FIELD PROCEDURES MANUAL

Geotechnical Data Collection for Exploration Geologists

PREPARED BY

Knight Piésold Ltd.
1400 - 750 West Pender Street
Vancouver, BC
V6C 2T8
Telephone: (604) 685-0543
Facsimile: (604) 685-0147

34 Commerce Crescent
P.O. Box 10
North Bay, ON
P1B 8G8
Telephone: (705) 476-2165
Facsimile: (705) 474-8095

Knight Piésold
CONSULTING
www.knightpiesold.com

FIELD PROCEDURES MANUAL

Geotechnical Data Collection for Exploration Geologists

Rev. No.	Revision	Date	Approved
0	Issued in Final	November 24, 2004	KJB

PREPARED BY

Knight Piésold Ltd.
1400 - 750 West Pender Street
Vancouver, BC
V6C 2T8
Telephone: (604) 685-0543
Facsimile: (604) 685-0147

34 Commerce Crescent
P.O. Box 10
North Bay, ON
P1B 8G8
Telephone: (705) 476-2165
Facsimile: (705) 474-8095

VA108-14/3-1
Revision 0
November 24, 2004

Knight Piésold
CONSULTING
www.knightpiesold.com

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

SECTION 1.0

Introduction

Knight Piésold
CONSULTING
ww.knightpiesold.com

1.1 INTEGRATED EXPLORATION AND GEOTECHNICAL DATA COLLECTION PROGRAM

The importance of obtaining correct and confident geotechnical data for new or existing mining projects cannot be over-emphasized. This information is necessary in order to characterize the geotechnical properties of the ore body and define parameters used in kinematic stability analyses which are required as part of the open pit or underground mine design. This manual presents field procedures and descriptions for the collection of geotechnical data used by Knight Piésold Ltd.

Geotechnical data collection can be easily integrated into exploration programs to provide complete geological-geotechnical data. Geotechnical data for open pit or underground mine design can be easily and readily collected from both exploration drill core and through surface mapping of natural rock outcrops and man-made excavations. Where possible, geotechnical data should be incorporated into a 3D ore reserve block model in order to facilitate the definition of a rock mass model and characterize the variability and distribution of the geotechnical properties. The additional time required to collect geotechnical data during an exploration program is insignificant when compared to the overall exploration program.

1.2 PLANNING OF THE DRILLING PROGRAM

Exploration drilling programs are commonly carried out in several phases with the initial phase based on a desk study using current information. Subsequent phases are typically planned around the interpretation and assessment of data collected from the initial phase. Geotechnical drilling should be carefully planned and integrated with the exploration drill hole program in order to optimise the collection of data.

Exploration drill holes are commonly targeted to intersect the main zones of mineralization. For open pit and underground mine design it is necessary to define the orientation of the rock mass structure including all rock mass discontinuities (joints, shears, faults, dykes) and the occurrence of this structure both laterally and vertically within the ore deposit. In order to achieve this it is sometimes necessary to target specific mineralised and non-mineralised areas in a variety of orientations and to depths that will penetrate beyond the boundary of the ore deposit.

SECTION 2.0

Geotechnical Data Collection from Drill Core

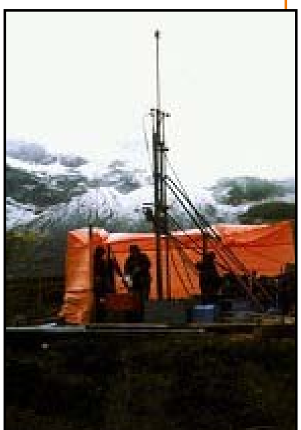
Knight Piésold
CONSULTING
ww.knightpiesold.com

Geotechnical Data Collection from Drill Core

2.1 DRILL CORE LOGGING

Geotechnical drill core logging should be carried out for all drill core and data entered directly into a spreadsheet such as shown in Table 2.1. A description of the geotechnical data to be collected in the logging sheet is presented below:

- Drill run data;
- Geology description;
- Rock Mass Rating (RMR) data;
- Discontinuity Data;
- Point Load Testing Data.



This information is typically collected by the onsite geotechnical engineer. However, in the absence of a geotechnical engineer, geologists can be trained to collect this data.

