1	9	joint	stepped	rough
99	75	164	1	0.4	6	joint	planar	smooth
100	58	321	1	1.0	8	joint	planar	rough
101	27	182	1	1.9	15	joint	planar	rough
102	70	169	1	2.1	10	joint	planar	smooth

ID	Orient1	Orient2	Traverse	SPACING(M)	LENGTH(M)	TYPE	SHAPE	SURFACE
103	76	231	1	2.2	9	joint	undulate	rough
104	84	143	1	1.9	7	joint	planar	smooth
105	64	308	1	2.6	12	joint	planar	rough
106	76	47	1	10.0	20	shear	planar	slick
107	62	179	1	0.4	6	joint	planar	rough
108	77	175	1	2.0	9	joint	planar	slick
109	61	322	1	0.7	7	joint	planar	rough
110	76	322	1	3.8	16	joint	planar	rough
111	78	90	1	1.7	8	joint	planar	smooth
112	85	78	1	0.7	6	joint	undulate	rough
113	63	97	1	2.7	11	joint	stepped	rough
114	80	230	1	2.0	8	joint	undulate	smooth
115	68	169	1	0.5	6	joint	stepped	rough
116	75	356	1	2.3	11	joint	stepped	rough
117	73	168	1	1.1	7	joint	stepped	rough
118	72	168	1	0.5	6	joint	planar	v.rough
119	85	106	1	1.5	11	joint	planar	smooth
120	85	322	1	6.8	17	joint	planar	rough
121	60	133	1	1.3	17	bedding	planar	smooth
122	89	317	1	3.4	10	joint	planar	smooth
123	88	69	1	5.5	12	joint	planar	smooth
124	85	145	1	3.8	10	joint	planar	smooth
125	69	45	1	2.2	8	joint	planar	rough
126	81	331	1	1.9	7	joint	planar	rough
127	65	331	1	1.9	11	joint	planar	v.rough
128	67	235	1	2.2	10	joint	undulate	smooth
129	71	146	1	2.0	18	joint	planar	rough
130	73	331	1	1.3	8	joint	stepped	rough
131	79	83	1	0.9	6	joint	planar	rough
132	49	140	1	1.6	20	bedding	planar	smooth
133	58	279	1	2.8	14	joint	planar	smooth
134	84	214	1	1.7	7	joint	planar	v.rough
135	83	75	1	1.0	6	joint	planar	rough
136	75	74	1	1.9	8	joint	undulate	v.rough
137	70	177	1	1.0	7	joint	planar	smooth
138	50	253	1	6.0	23	shear	planar	slick
139	65	38	1	1.9	8	joint	planar	rough
140	70	86	1	3.0	11	joint	planar	smooth
141	53	323	1	3.0	17	joint	planar	v.rough
142	45	23	1	2.3	8	joint	stepped	smooth
143	58	14	1	1.8	7	joint	undulate	rough
144	46	28	1	2.0	8	joint	planar	v.rough
145	67	88	1	2.1	9	joint	stepped	smooth
146	53	317	1	2.2	14	joint	planar	v.rough
147	77	93	1	0.9	6	joint	planar	polished
148	56	333	1	6.3	30	joint	planar	v.rough
149	58	303	1	2.6	13	joint	planar	smooth
150	62	307	1	1.3	9	joint	stepped	v.rough
151	72	320	1	1.3	6	joint	planar	polished
152	76	174	1	0.5	6	joint	undulate	rough
153	57	176	1	1.5	9	joint	planar	v.rough

ID	Orient1	Orient2	Traverse	SPACING(M)	LENGTH(M)	TYPE	SHAPE	SURFACE
154	66	160	1	2.3	11	joint	undulate	smooth
155	60	336	1	0.7	8	joint	planar	v.rough
156	70	178	1	0.6	6	joint	planar	polished
157	89	321	1	3.0	9	joint	planar	smooth
158	72	87	1	2.6	10	joint	planar	v.rough
159	76	34	1	2.6	8	joint	planar	rough
160	64	321	1	2.2	9	joint	undulate	v.rough
161	79	85	1	5.4	14	joint	planar	v.rough
162	76	166	1	0.6	6	joint	planar	v.rough
163	52	269	1	1.9	12	joint	planar	v.rough
164	73	325	1	3.0	8	joint	planar	v.rough
165	81	74	1	0.8	6	joint	undulate	v.rough
166	61	176	1	1.1	8	joint	undulate	rough
167	76	83	1	0.9	6	joint	planar	rough
168	82	69	1	1.7	7	joint	planar	rough
169	33	303	1	1.8	15	joint	planar	rough
170	81	169	1	2.0	8	joint	planar	smooth
171	58	330	1	4.3	21	joint	planar	v.rough
172	79	172	1	1.4	7	joint	planar	rough
173	68	187	1	0.4	6	joint	planar	rough
174	30	272	1	2.0	16	joint	planar	rough
175	75	67	1	1.1	7	joint	stepped	rough
176	79	38	1	8.0	25	shear	planar	slick
177	68	176	1	1.5	8	joint	planar	v.rough
178	64	321	1	1.6	8	joint	planar	smooth
179	58	189	1	2.4	12	joint	planar	rough
180	74	48	1	1.9	8	joint	planar	smooth
181	89	317	1	1.6	7	joint	planar	smooth
182	66	309	1	1.0	7	joint	planar	smooth
183	86	322	1	3.0	10	joint	stepped	smooth
184	60	109	1	1.4	16	joint	stepped	rough
185	72	327	1	3.8	13	joint	planar	slick
186	61	38	1	1.9	8	joint	planar	v.rough
187	75	320	1	6.3	20	joint	planar	rough
188	73	81	1	0.9	6	joint	planar	v.rough
189	54	338	1	2.2	15	joint	planar	v.rough
190	82	332	1	1.9	7	joint	planar	v.rough
191	72	82	1	1.9	8	joint	planar	v.rough
192	54	126	1	1.9	20	bedding	planar	smooth
193	86	267	1	1.8	7	joint	planar	rough
194	51	311	1	2.6	16	joint	planar	rough
195	68	319	1	4.3	16	joint	undulate	rough
196	74	73	1	2.6	9	joint	planar	rough
197	39	58	1	2.6	10	joint	stepped	rough
198	67	72	1	2.5	9	joint	stepped	smooth
199	71	82	1	0.8	6	joint	planar	smooth
200	30	225	1	1.2	11	joint	undulate	smooth
201	79	62	1	5.2	12	joint	undulate	smooth
202	73	331	1	1.9	9	joint	undulate	smooth
203	80	319	1	1.9	7	joint	undulate	smooth
204	25	181	1	2.0	16	joint	planar	smooth

ID	Orient1	Orient2	Traverse	SPACING(M)	LENGTH(M)	TYPE	SHAPE	SURFACE
205	59	246	1	1.7	10	joint	planar	smooth
206	64	43	1	0.4	6	joint	planar	smooth
207	73	315	1	0.4	6	joint	planar	rough
208	74	48	1	4.3	11	joint	undulate	smooth
209	69	94	1	1.0	7	joint	planar	rough
210	86	45	1	2.2	7	joint	planar	smooth
211	55	318	1	4.3	22	joint	undulate	rough
212	61	323	1	3.8	17	joint	planar	rough
213	52	139	1	1.1	17	joint	undulate	smooth
214	63	129	1	1.0	15	bedding	planar	smooth
215	89	326	1	3.8	16	joint	undulate	smooth
216	83	164	1	3.6	10	joint	planar	smooth
217	78	72	1	1.9	8	joint	planar	smooth
218	70	117	1	1.4	16	joint	planar	smooth
219	67	349	1	1.7	10	joint	planar	smooth
220	63	123	1	1.7	18	bedding	planar	smooth
221	64	1	1	2.4	14	joint	undulate	v.rough
222	56	330	1	2.2	14	joint	planar	rough
223	14	317	1	1.6	13	joint	planar	v.rough
224	69	158	1	0.6	6	joint	planar	smooth
225	63	115	1	1.3	16	bedding	planar	smooth
226	81	36	1	3.8	9	joint	planar	smooth
227	47	119	1	1.5	19	bedding	planar	smooth
228	79	164	1	0.6	6	joint	planar	smooth
229	70	102	1	1.1	7	joint	planar	smooth
230	61	162	1	0.7	7	joint	stepped	rough
231	66	178	1	0.6	7	joint	planar	rough
232	56	133	1	1.0	16	joint	undulate	rough
233	71	85	1	3.0	10	joint	planar	rough
234	54	153	1	1.8	7	joint	planar	rough
235	54	119	1	0.9	15	joint	undulate	rough
236	61	327	1	3.4	17	joint	planar	rough
237	65	173	1	0.5	6	joint	undulate	rough
238	78	80	1	2.1	8	joint	stepped	rough
239	52	293	1	1.3	10	joint	undulate	smooth
240	70	266	1	1.6	8	joint	planar	rough
241	51	119	1	1.7	20	bedding	planar	smooth
242	63	176	1	1.0	8	joint	planar	rough
243	62	343	1	1.7	11	joint	planar	smooth
244	73	325	1	3.4	14	joint	planar	v.rough
245	61	306	1	3.8	17	joint	planar	smooth
246	51	137	1	1.7	20	bedding	planar	smooth
247	73	328	1	1.9	10	joint	planar	smooth
248	84	83	1	0.9	6	joint	planar	smooth
249	73	318	1	2.6	10	joint	planar	smooth
250	79	89	1	2.6	9	joint	planar	smooth
251	77	322	1	3.8	14	joint	planar	smooth
252	85	144	1	4.3	10	joint	undulate	rough
253	56	308	1	3.0	16	joint	planar	rough
254	53	122	1	1.0	16	joint	planar	v.rough
255	57	269	1	1.8	11	joint	planar	smooth

ID	Orient1	Orient2	Traverse	SPACING(M)	LENGTH(M)	TYPE	SHAPE	SURFACE
256	85	145	1	1.9	7	joint	undulate	v.rough
257	64	77	1	5.4	15	joint	undulate	smooth
258	53	112	1	1.2	16	joint	undulate	rough
259	70	32	1	3.8	10	joint	planar	smooth
260	89	68	1	2.1	8	joint	undulate	rough
261	54	126	1	2.1	21	bedding	planar	smooth
262	74	332	1	2.2	9	joint	undulate	rough
263	36	273	1	1.8	14	joint	planar	rough
264	67	48	1	2.2	8	joint	planar	rough
265	43	342	1	0.7	9	joint	planar	rough
266	39	266	1	10.0	20	shear	planar	slick
267	72	272	1	2.2	9	joint	undulate	rough
268	66	170	1	1.1	9	joint	planar	rough
269	84	154	1	1.6	11	joint	planar	rough
270	75	319	1	3.4	13	joint	planar	smooth
271	87	327	1	4.8	20	joint	planar	smooth
272	77	218	1	1.9	8	joint	undulate	smooth
273	67	79	1	0.8	7	joint	stepped	smooth
274	81	332	1	3.8	10	joint	undulate	rough
275	62	321	1	6.3	25	joint	planar	smooth
276	68	348	1	1.6	10	joint	undulate	v.rough
277	88	327	1	2.6	13	joint	undulate	smooth
278	66	91	1	0.9	7	joint	planar	rough
279	61	221	1	1.6	9	joint	planar	polished
280	75	172	1	1.6	8	joint	planar	rough
281	79	164	1	0.5	6	joint	planar	rough
282	70	320	1	4.3	15	joint	planar	rough
283	51	312	1	5.8	29	joint	planar	smooth
284	60	262	1	1.9	10	joint	planar	smooth
285	84	313	1	0.4	6	joint	planar	smooth
286	79	38	1	3.4	9	joint	planar	smooth
287	64	176	1	3.0	12	joint	planar	polished
288	64	289	1	3.0	13	joint	planar	smooth
289	87	142	1	2.6	9	joint	planar	rough
290	75	69	1	1.7	8	joint	stepped	v.rough
291	39	264	1	6.0	19	shear	planar	slick
292	74	78	1	1.1	7	joint	planar	rough
293	71	98	1	0.9	7	joint	planar	smooth
294	75	24	1	1.3	6	joint	undulate	rough
295	78	88	1	1.9	8	joint	planar	smooth
296	66	172	1	2.0	10	joint	planar	smooth
297	77	311	1	1.9	8	joint	planar	smooth
298	84	313	1	3.8	14	joint	planar	polished
299	66	9	1	2.0	7	joint	planar	smooth
300	87	296	1	1.0	6	joint	planar	rough
301	67	71	1	2.6	9	joint	planar	rough
302	79	73	1	2.5	9	joint	planar	smooth
303	88	1	1	1.5	7	joint	planar	rough

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.

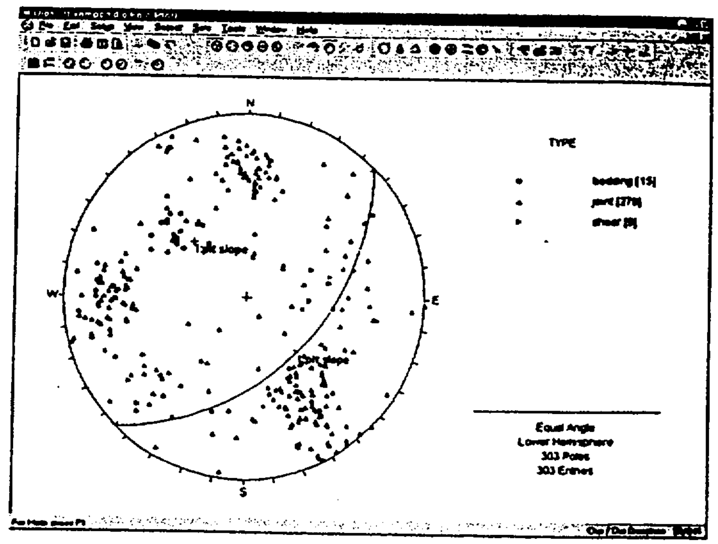


Figure 4-3: Symbolic Pole Plot of discontinuity TYPE. Great circle representing the pit slope has also been added.

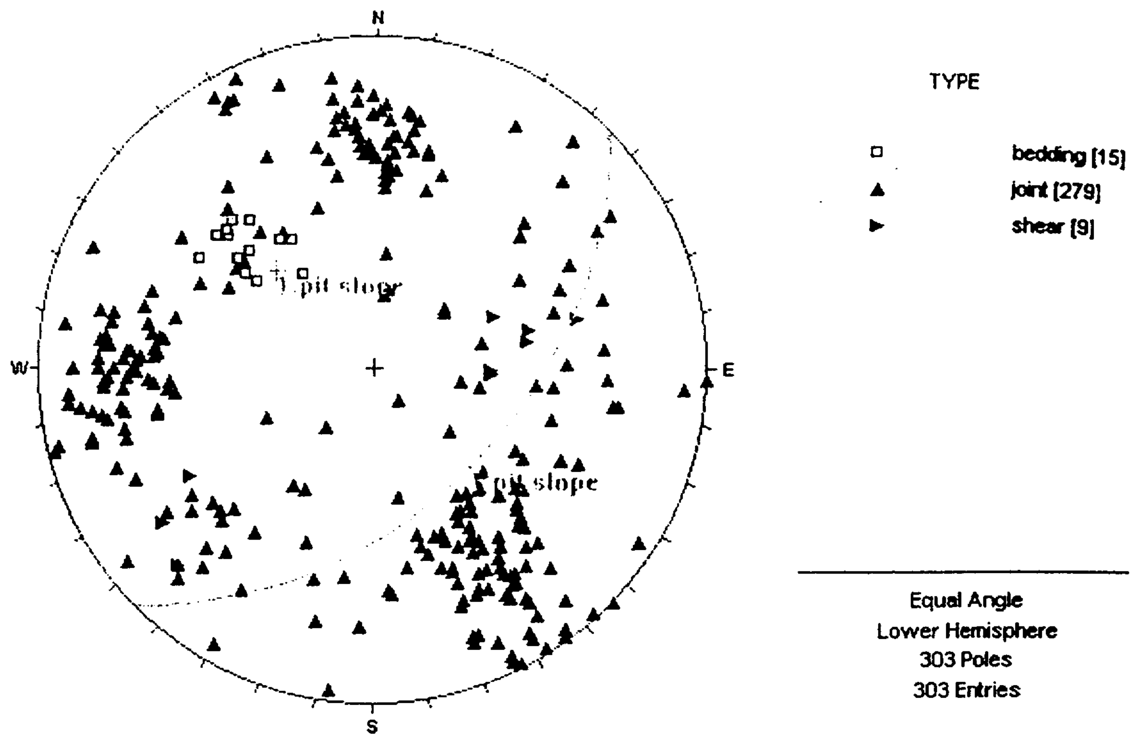
In the above figure, you will notice that a great circle has been added to the plot, representing the pit slope.