2.1.1 Drill Run Data

Run Length

The run length is the length of drilling per run prior to retrieval of the core barrel and is typically the length of the core barrel being used. In difficult drilling conditions, it is common that some core may remain in the hole and/or shorter run lengths are drilled so as to not damage the drill core and/or equipment.

Core Recovery

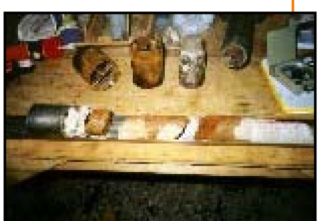
Core recovery is the measured recovery of drill core per run. Recovery is expressed as a ratio (or percentage) of the total length of core recovered to the length of the run drilled. Because the core is sometimes broken up, the total length of core recovered is often measured by reassembling the broken pieces.

Rock Quality Designation, RQD

Rock quality designation (RQD) is the fraction of core recovered that is longer than 10 cm (4 inches). It is calculated as the ratio (or percentage) of the sum of the length of core pieces longer than 10 cm (4 inches) to the length of the run drilled. As shown on Figure 2.1, the length is measured along the centre-line of the core, and drilling induced breaks should not be included. In order to correctly determine the RQD where significant veining is present throughout the core it is important to lightly tap veined core pieces with a hammer. Those pieces that remain intact after the hammer tap should be included in the RQD determination.

2.1.2 Geology Comments

A description is required of each main rock unit and should include rock type (e.g. quartz monzonite), colour, texture (fine grained, etc.) and type of alteration (e.g. potassic, argillic). Also of equal importance is the identification and recording of faults, dykes and shear zones.



2.1.3 Rock Mass Rating (RMR) Data

Estimated Rock Strength

The unconfined compressive strength (UCS) of intact rock, measured in MPa or psi, is estimated in the field. Table 2.2 illustrates a classification system for field hardness testing of rocks and soils. This classification system is an indirect method that approximates the strength of intact rock based on hammer blows of the rock sample in question. These tests can then be calibrated by on-site point load tests (PLT) at random intervals.

Number of Discontinuities per Run

The number of discontinuities (joints, shears, veins, etc.) per run should be recorded. It is important that this number represents only actual (broken, open) joints and should not include drill breaks, healed joints or veining. The latter two will be recorded separately in the geological log sheet.

Joint Condition

A joint condition rating should be recorded as an average rating value per drill run. In cases where mixed joint conditions occur within a single drill run the lowest applicable joint condition rating should be selected and recorded. The joint condition rating is based on the rock mass rating (RMR) classification by Bieniawski (1989), and is defined with joint condition descriptions for persistence (joint length), aperture, roughness, infilling and weathering. A detailed description of joint condition rating is presented in Table 2.3.

Groundwater Rating

A description of the groundwater rating based on Bieniawski's RMR classification (1989) is also presented in Table 2.3.

2.1.4 Discontinuity Data

Discontinuity logging should be carried out for discontinuities in oriented drill core. For non-oriented drill core, individual discontinuity orientation data may not be required although it is often useful to count the number of discontinuities and describe the condition as well as the alpha angle. Detailed discontinuity logging procedure for oriented drill core is described in Appendix A.

2.1.5 Point Load Test Data

Point load tests (PLT) are done on either random intervals for calibration of rock hardness as described in Section 2.1.3, or at regular intervals. The PLT results can be calibrated by laboratory unconfined compressive strength (UCS) test. PLT procedures are described in further detail in Appendix B.

2.2 SAMPLE PREPARATION

Samples for field and laboratory testing should be selected as representative samples from the drill core. When removing samples, spacer blocks should be placed in the core boxes and the type of sample (UCS, shear, SG, etc.), sample number and length of sample should be recorded. The sample number, length of sample, and the date should also be clearly marked, both on the drill core sample bag and spacer block. Photographs should be taken of each sample. If required, samples should be broken carefully to preserve the integrity of the remaining drill core and samples should be placed in appropriate sample bags or containers.

2.3 FIELD TESTING

Field testing of drill core may comprise point load (PLT) testing as a quick means of estimating the intact rock strength, as well as direct shear testing of discontinuities. Detailed description of these two testing methods is presented in Appendix B.