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.


N
S
E
W
pit slope
pit slope
TYPE
bedding [15]
joint [279]
shear [9]
Equal Angle
Lower Hemisphere
303 Poles
303 Entries

Contour Plot

Now let's view the contoured data.

Select: View → Contour Plot

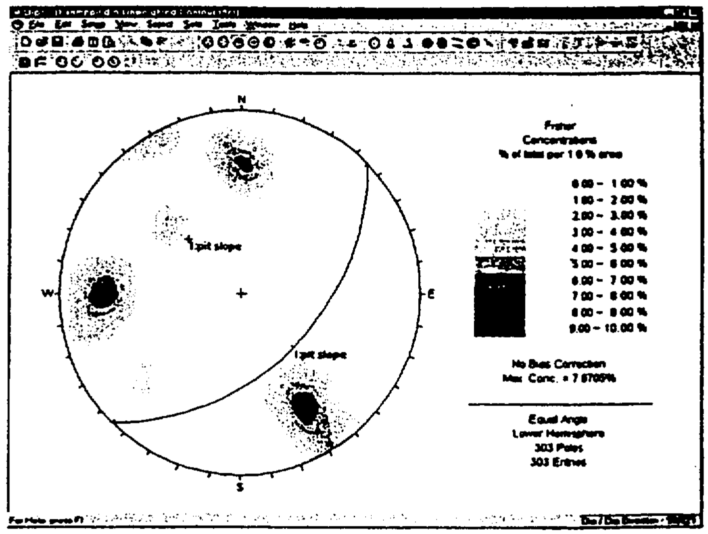
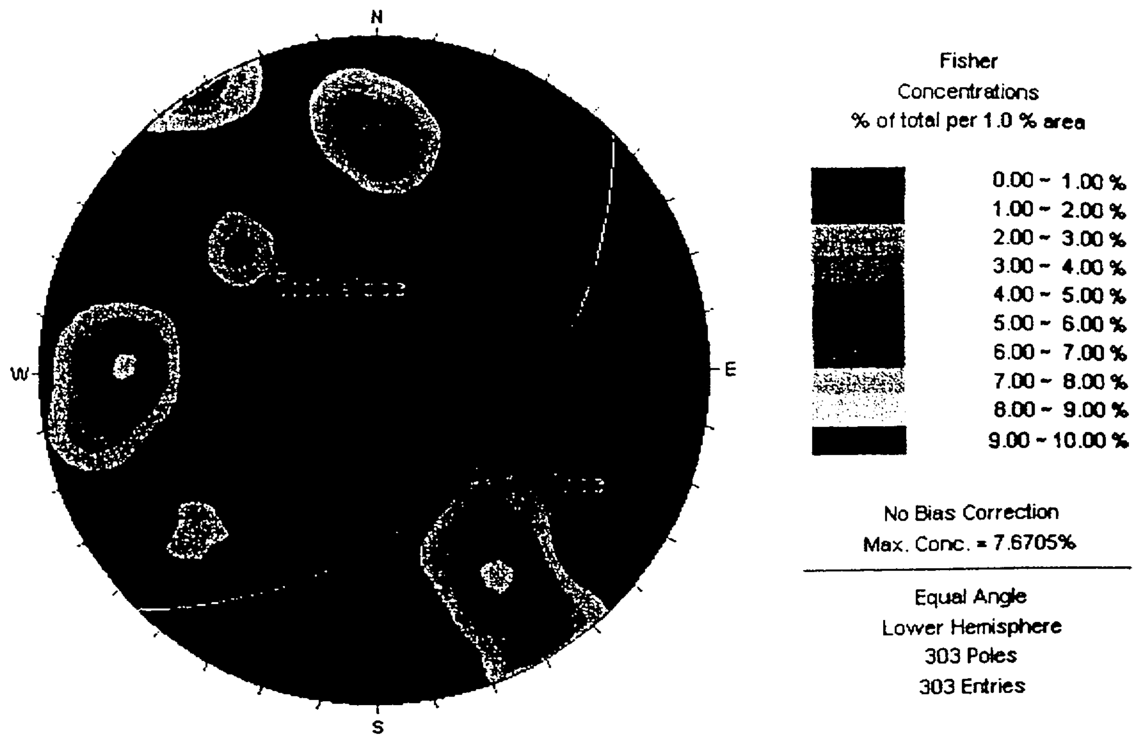


Figure 4-5: Unweighted Contour Plot of EXAMPPIT.DIP data.

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


N
W
E
S
Fisher
Concentrations
% of total per 1.0 % area
0.00 ~ 1.00 %
1.00 ~ 2.00 %
2.00 ~ 3.00 %
3.00 ~ 4.00 %
4.00 ~ 5.00 %
5.00 ~ 6.00 %
6.00 ~ 7.00 %
7.00 ~ 8.00 %
8.00 ~ 9.00 %
9.00 ~ 10.00 %
No Bias Correction
Max. Conc. = 7.6705%
Equal Angle
Lower Hemisphere
303 Poles
303 Entries

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.

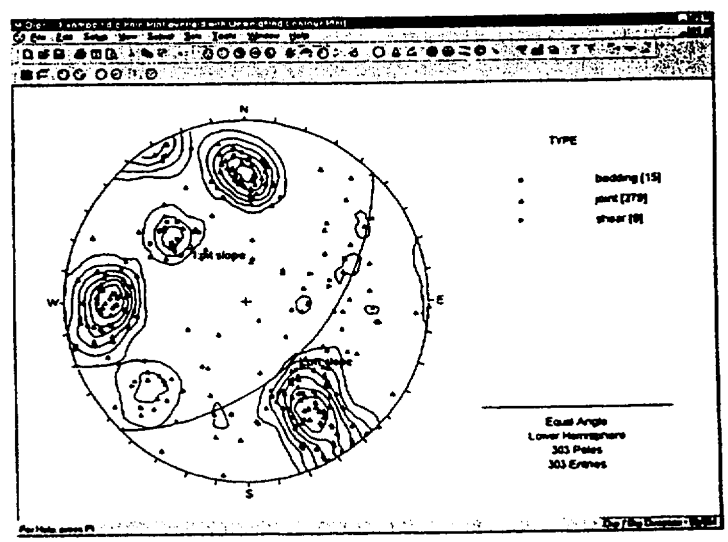
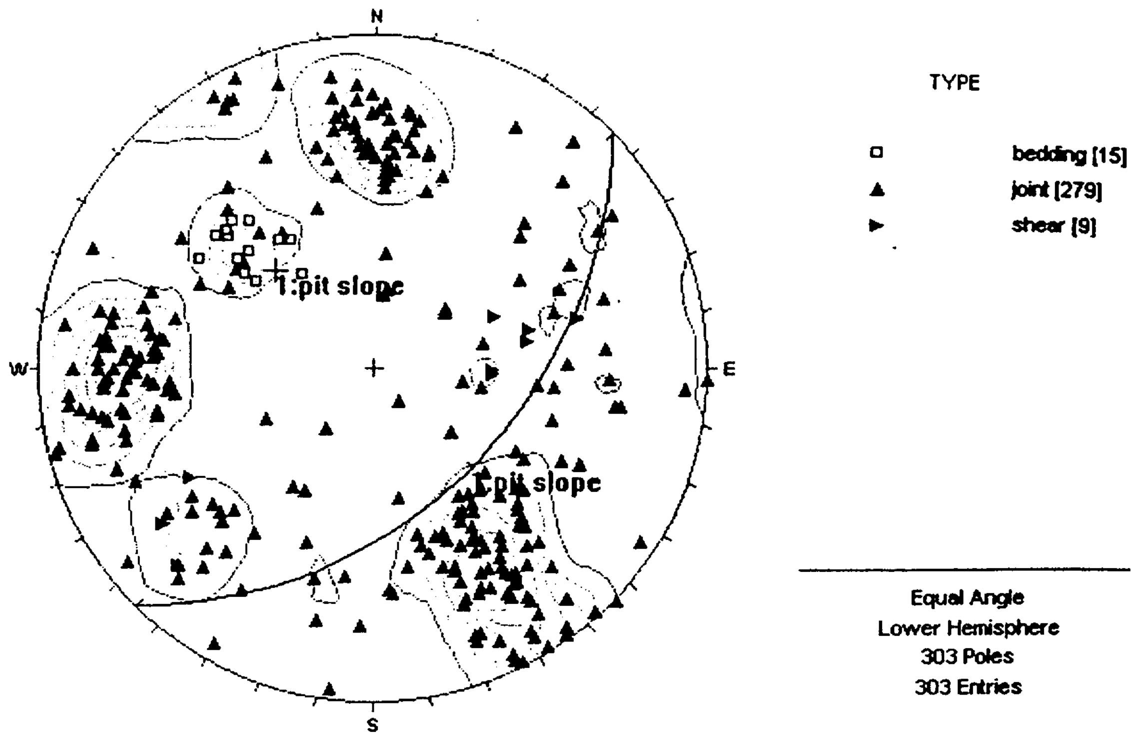


Figure 4-7: Overlaid Contours on Pole Plot.


N
S
W
E
1:pit slope
2:pit slope
TYPE
bedding [15]
joint [279]
shear [9]
Equal Angle
Lower Hemisphere
303 Poles
303 Entries

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 persistance.

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.

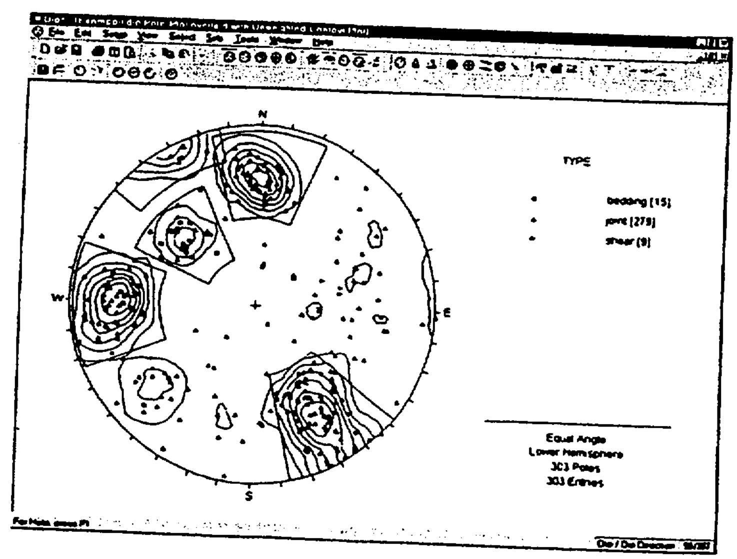
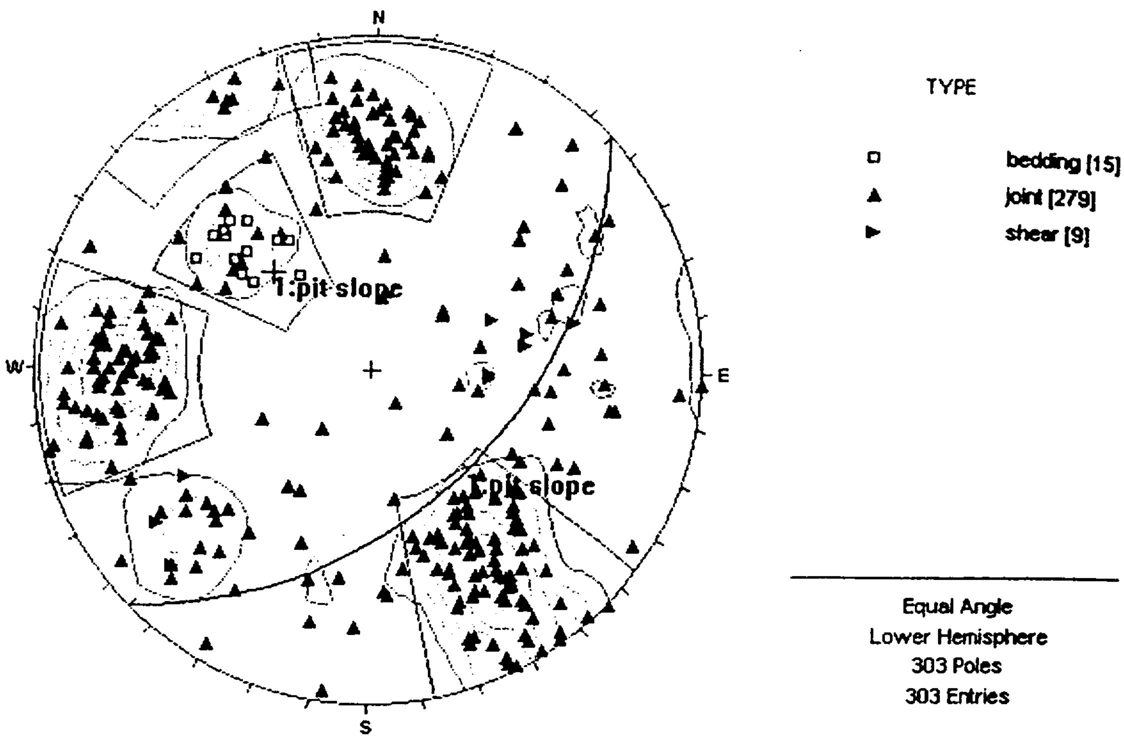


Figure 4-8: Set Windows formed around the four principal joint sets, using the Add Set Window option.


N
W
E
S
1:pit slope
1:pit slope
TYPE
bedding [15]
joint [279]
shear [9]
Equal Angle
Lower Hemisphere
303 Poles
303 Entries

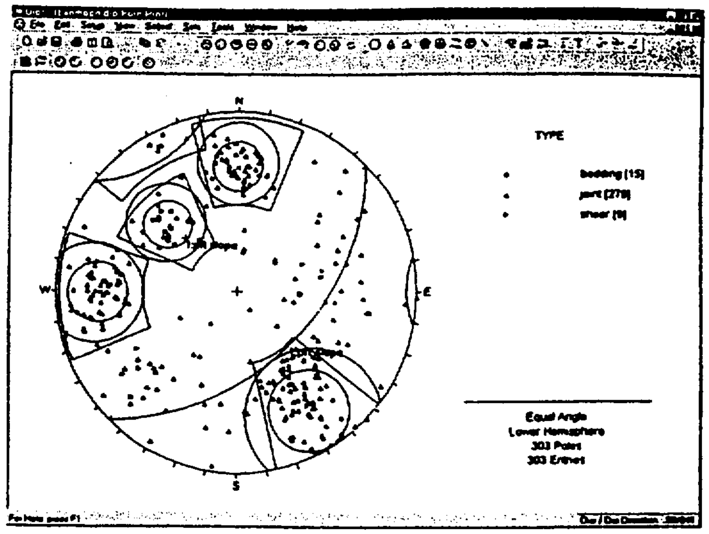


Figure 4-12: Variability cones displayed on Pole Plot.

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

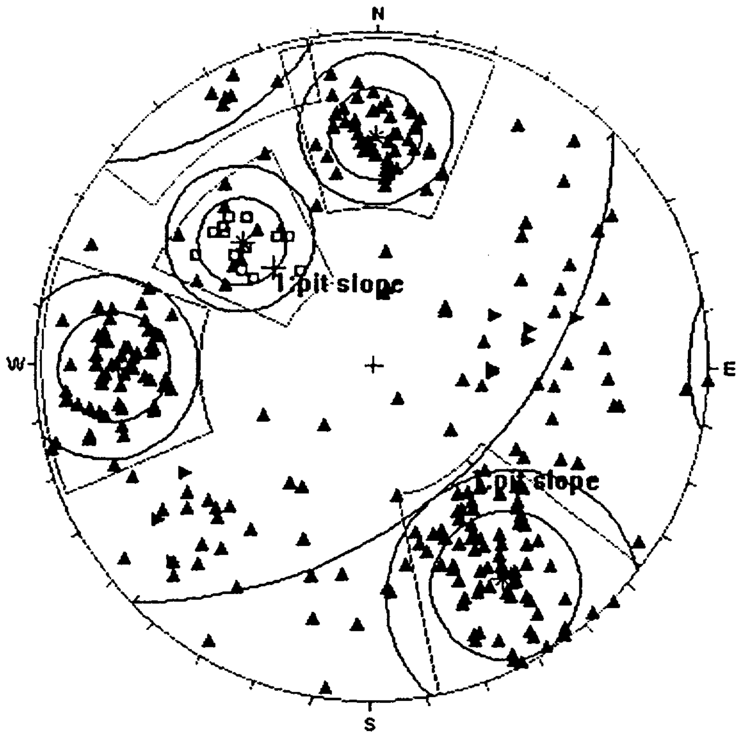
(The following analysis is based on Goodman 1980. See the reference at the end of this tutorial).

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.



TYPE

□	bedding [15]
▲	joint [279]
►	shear [9]

Equal Angle
Lower Hemisphere
303 Poles
303 Entries

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.

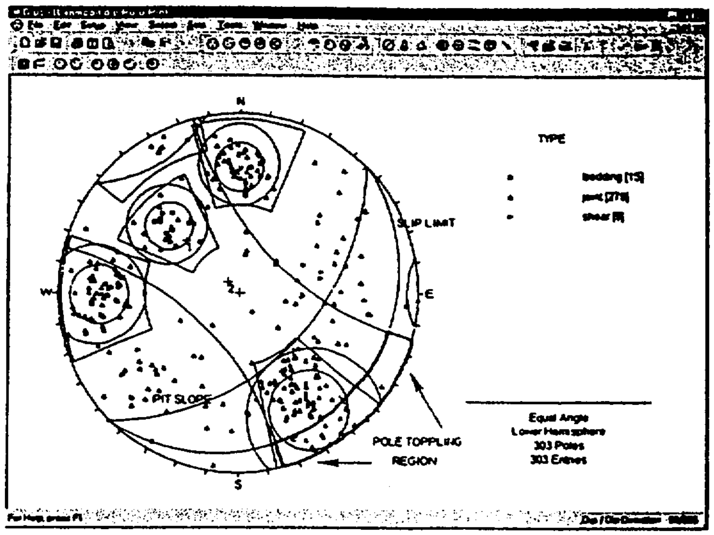
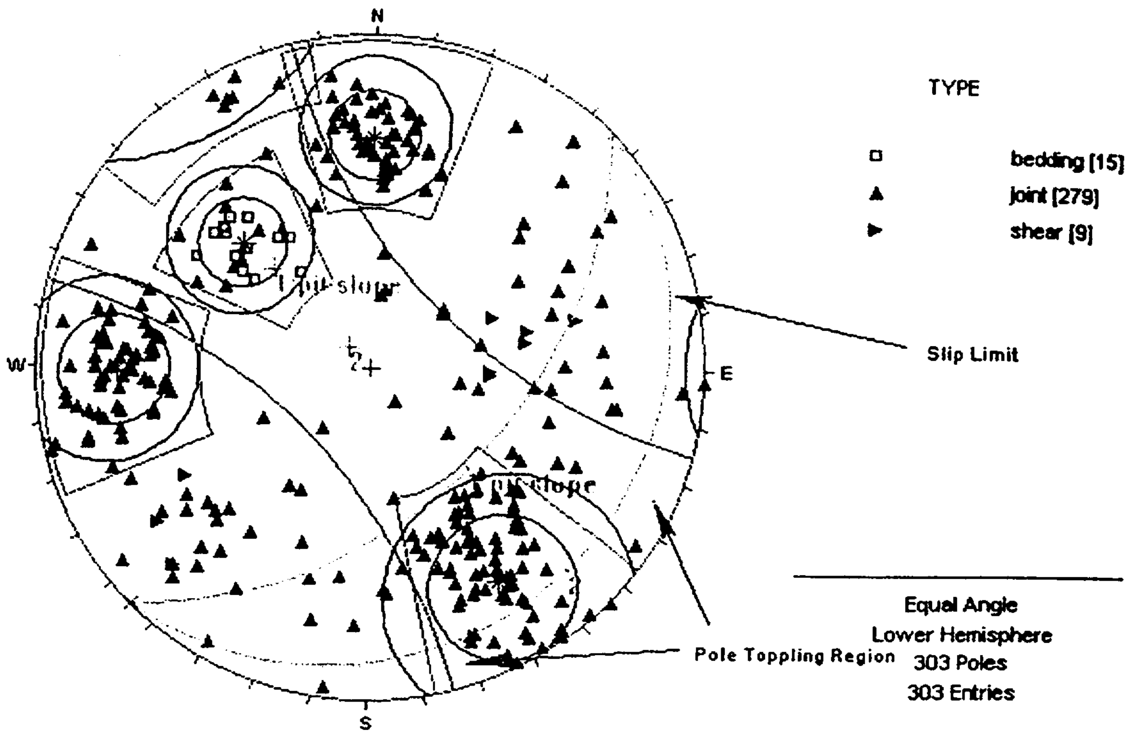


Figure 4-13: Toppling risk is indicated by the relative number of poles within joint set which fall within the outlined pole toppling region. Visual estimate indicates about 25 – 30% toppling risk for joint set 4, based on the 95% variability cone.

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.


N
W
E
S
TYPE
bedding [15]
joint [279]
shear [9]
Slip Limit
Pole Toppling Region
Equal Angle
Lower Hemisphere
303 Poles
303 Entries

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

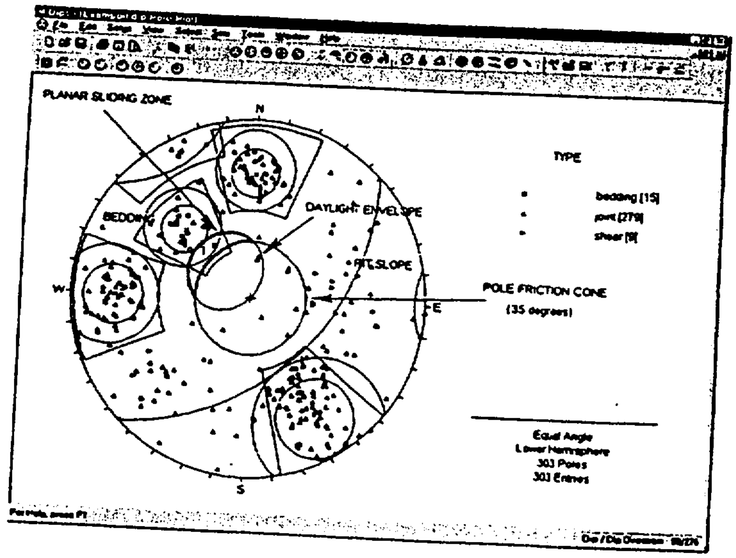


Figure 4-15: Planar sliding zone is represented by crescent shaped region. Only a small area overlaps the bedding joint set, therefore the risk of planar sliding is minimal.

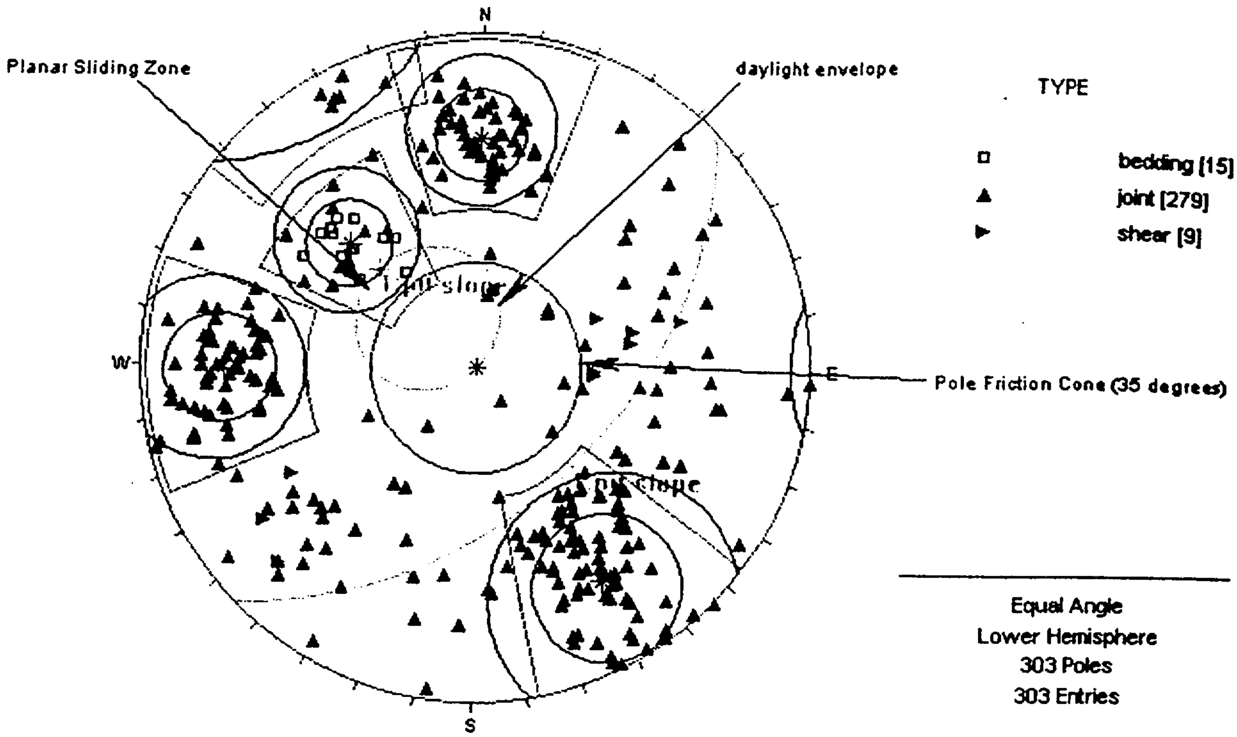
Again, the variability cones give a statistical estimate of failure probability. Only a small percentage (< 5 %) of the bedding joint set falls within this zone.

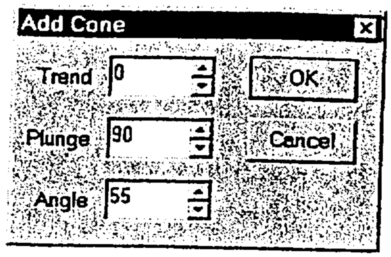
Planar sliding is unlikely to be a problem.

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.


Planar Sliding Zone
daylight envelope
N
W
E
S
Pole Friction Cone (35 degrees)
TYPE
bedding [15]
joint [279]
shear [9]
Equal Angle
Lower Hemisphere
303 Poles
303 Entries



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.

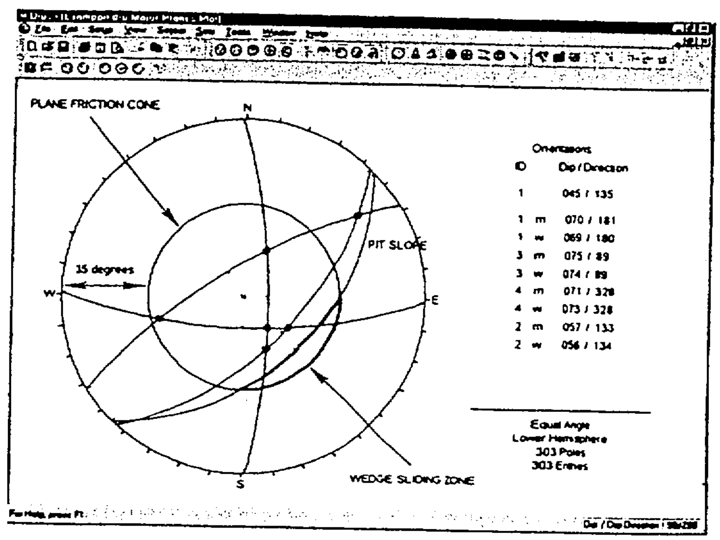
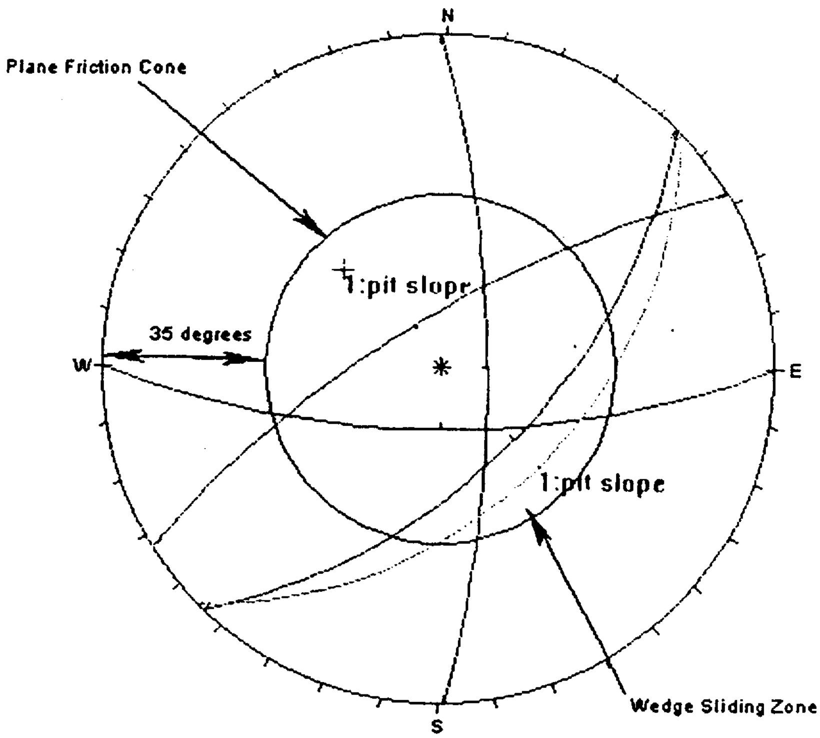


Figure 4-16: Major Planes Plot showing WEIGHTED MEAN planes, pit slope and friction cone. Wedge sliding zone is represented by crescent shaped region. Since no plane intersections (black dots) fall within this region, wedge sliding failure should not be a concern.