2.4 DRILL CORE PHOTOGRAPHS

All drill core should be photographed for records. Photographs should be taken in good light, from directly above the core boxes. The photographs should include the entire length of the core boxes with no shadows covering the cores. Photographs should be taken such that all information on the box and identification board appears in the photograph including project name and location, date, drill hole number, core box number, dates drilled and end of hole depth. Depth markers should appear clearly in the photographs.

2.5 STORAGE OF DRILL CORE

All drill core should be stored in strong wooden boxes with suitable wooden covers that allow for easy access, protection and will prevent the loss of core pieces. The core boxes should be clearly and correctly labelled on the outside of the box as well as along one end (for ease of identifying boxes when in racks). The labels should include the project name, drill hole number, date, box number and depths of drill core inside the box. Drill core boxes should be stored under a cover (core shed, under plastic or weatherproof tarps) and preferably on racks.

SECTION 3.0

Geotechnical Data Collection from Rock Outcrops

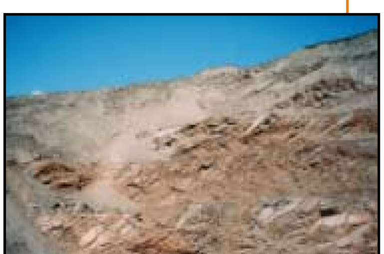
3.1 ROCK OUTCROP MAPPING

Rock outcrop mapping can be carried out along all natural outcrops or man-made excavations such as exploration adits, road-cuts, and bench faces, etc. A typical mapping sheet is shown in Table 3.1. Geotechnical information including rock material and structural data should be collected from outcrop mapping. Outcrop mapping is the only reliable means to estimate large scale roughness and persistence.

3.1.1 Rock Material Data

Rock Type and Alteration

A lithological description is required of each main rock unit and should include rock type (e.g. quartz monzonite), colour, texture (fine-grained, etc.) and type of alteration (e.g. potassic, argillic).



Rock Material Weathering

Rock material weathering is the degree of weathering of the solid rock pieces between joints and varies from fresh to extremely weathered. An average weathering description should be selected to represent the average weathering conditions of the rock mass. A detailed description of the weathering grades is presented in Table 3.2.

Estimated Rock Strength

Estimates of rock strength can be made based the descriptions presented in Table 2.2 and the use of either a pocket knife and/or geological hammer. Average rock strengths should be selected per rock type.

3.1.2 Structural Data

Discontinuity Type

The type of discontinuity should be recorded. Open and healed joints, open and healed veining, bedding, shear, fault, foliation, schistocity, cleavage, etc., with appropriate corresponding abbreviations such as OJ, HJ, OV, HV, etc. It is strongly recommended that a standard set of abbreviation be adopted at the outset.

Discontinuity Orientation

The true orientations of discontinuities can be measured directly from natural outcrops or man-made excavations using a compass. Measurements are commonly recorded in the form of dip and dip direction (direction perpendicular to strike). It should be noted that the correct magnetic declination should be set on the compass for the project site.

Joint Surface Conditions

The description of joint condition is generally based on the RMR classification (Bieniawski, 1989) for persistence, aperture, roughness, infilling and weathering. Detailed field record symbols are presented in Table 3.1. The persistence (or length) of discontinuity can typically be measured directly. A description of the joint roughness should be included as they are better defined on surface outcrops. The large-scale shape and roughness profiles are presented in Figure 3.1 (After ISRM, 1981).

Discontinuity Spacing

The true spacing of discontinuities can typically be measured directly from natural outcrops or man-made excavations as the perpendicular distance between adjacent discontinuities of the same set (same orientation) using the spacing classification of ISRM (1981) as shown on Table 3.1.

Others

The water condition and RQD of outcrop rock can be estimated based on field observations. These data will be incorporated into RMR classification system (Bieniawski, 1989).

3.2 PHOTOGRAPHS OF ROCK OUTCROPS

Photographs should be taken of all natural outcrops and/or man-made excavations such as exploration adits or road cuttings in/upon which geotechnical data has been measured and recorded. Both far field and up-close photographs should be taken to illustrate variations in rock types, all joint sets, typical or important joint surfaces as well as joint spacing and persistence. A measuring tape or similar measuring instrument should be used as a scale in each photograph.