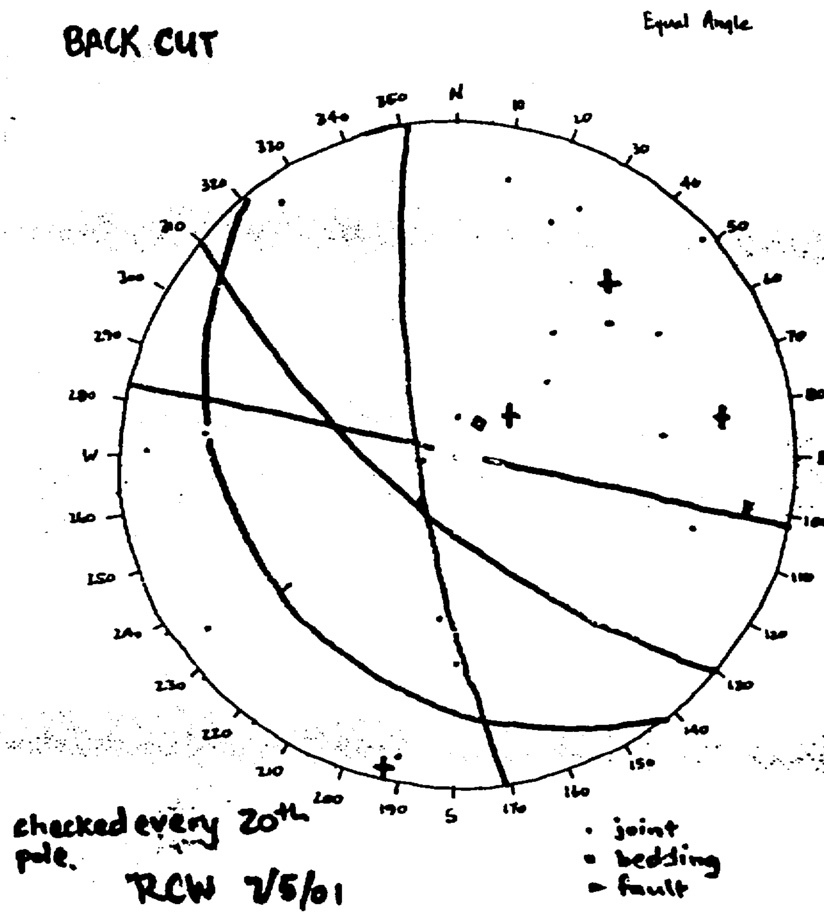
Orientations

ID		Dip / Direction
1		045 / 135
1	m	070 / 181
1	w	069 / 180
2	m	071 / 328
2	w	073 / 328
3	m	057 / 133
3	w	056 / 134
4	m	075 / 89
4	w	074 / 89

Equal Angle
Lower Hemisphere
303 Poles
303 Entries

ATTACHMENT 3

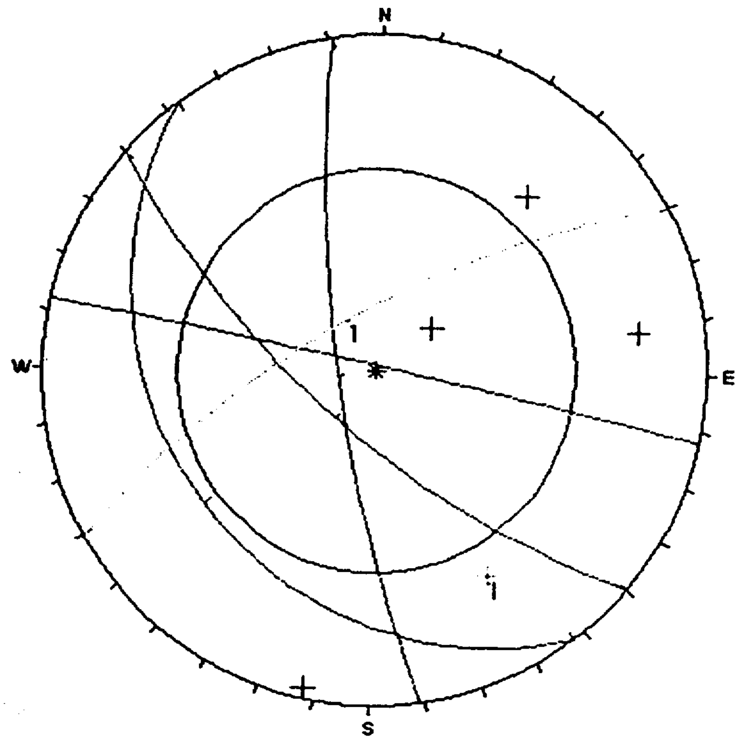
DIPS Data Presentation Verification Runs


BACK CUT
Equal Angle
N
10
20
30
40
50
60
70
80
E
100
110
120
130
140
150
160
170
S
190
200
210
220
230
240
250
260
W
280
290
300
310
320
330
340
350
checked every 20th pole.
RCW 7/5/01
• joint
▪ bedding
▬ fault

RCW ✓

Page 1 of 1

Back Cut, Wedge Slide



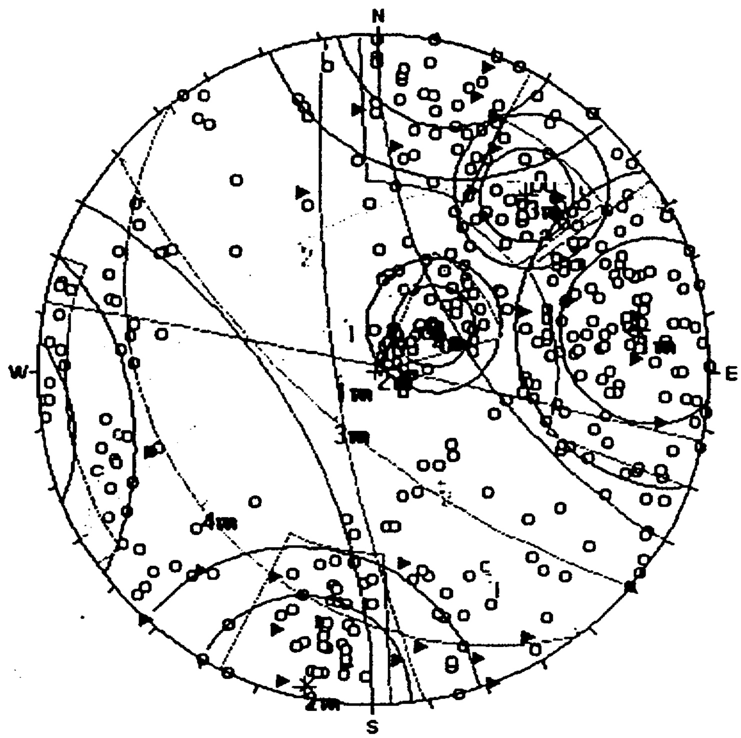
Orientations

ID		Dip / Direction
1		070 / 330
1	m	077 / 261
1	w	077 / 261
2	m	088 / 12
2	w	088 / 12
3	m	069 / 220
3	w	069 / 220
4	m	024 / 232
4	w	024 / 232

Equal Angle
Lower Hemisphere
421 Poles
421 Entries

Page 1 of 1

Back Cut, Topple

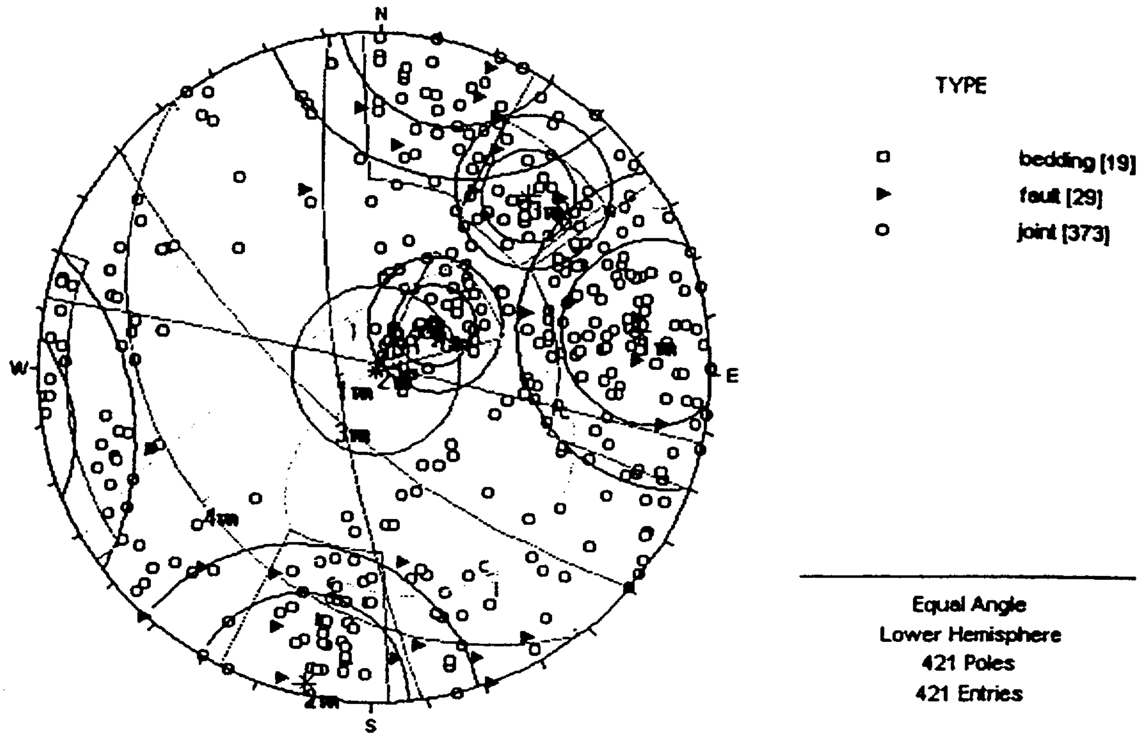


TYPE

□	bedding [19]
▶	fault [29]
o	joint [373]

Equal Angle
Lower Hemisphere
421 Poles
421 Entries

Back Cut, Planar Slide



ATTACHMENT 4

DIPS Program Manual

rocscience

Geomechanics Software & Research

User's Guide

Dips

Plotting, analysis and presentation of structural data using spherical projection techniques

Designed for Windows 95/98/NT®

Table of Contents

Getting Started

DIPS is designed to work on Windows 95, 98 and Windows NT 4.0 operating systems.

To install DIPS on your computer:

1. Insert the CD-ROM.
2. Setup should begin automatically displaying the main Rocscience Installation window.
3. If not, select Add / Remove Programs from the Control Panel and click on the Install button. Follow the directions until the main Rocscience Installation window is displayed.
4. Click on the DIPS button.
5. Click on the INSTALL FULL VERSION button.
6. Follow the installation instructions. During installation you will be asked to enter your seventeen character alphanumeric serial number. Enter the serial number located on the outside of the CD case to install the program. Proceed until the installation is complete and you are back to the Rocscience Installation window.
7. Click on the RETURN button.
8. If you have NOT previously installed the hardlock driver software for any other Rocscience program proceed with step 9. Otherwise go to step 13.
9. Click on the HARDLOCK button.
10. Click on the INSTALL DRIVER FOR 95,98,NT button.

11. Proceed until the hardlock driver installation is complete and you are back to the Rocscience Installation window.

12. Click on the RETURN button.

13. Click on the EXIT button.

14. To run DIPS, you will also need the hardlock supplied with the program. The hardlock must be attached to the parallel port on your computer during execution of the program. Attach the DIPS hardlock to the parallel port of your computer.

15. The installation process creates a ROCSCIENCE menu in your START...PROGRAMS menu. In the ROCSCIENCE menu there will be a DIPS menu containing the DIPS application. Run the DIPS application.

16. If you are a first time user, follow the "Quick Tour of DIPS" and "Creating a DIPS File" tutorials presented in this manual, to get acquainted with the basic features of DIPS.

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 utilise 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 stereonets. 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.

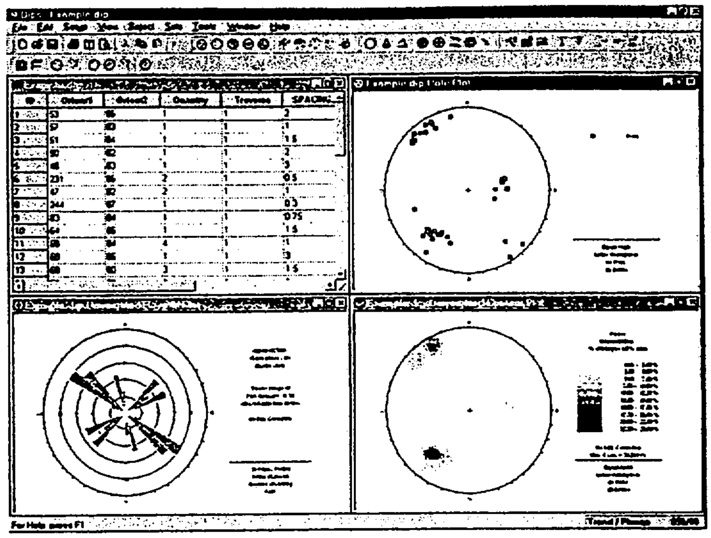
In this manual, instructions such as:

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.

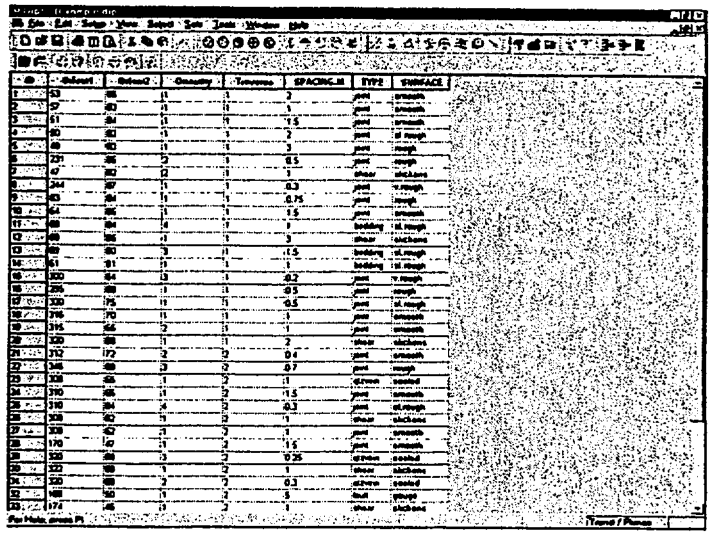


Figure 2-1: Grid View of EXAMPLE.DIP file.

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.

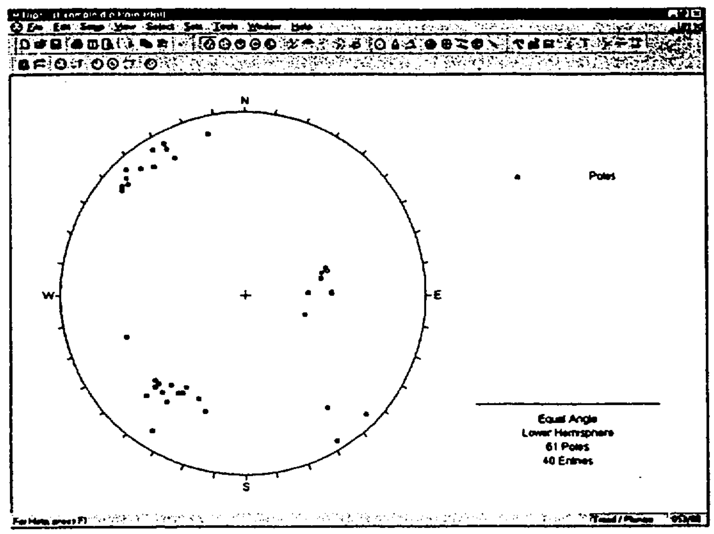


Figure 2-2: Pole Plot of EXAMPLE.DIP data.

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:

Trend / Plunge 122/56

- 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.

Strike / Dip Right 220/45

- 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

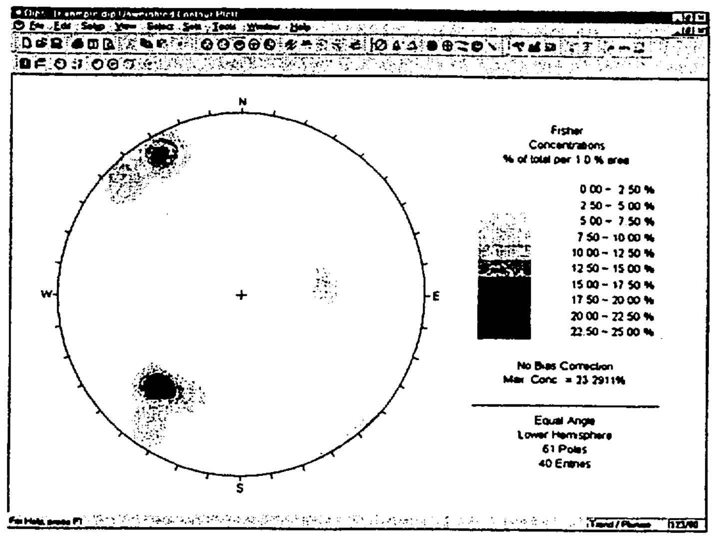


Figure 2-3: Contour Plot of EXAMPLE.DIP data.

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.

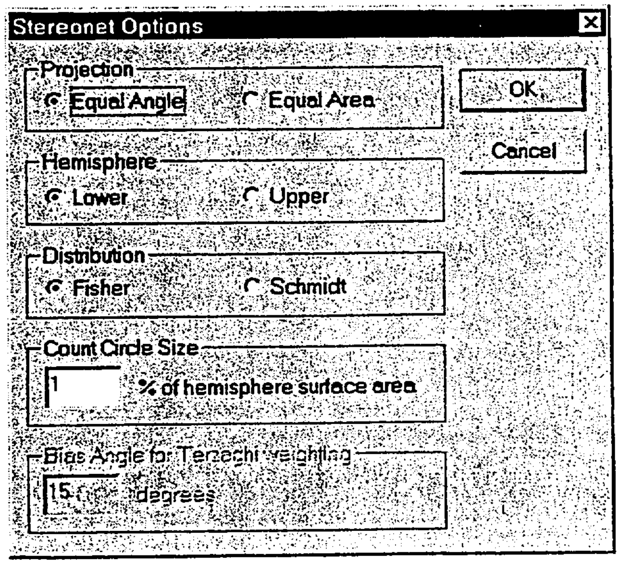


Figure 2-4: Stereonet Options dialog.

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.

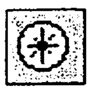
See the Stereonet Options topic in the DIPS Help system, for complete details about all of the DIPS Stereonet options.

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.

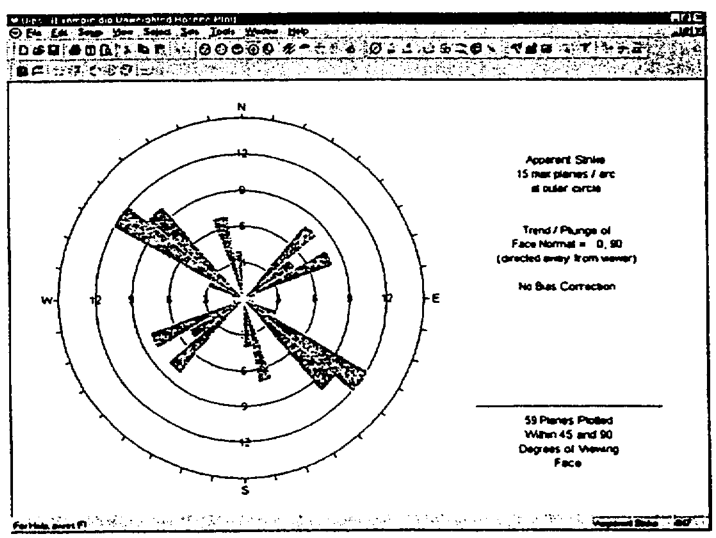


Figure 2-5: Rosette Plot of EXAMPLE.DIP data.

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.

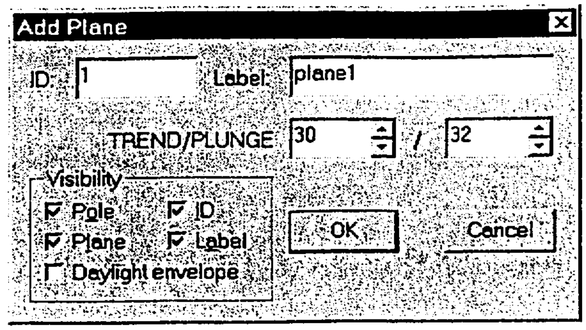


Figure 2-6: Add Plane dialog.

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

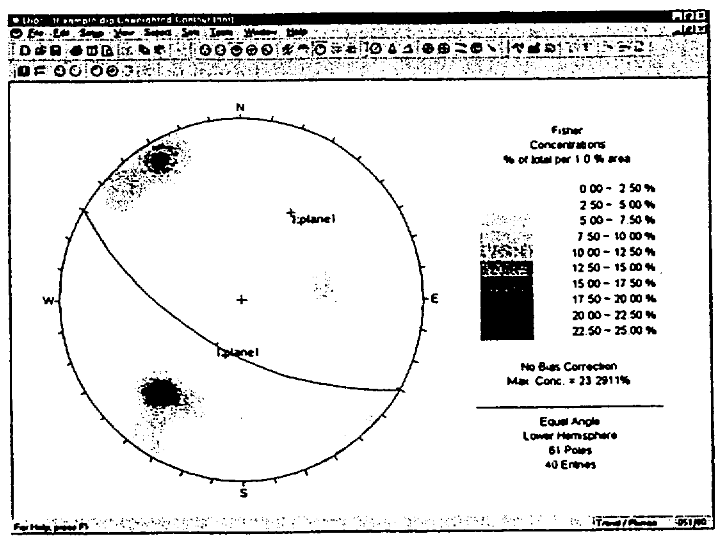


Figure 2-7: Added plane / pole displayed on Contour Plot.

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.

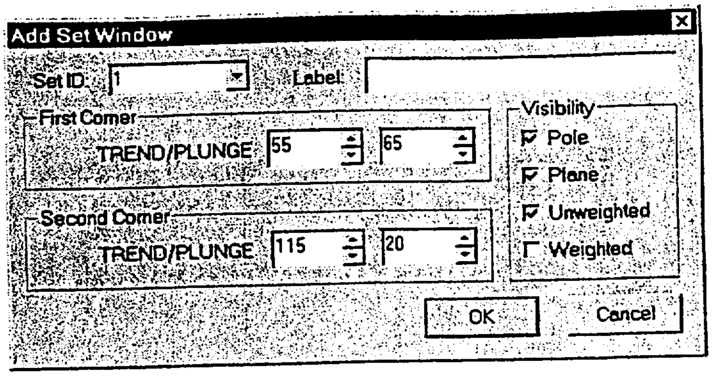


Figure 2-8: Add Set Window dialog.

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.

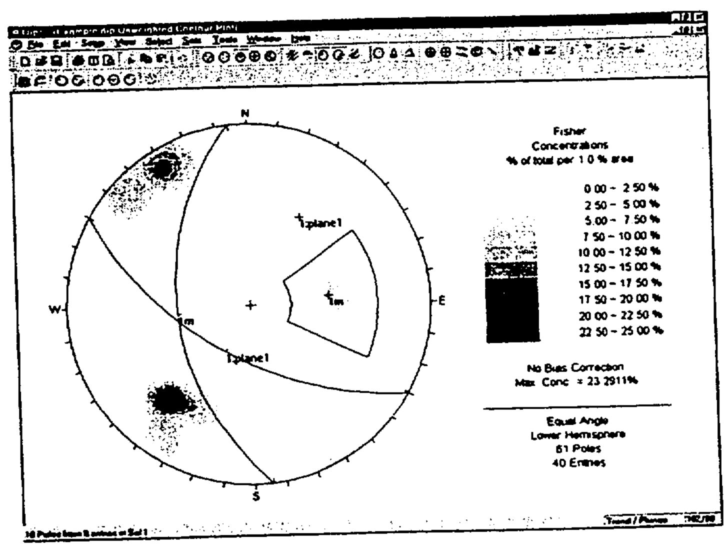


Figure 2-9: Set Window and Unweighted mean pole / plane displayed for Set 1.

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

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

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.

- 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.

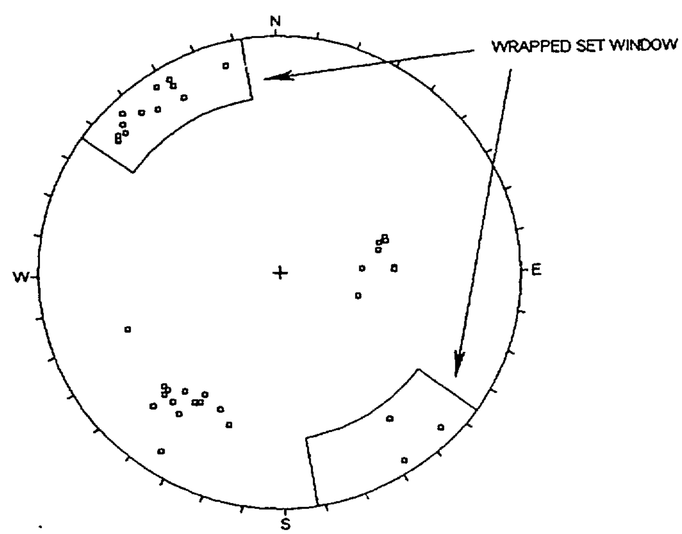


Figure 2-10: Wrapped Set Window.

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.

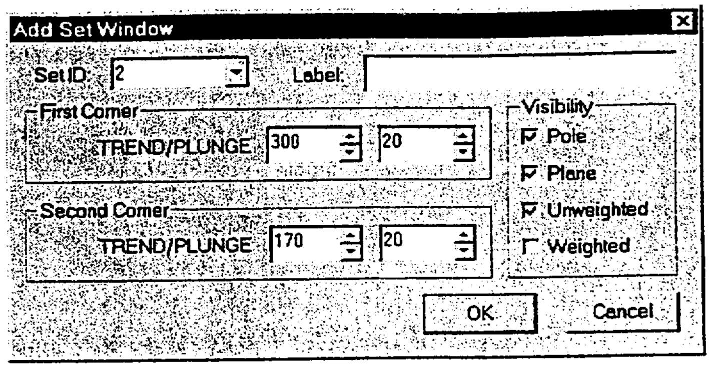
Select: Sets → Add Set Window

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.

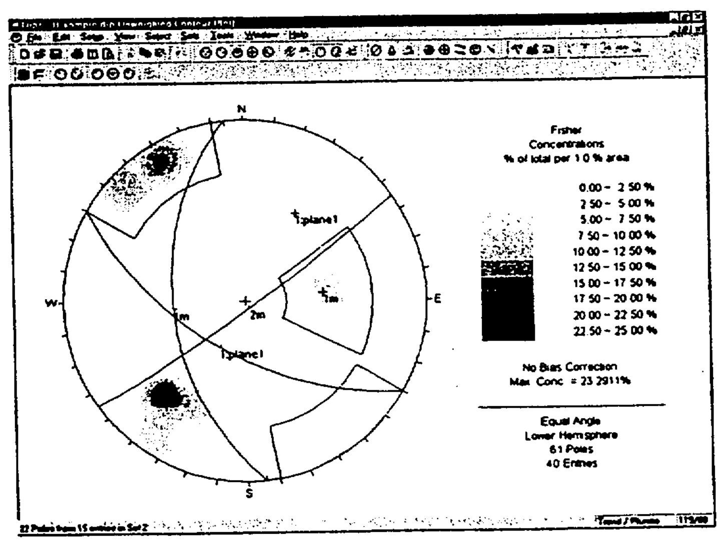


Figure 2-11: Set Windows and Unweighted mean poles / planes displayed for Sets 1 and 2.

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).

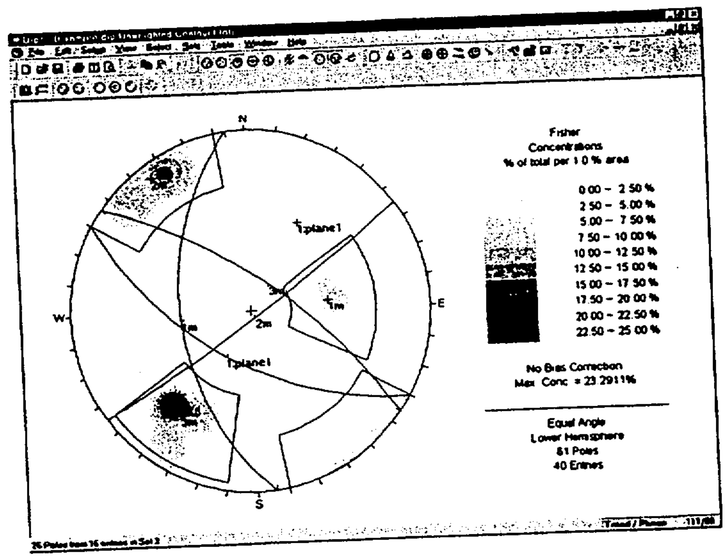


Figure 2-12: Set Windows and Unweighted mean poles / planes displayed for Sets 1 , 2 and 3.

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

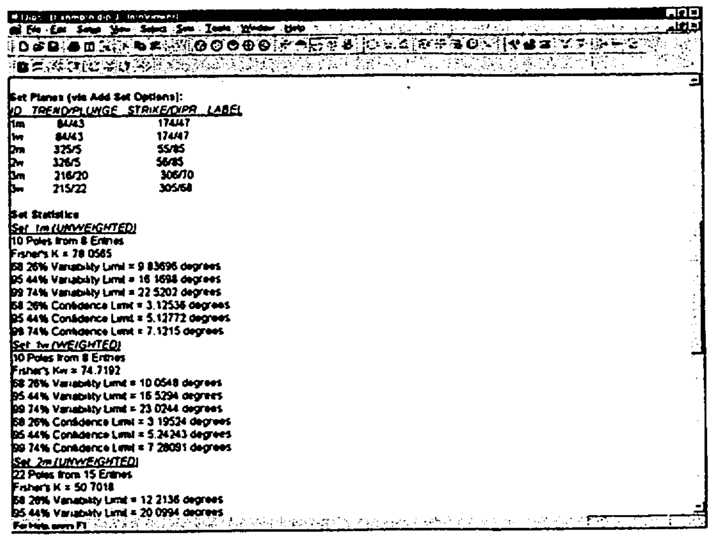


Figure 2-13: Info Viewer display of Set information.

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

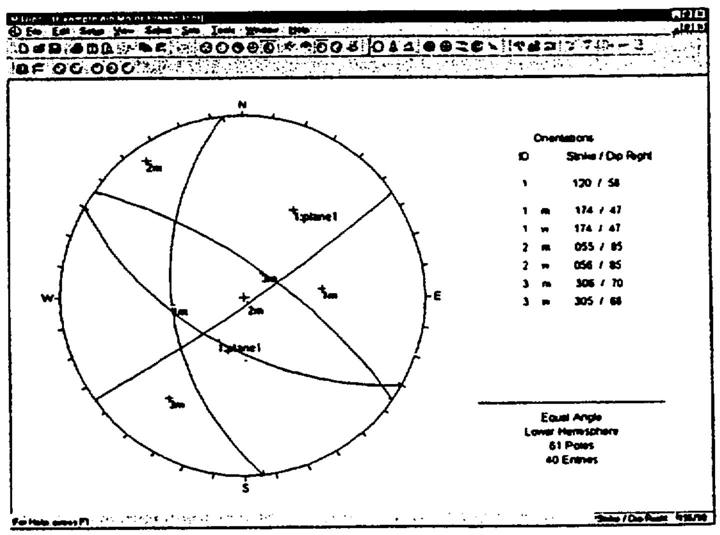


Figure 2-14: Major Planes Plot.

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

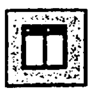
New stereonet plot views can be generated at any time, by selecting the New Plot View option in the Window menu. Let's generate two new plot views, so that we can view different plots at the same time.

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:

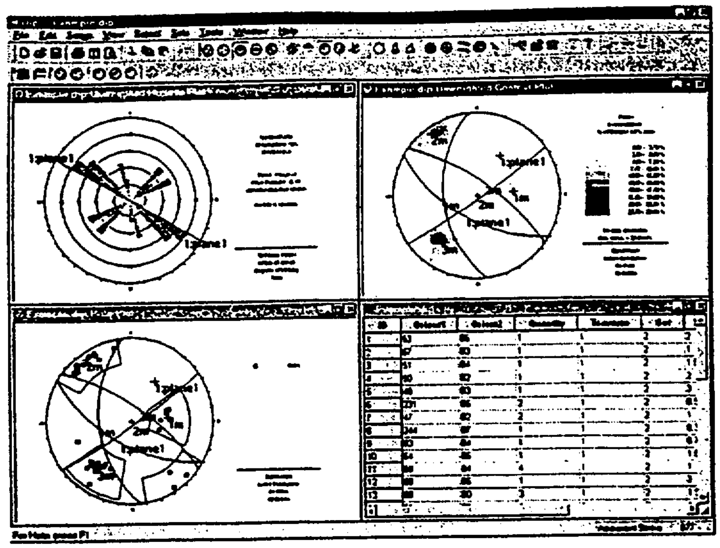


Figure 2-15: Tiled display of four views, EXAMPLE.DIP file.

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.