SECTION 4.0

Geotechnical Data Presentation

Knight Piésold
CONSULTING
ww.knightpiesold.com

4.1 GENERAL

The geotechnical characterization of an ore reserve requires a significant amount of data reduction, processing and interpretation for the derivation of the open pit slope and/or underground mine design parameters.

For mining projects it is common to characterize rock mass properties from drill core and surface mapping using the rock mass rating classification system. A kinematic analysis is typically done using stereographic plots.

In addition, every effort should be made to input all geotechnical data into an integrated database within the ore reserve database. This can facilitate the geotechnical characterization of the ore reserve and allow correlations to be made between geotechnical data and rock and alteration types throughout the ore reserve to assist in open pit slope and/or underground mine designs.

4.2 RMR ROCK MASS CLASSIFICATION

The rock mass characteristics observed during core logging are summarized for each drill run and used to estimate the quality of the rock mass using the rock mass rating (RMR) classification system (Bieniawski, 1989). Each drill run is evaluated on five rock mass parameters as follows:

- Intact rock strength (unconfined compressive strength, UCS);
- Rock quality designation (RQD);
- Joint spacing;
- Joint condition;
- Groundwater conditions.

Each parameter is assigned a rating value. The values are added together to form the RMR for the drill run. RMR values range from near 0 for very poor rock, to 100 for very good rock. Table 4.1 illustrates the RMR (1989) classification system and corresponding ratings.

Intact rock strength (UCS) may be determined from field estimation, and laboratory/ field testing. The intact rock strength component of the RMR Classification System is assigned a value from 1 to 15.

The RQD values are determined for each core run by adding up the lengths of all intact core longer than 10 cm (4 inches) and presenting this as a percentage of the actual length of the drill run. The RQD component of the RMR Classification System is assigned a value from 3 to 20.

Joint spacing describes the average distance between discontinuities. They are determined by counting the total number of natural discontinuities encountered in a drill run and dividing it by the length of drill run. The joint spacing component of the RMR rating is from 5 to 20.

The joint condition is based on an evaluation of the average persistence, aperture, roughness, infilling and weathering of discontinuities. Each attribute is rated on a scale of 0 to 6 and combines for an overall component rating from 0 to 30 for the RMR classification system.

The RMR rating of groundwater conditions ranges from dry (rating = 15) to flowing (rating = 0).

4.3 STEREOGRAPHIC PRESENTATION OF DISCONTINUITY DATA

Discontinuity data is presented for interpretation using stereographic projection (stereonets). DIPS® is a commercially available stereonet program developed by Rocscience Inc., which allows for contour plotting, statistical analysis and presentation of discontinuity data. The program is capable of generating histograms of joint data such as roughness, infilling type and depth. Figure 4.1 presents a contoured stereonet plot of discontinuity orientations from the DIPS® program. The peak planes are selected based on the peak concentrations of poles.

Discontinuity orientation and characteristics data can be copied into DIPS fairly easily if data is recorded on a spreadsheet program such as Microsoft Excel. Care at the outset to establish a standardized set of notations will greatly increase the effectiveness of the database.

4.4 3D MODEL PRESENTATION OF GEOTECHNICAL DATA

Geological information from exploration programs is commonly input into three dimensional (3D) ore reserve block models to provide insight into potential areas of stability concern and to develop a predictive tool for the rock mass.

By incorporating the individual geotechnical parameters of the RMR rock mass classification system as well as the calculated RMR values per drill run from each drill hole the 3D ore reserve/geologic database model can be used to characterize the variability of the entire ore reserve using the internal extrapolation techniques built into the program.

Furthermore, average RMR values can be assigned for each of the defined rock and alteration types to enable comprehensive characterization of the geotechnical conditions within the ore reserve to facilitate open pit slope and/or underground mine design.

SECTION 5.0

References

Knight Piésold
CONSULTING
ww.knightpiesold.com

References

Bieniawski, Z.T., Engineering Rock Mass Classifications. 1989.

Call, R.D., Savely, J.P., and Pakalnis, R. 1982. A Simple Core Orientation Technique, 3rd Stability Surface Mining Conference, Vancouver, B.C.

International Society of Rock Mechanics, Rock Characterization and Testing - Suggested Methods 1981. Ed. E.T. Brown.

Priest, S.D. and Hudson, J.A. 1976. Discontinuity Spacings in rock. Int. J. Rock. Mech. & Min. Sci. & Geomech. Abstr. Vol. 13. pp. 135-148.

TABLES

Knight Piésold
CONSULTING

TABLE 2.1

GEOTECHNICAL DRILLHOLE LOGGING DATA SHEET
(ROCK MASS CLASSIFICATION - RMR, 1989)

PROJECT: ______________________
Client: ______________________
Drilling Company: ______________________
Location: ______________________
Coordinates : ______________________

Surface Elevation: ______ m
______ ft
Total Depth: ______ m
______ ft
Azimuth: ______ deg
Dip: ______ deg **(down is positive)**

Drill Type: ______
Core Diameter: From ______ to ______ m ______ ______ mm
______ to ______ m ______ ______ mm

Drillhole Number: ______________

Logged By: ______________
Reviewed By: ______________
Date Started: ______________
Date Completed: ______________

Print Nov/30/04 12:25:35

M:\1\08\00014\03\A\Report\1-Geotech Manual\Tables\[Table 2.1_r0 Geotech Logging Sheet.xls]Data - Calc Sheet

Rev'd Nov 24, 2004

DRILL RUN DATA											GEOLOGY - COMMENTS		RMR DATA (BY RUN)										RMR CALCULATIONS (BY RUN)						DISCONTINUITY DATA												PLT STRENGTH DATA / CALCs.							
																Joint Condition Rating																																
Depth From (ft)	Elev. From (ft)	Depth From (m)	Elev. From (m)	Depth To (ft)	Depth To (m)	Run Length (m)	Recov. Length (m)	Recov. (%)	RQD Length (m)	RQD (%)	Rock Type	Weathered State, Structure, Color, Grain Size, Rock Material Strength, Rock Type,	UCS (Est.) (MPa)	# of Joints	Joint Set Spac. (mm)	Persis- P	Apert- A	Rough R	Infill I	Weath W	TOTAL	Ground Water Rating	RMR-89 UCS Rating	RMR-89 RQD Rating	RMR-89 Joint Spac. Rating	RMR-89 Joint Condition Rating	RMR-89 Water Rating	**RMR-89 Total**	Depth (m)	Elev. (m)	Alpha (deg.)	Beta (deg.)	Disc. Type	Aper. (mm)	Fill. Type	Joint Condition Jc	QTY	Orientation of Slick wrt vertical (degrees)-clockwise from reference line	Sampled?	Orientation Quality	Depth (m)	Elev. (m)	Date Tested	Core Diameter (mm)	Gauge Value (psi)	Gauge Value (kPa)	UCS (Isx24) (MPa)	Strength Designation Grade

Rev. 0 - Issued for Manual

TABLE 2.2

DESCRIPTION OF SOIL AND ROCK STRENGTHS

M:\1\08\00014\03\A\Report\1-Geotech Manual\Tables\[Table 2.2_r0 Rock Strength.xls]UC
Print Nov/30/04 12:27:35
Rev'd Nov/24/04

Grade	Description (Note 1)	Identification	Approximate Range of Unconfined Compressive Strength, UCS, (MPa) (Note 2)
S1	Very soft	Easily penetrated several inches by fist.	<0.025
S2	Soft	Easily penetrated several inches by thumb.	0.025 - 0.05
S3	Firm	Can be penetrated several inches by thumb with moderate effort.	0.05 - 0.10
S4	Stiff	Readily indented by thumb but penetrated only with great effort.	0.10 - 0.25
S5	Very stiff	Readily indented by thumb nail.	0.25 - 0.50
S6	Hard	Indented with difficulty by thumb nail.	>0.50
R0	Extremely weak rock	Indented by thumb nail.	0.25 - 1.0
R1	Very weak rock	Crumbles under firm blow with point of geological hammer. Can be peeled by a pocket knife.	1.0 - 5.0
R2	Weak rock	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer.	5.0 - 25
R3	Medium strong rock	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single firm blow of geological hammer.	25 - 50
R4	Strong rock	Specimen requires more than one blow of geological hammer to fracture it.	50 - 100
R5	Very strong rock	Specimen requires many blows of geological hammer to fracture it.	100 - 250
R6	Extremely strong rock	Specimen can only be chipped with geological hammer.	>250

Notes:

1. Use S1 to S6 grades for soils and fault gouge.
2. Pocket penetrometer can be used to measure uniaxial compressive strength on soils.