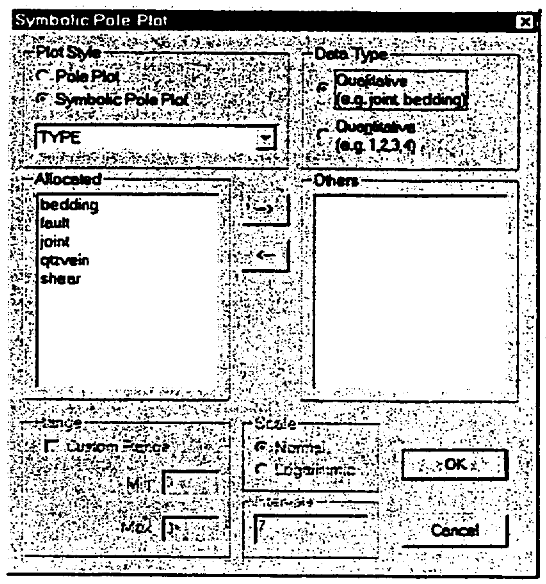


Figure 2-16: Symbolic Pole Plot dialog.

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.

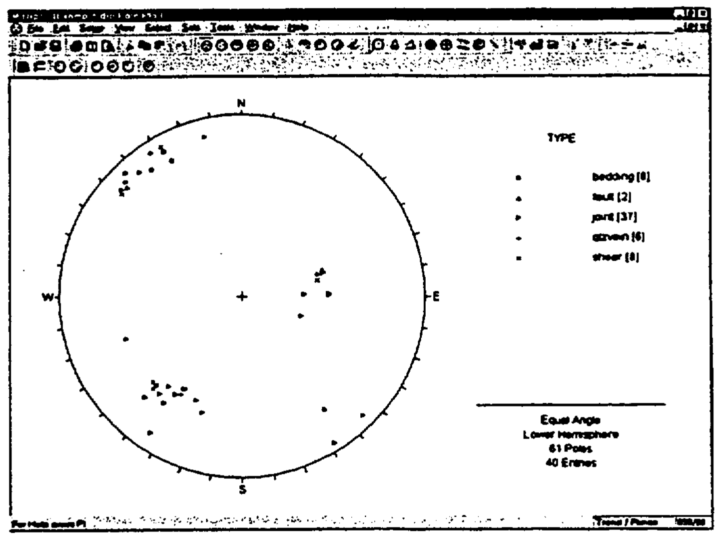


Figure 2-17: Symbolic Pole Plot of data in the TYPE column.

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.

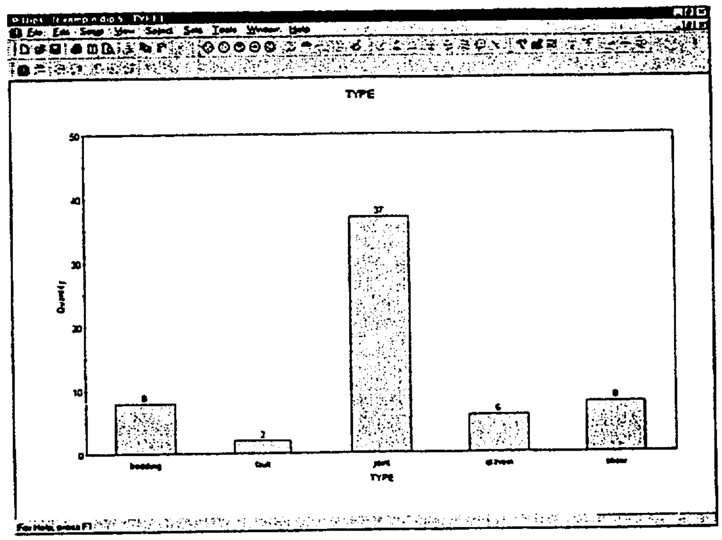


Figure 2-18: Histogram corresponding to Symbolic Pole Plot.

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.

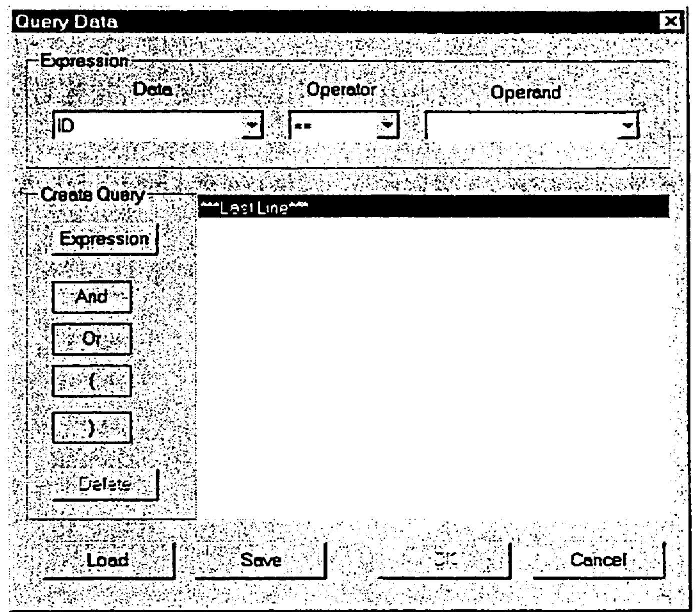


Figure 2-19: Query Data dialog.

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.

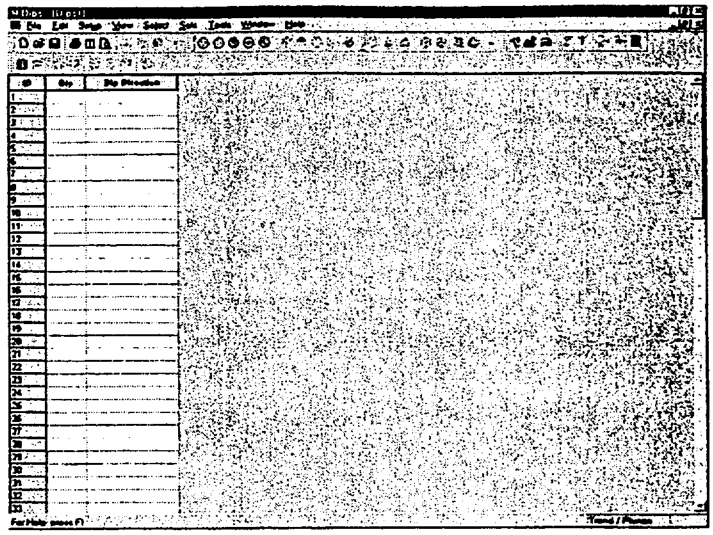
You should now be looking at a new Grid view, containing only the data in Set 1. Notice that all of the data in the SET Column of the new file = 1, as we would expect.

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.

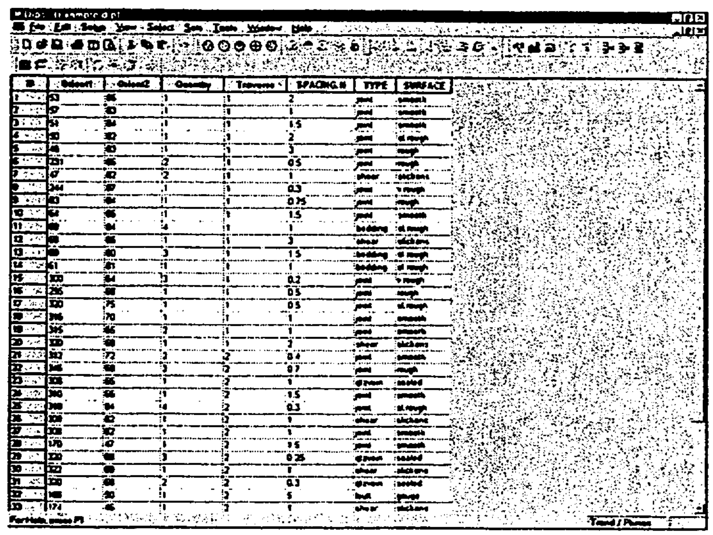


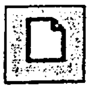
Figure 3-1: Grid View of EXAMPLE.DIP file.

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

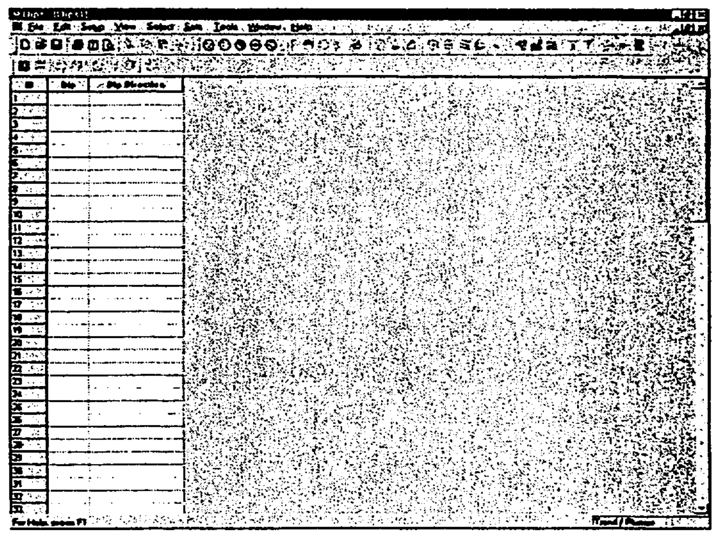


Figure 3-2: Grid View of New File.

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

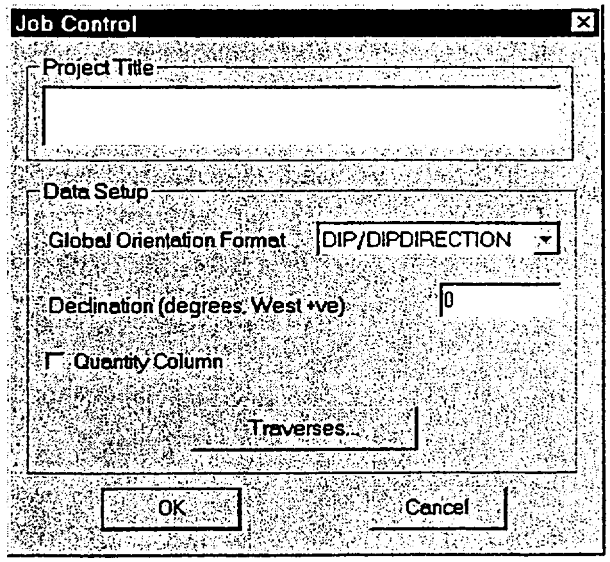


Figure 3-3: Job Control dialog.

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.

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

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

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 WEST declination, and a NEGATIVE value corrects for EAST 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...)

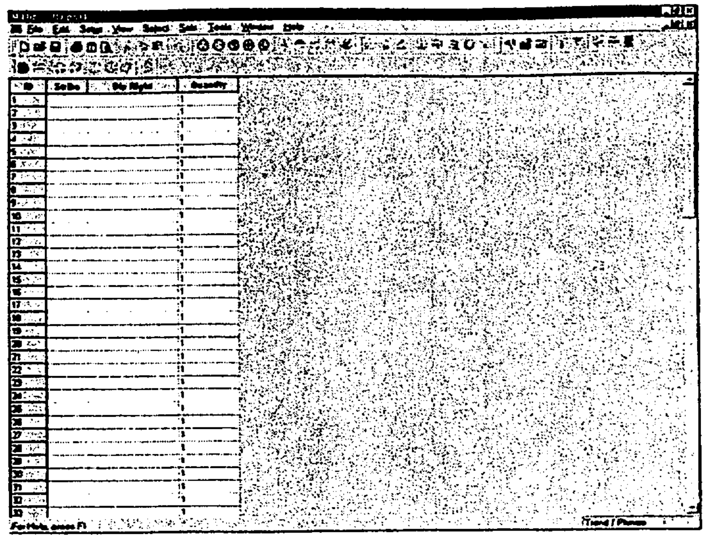


Figure 3-4: Quantity Column added to spreadsheet.

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.

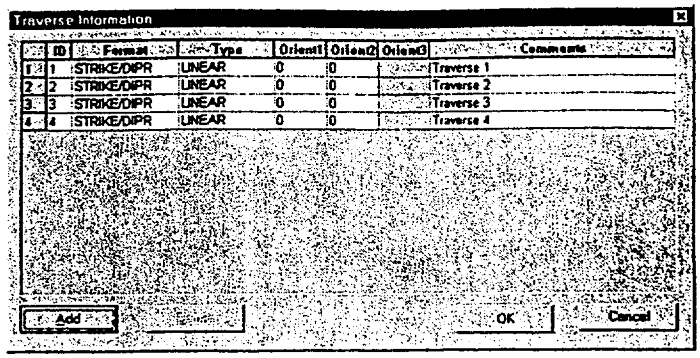


Figure 3-5: Traverse Information dialog.

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.

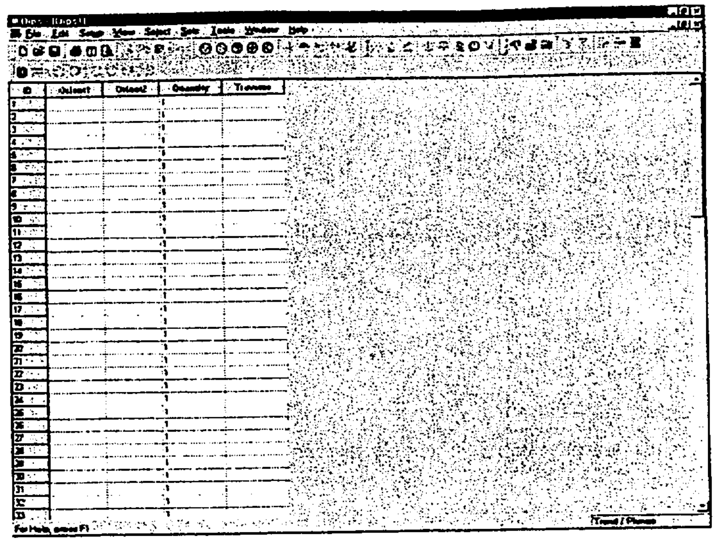


Figure 3-6: Traverse Column added to spreadsheet.

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:

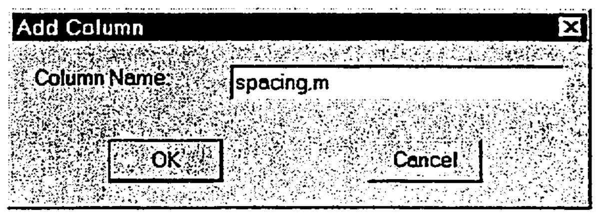


Figure 3-7: Add Column dialog.

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.

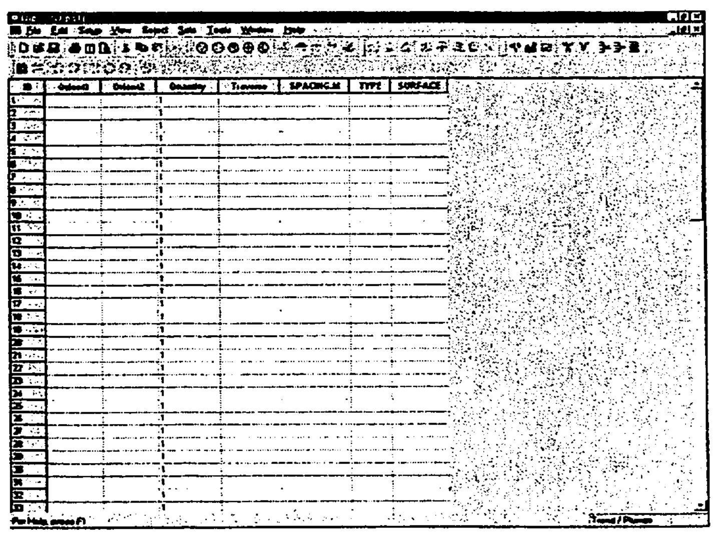


Figure 3-8: Three Extra Columns added to spreadsheet.

Entering Data

To conclude this tutorial, we will:

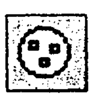
- Open the EXAMPLE.DIP file, and copy the data into our new file.
- Generate Pole Plots for both files, and hopefully they will be identical!

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

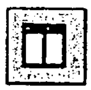
7. This will generate a Pole Plot of the data in the new file.

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

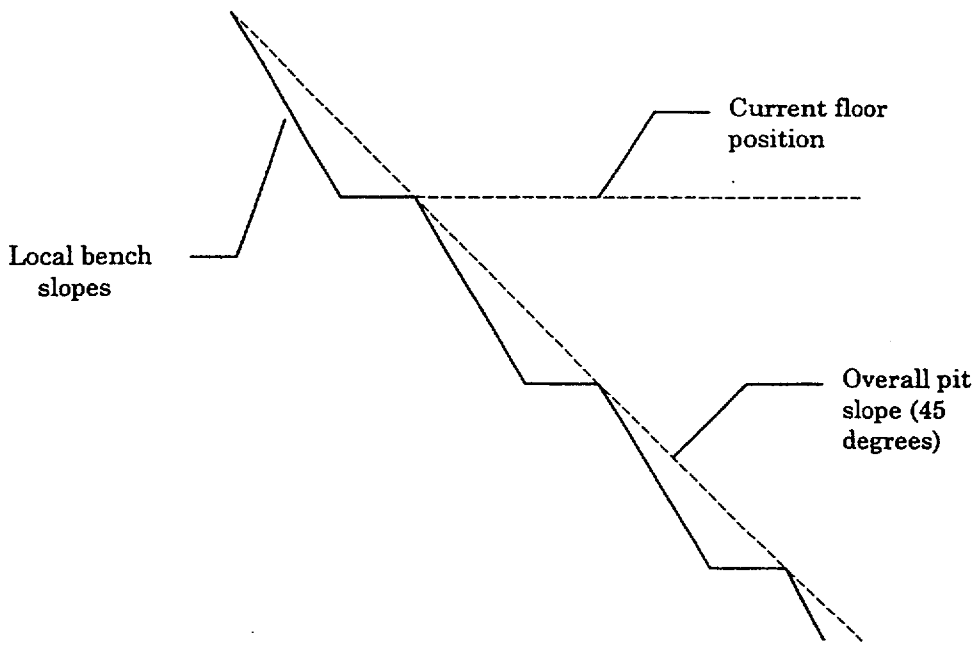
11. Compare the two Pole Plots. They should be identical. If not, then examine the Job Control and Traverse dialogs of the new file, and make sure they are the same as the EXAMPLE.DIP file. Also check that the data in the new file ends at the fortieth row, since the EXAMPLE.DIP file contained forty rows.

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.

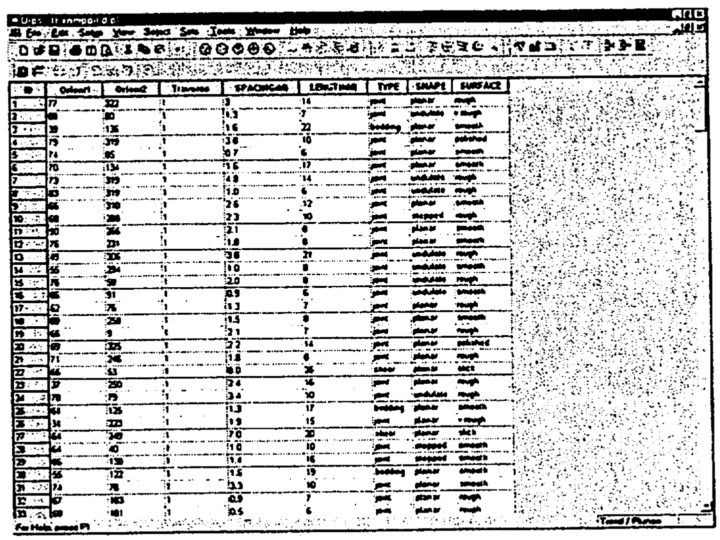


Figure 4-1: EXAMPPIT.DIP data.

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

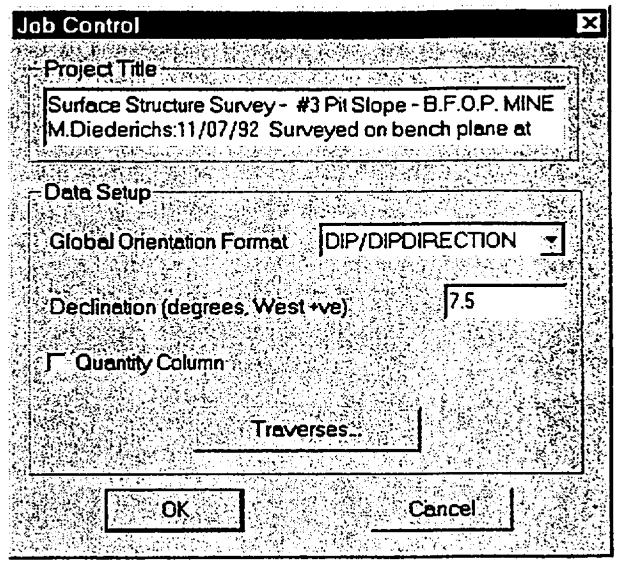


Figure 4-2: Job Control information for EXAMPPIT.DIP file.

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.

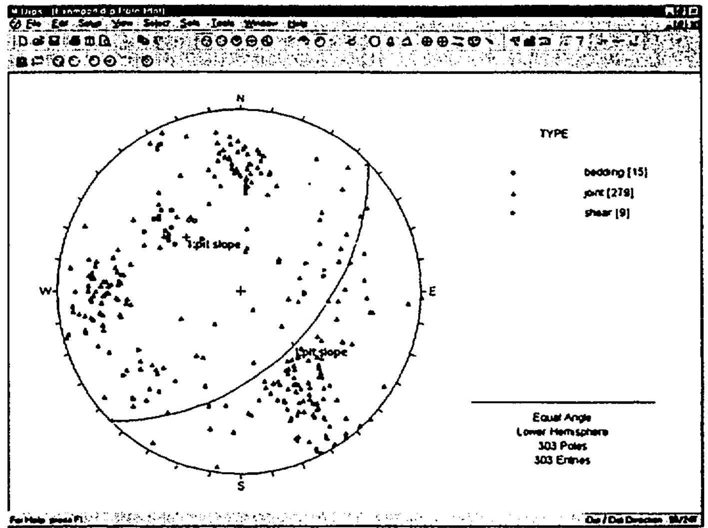


Figure 4-3: Symbolic Pole Plot of discontinuity TYPE. Great circle representing the pit slope has also been added.

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.

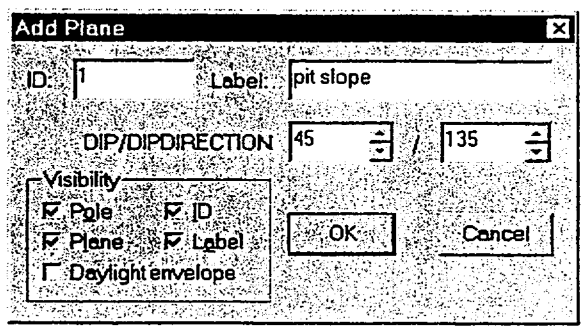


Figure 4-4: Add Plane dialog.

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

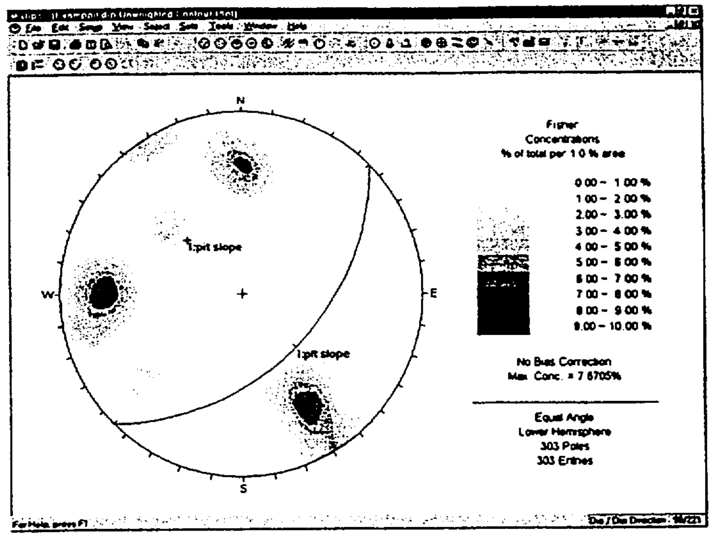


Figure 4-5: Unweighted Contour Plot of EXAMPPIT.DIP data.

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.*

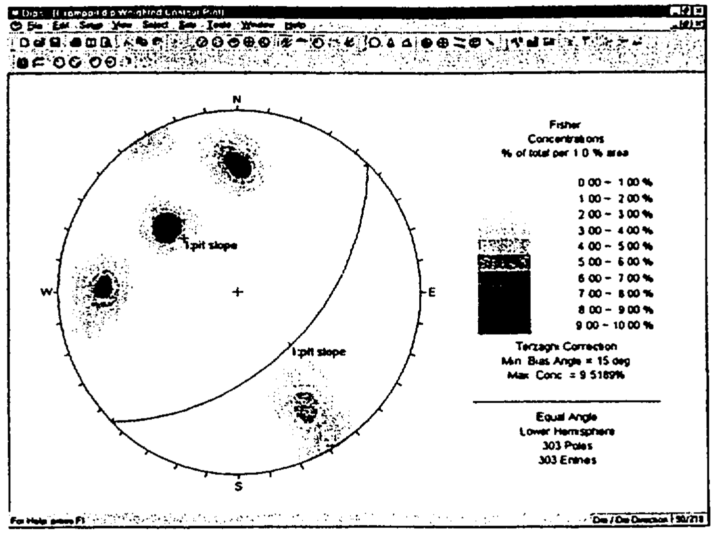


Figure 4-6: WEIGHTED Contour Plot of EXAMPPIT.DIP data.

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.

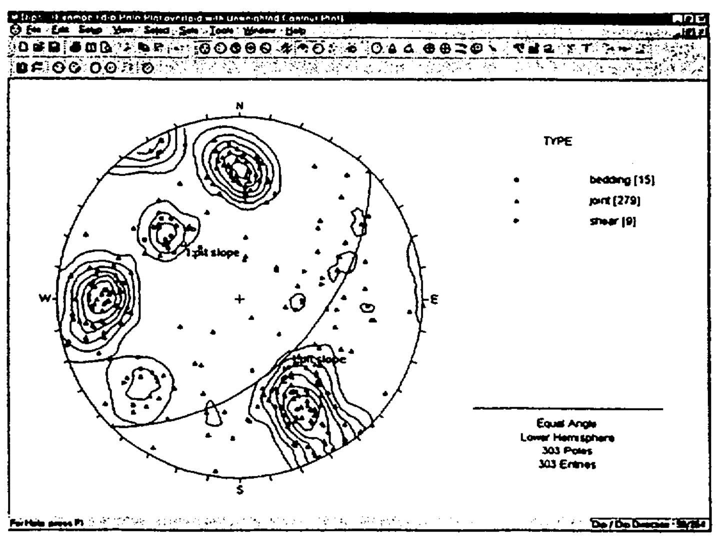


Figure 4-7: Overlaid Contours on Pole Plot.

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 persistance.

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.

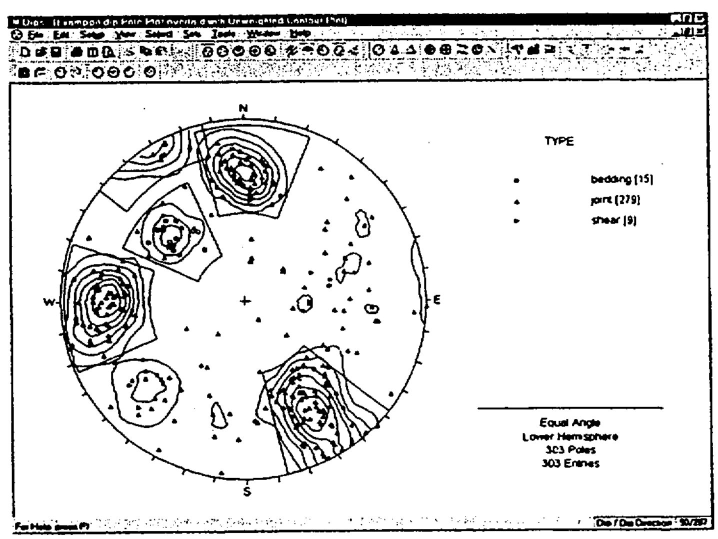


Figure 4-8: Set Windows formed around the four principal joint sets, using the Add Set Window option.

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.

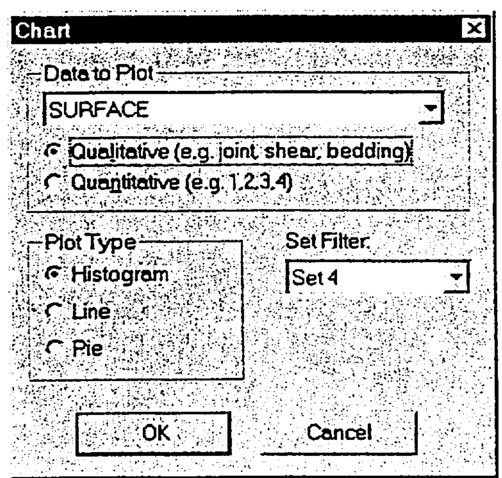


Figure 4-9: Chart dialog.

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.

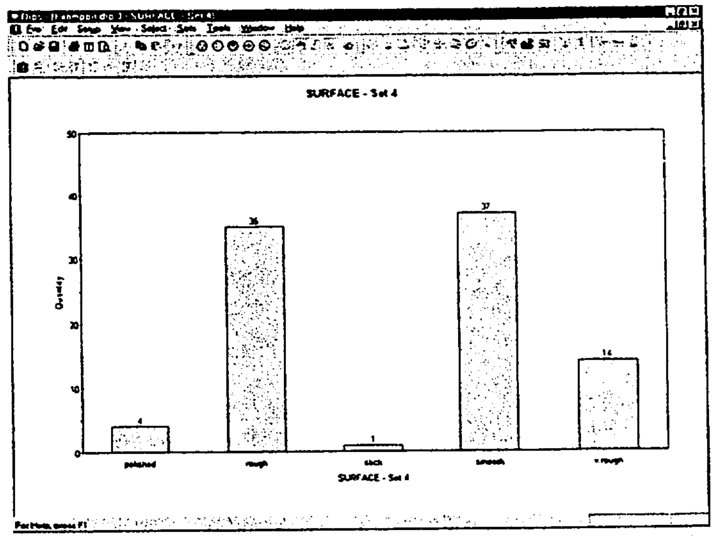


Figure 4-10: Histogram of SURFACE properties for joint set 4.

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

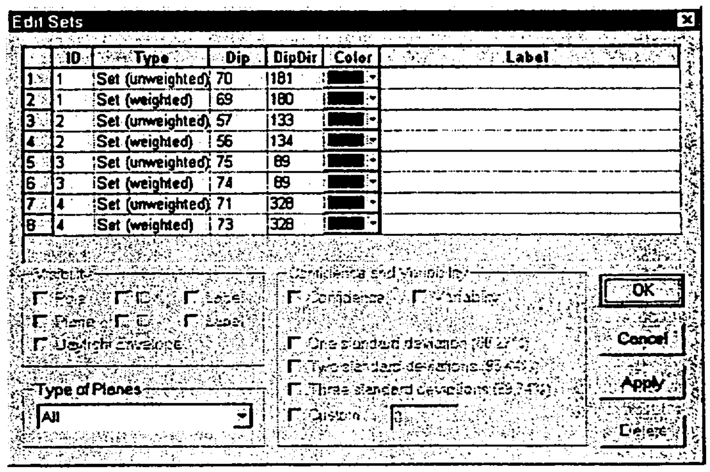


Figure 4-11: Edit Sets dialog.

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.

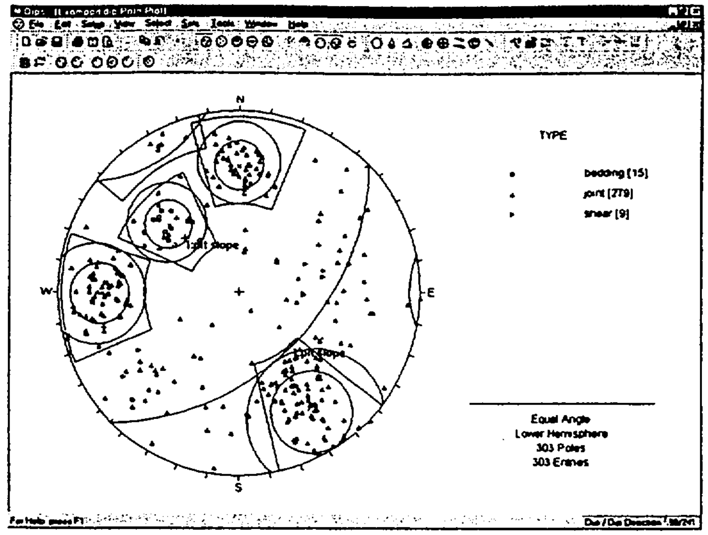


Figure 4-12: Variability cones displayed on Pole Plot.

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.

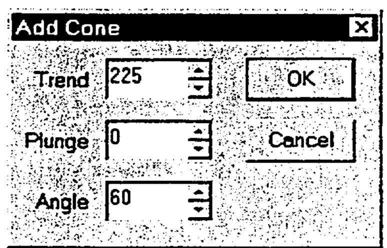
In the Add Plane dialog, if your graphically entered coordinates are not exactly 10 / 135, then enter these exact coordinates and select OK.

NOTE: the DIP angle for this plane is derived from the PIT SLOPE ANGLE – 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.*

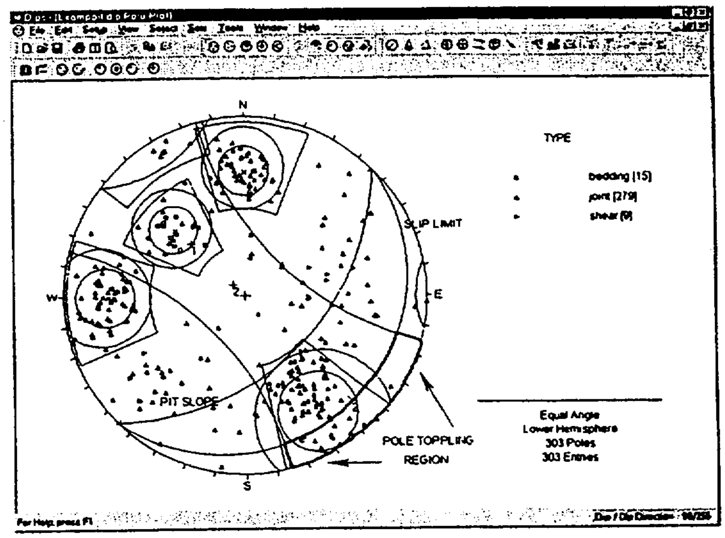


Figure 4-13: Toppling risk is indicated by the relative number of poles within joint set which fall within the outlined pole toppling region. Visual estimate indicates about 25 – 30% toppling risk for joint set 4, based on the 95% variability cone.

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.

Planar Sliding

*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.*

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

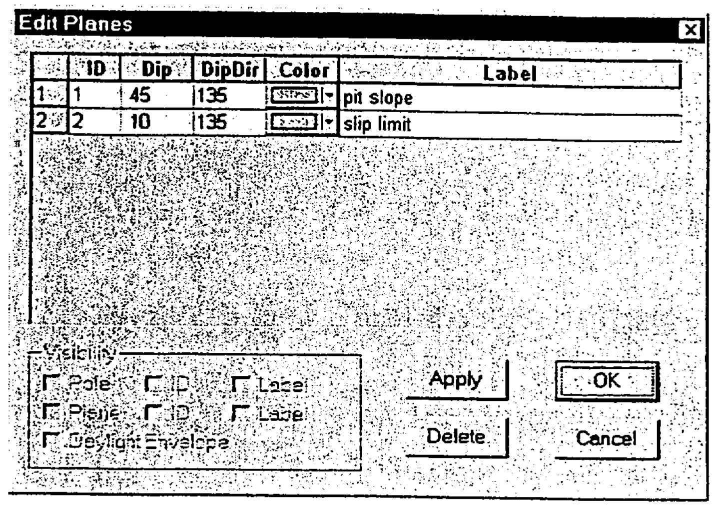


Figure 4-14: Edit Planes dialog.

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.

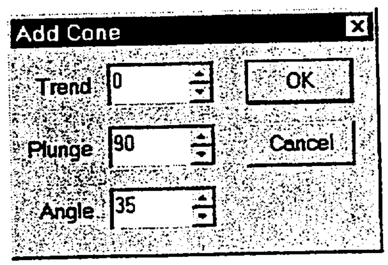
A Daylight Envelope for the Pit Slope plane should be visible on the stereonet.

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.

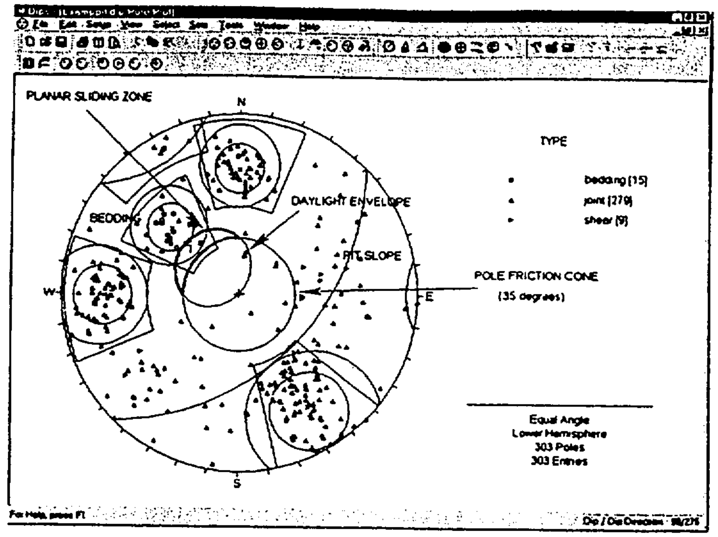


Figure 4-15: Planar sliding zone is represented by crescent shaped region. Only a small area overlaps the bedding joint set, therefore the risk of planar sliding is minimal.

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.

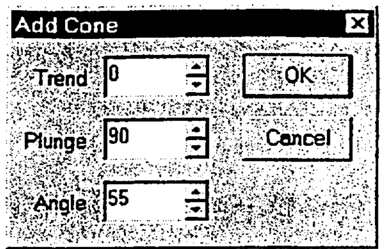
Select: Sets → Edit Sets

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.*

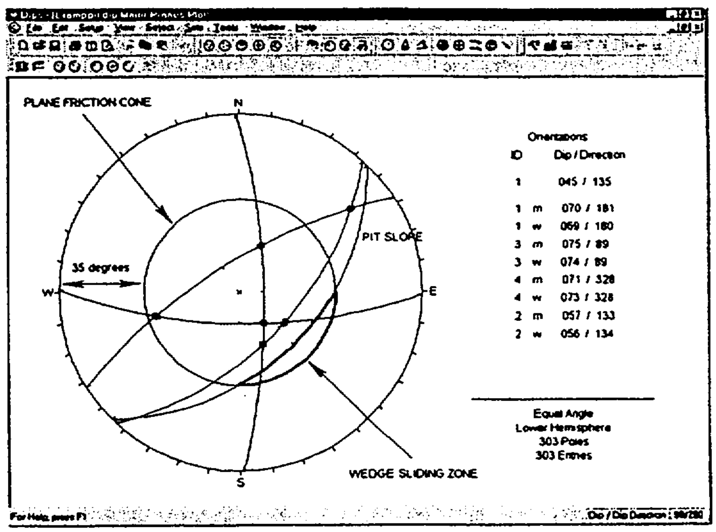


Figure 4-16: Major Planes Plot showing WEIGHTED MEAN planes, pit slope and friction cone. Wedge sliding zone is represented by crescent shaped region. Since no plane intersections (black dots) fall within this region, wedge sliding failure should not be a concern.

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?

Other Pit Orientations

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.

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

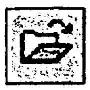
Goodman, R.E. 1980. Introduction to Rock Mechanics (Chapter 8), Toronto: John Wiley, pp 254-287.

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.

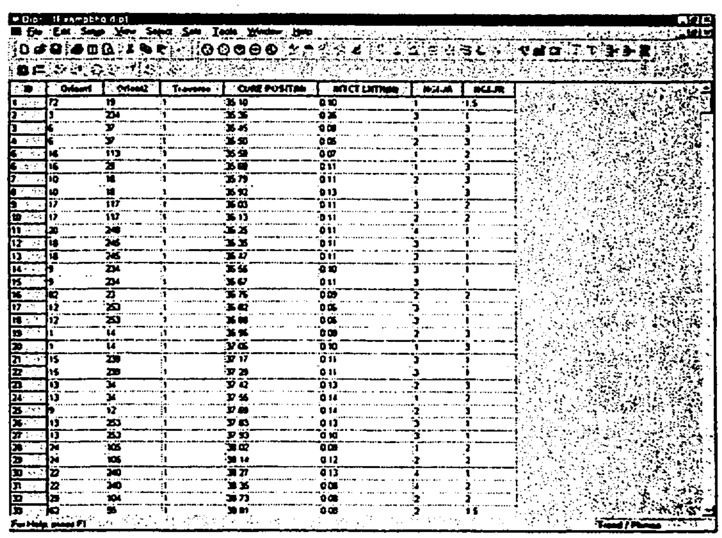


Figure 5-1: EXAMPBHQ.DIP data.

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

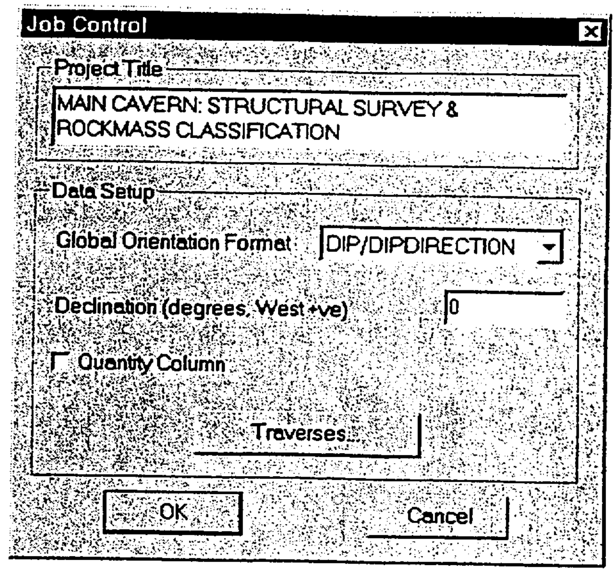


Figure 5-2: Job Control information for EXAMPBHQ.DIP file.

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

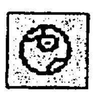
Use a spreadsheet and the INTACT LENGTH extra data column to determine a value for RQD.

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

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

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.

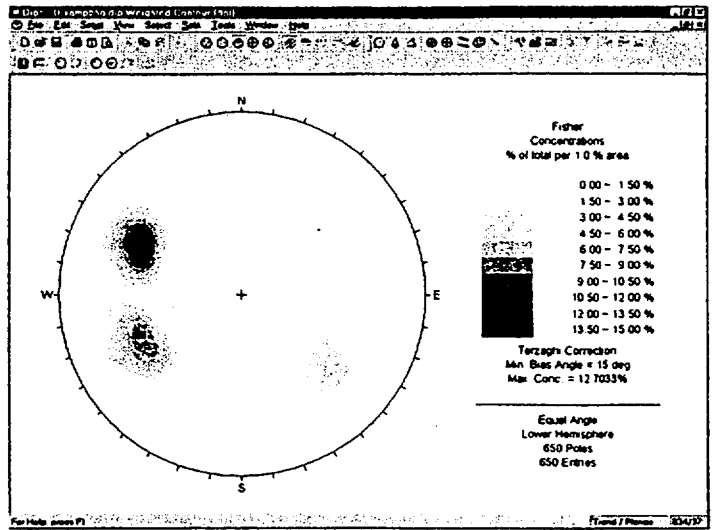


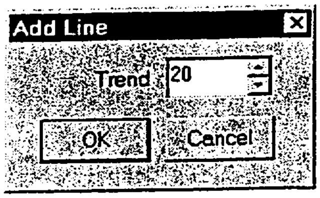
Figure 5-3: Weighted Contour Plot of combined borehole data, converted to global orientations. The 3 well defined joint sets result in Barton's JN = 9.

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.

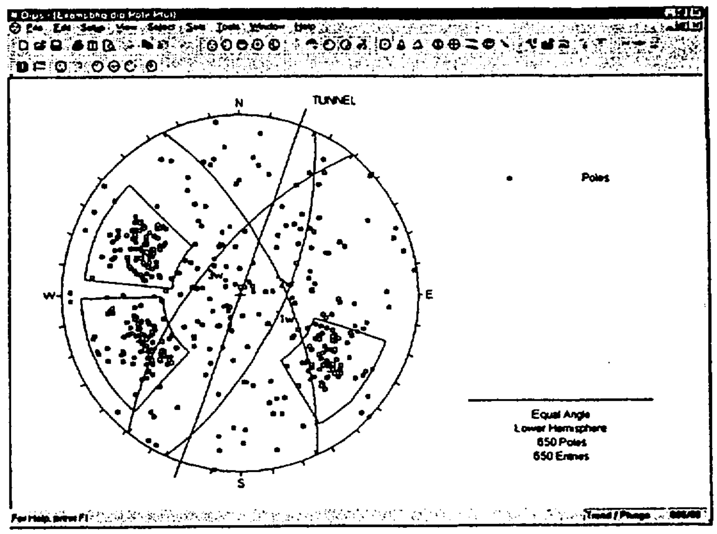


Figure 5-4: Mean planes with superimposed tunnel axis.

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.

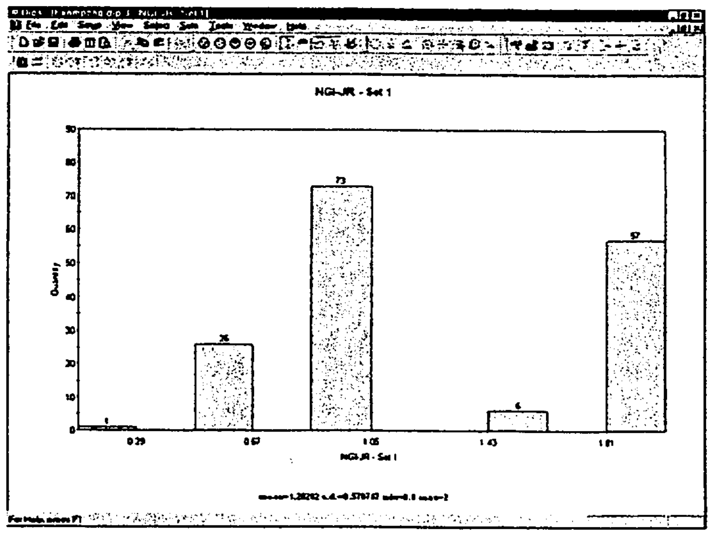


Figure 5-5: Joint Roughness, JR, for joint set 1. Mean = 1.28.

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.

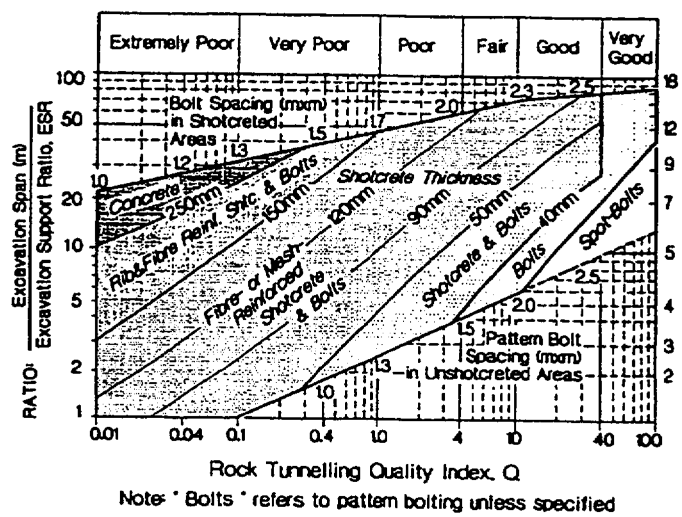


Figure 5-6: Tunneling support guidelines, based on the tunneling quality index Q (bolt lengths modified for cablebolting). Ref. 1, after original Ref. 3.