Reference: Brown, 1981.

Rev. 0 - Issued for Manual

Knight Piésold
CONSULTING

TABLE 2.3

JOINT CONDITION AND GROUNDWATER RATING

M:\1\08\00014\03\A\Report\1-Geotech Manual\Tables\[Table 2.3_r0 Joint Condition.xls]JCs

Print Nov/30/04 12:28:04
Rev'd Nov/24/04

Joint Condition Rating					
Persistence	< 1 m	1 - 3m	3 - 10m	10 - 20m	> 20m
RATING	6	4	2	1	0
Aperture	None	< 0.1mm	0.1 - 1.0mm	1 - 5mm	5 - 10mm
RATING	6	5	4	1	0
Roughness	Very Rough, Stepped	Rough Undulating / Stepped	Slightly Rough, Undulating	Smooth, Planar	Polished or Slickensided
RATING	6	5	3	1	0
Infilling	None	Hard Infilling		Soft Infilling	
		< 5 mm	> 5 mm	< 5mm	> 5 mm
RATING	6	4	3	2	0
Weathering	Fresh and Unweathered	Slightly weathered - rock strength unchanged, weathering on joints only	Moderately weathered - rock is discolored, but strength is only slightly affected, discontinuities weathered	Highly weathered - rock is discolored and strength is significantly reduced by weathering	Completely weathered - original fabric and relict structures remain but, rock is decomposed and friable
RATING	6	5	3	1	0

Groundwater Rating					
Description	Dry	Damp	Wet	Dripping	Flowing
RATING	15	10	7	4	0

Reference: Bieniawski, 1989.

Rev. 0 - Issued for Manual

TABLE 3.1

ROCK OUTCROP MAPPING DATA SHEET

Print Nov/30/04 12:25:35
M:\1\08\00014\03\A\Report\1-Geotech Manual\Tables\[Table 3.1_r0 Mapping Sheet.XLS]Mapping
Rev'd Nov/24/04

Knight Piésold
C O N S U L T I N G

PROJECT ____________________
LOCATION ____________________
INSPECTOR ____________________

EXPOSURE MAPPING DATA SHEET

TRAVERSE START ____________________ ELEVATION ____________________
TRAVERSE END ____________________ ELEVATION ____________________

SHEET_____ **OF** _____

DATE: *DAY MTH YR*

ROCK MATERIAL

CHAINAGE	TYPE	WEATHERING	ALTERATION	STRENGTH	REMARKS
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					

STRUCTURE

CHAINAGE	TYPE	DIP	DIP DIR	SET No.	INFILL TYPE	INFILL STR	APERTURE	ROUGH	SHAPE	JCS	WEATHERING	PERSIST	SPACING	WATER	EST RQD	REMARKS
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																
.																

WEATHERING	ALTERATION	TYPE	INFILLING	APERTURE	ROUGHNESS	PERSISTENCE	SPACING	STRENGTH	WATER
1. FRESH	1. UNALTERED	1. JOINT	1. CLEAN	1. < 0.1 mm	1. ROUGH	1. < 1 m	1. < 2 cm	R0 0.25 - 1.0 MPa	1. DRY, NO FLOW
2. SLIGHTLY	2. JOINTS ONLY	2. BEDDING	2. SURFACE STAIN	2. 0.1-0.25 mm	2. SMOOTH	2. 1 - 3 m	2. 2 - 6 cm	R1 1 - 5 MPa	2. DRY, STAINED
3. MODERATELY	3. DISCOLOURED	3. FAULT	3. NON-COHESIVE	3. 0.25-0.5 mm	3. SLICKENSIDED	3. 3 - 10 m	3. 6 - 20 cm	R2 5 - 25 MPa	3. DAMP, NO FREE
4. HIGHLY	4. PERVASIVE	4. SHEAR	4. CLAY GOUGE	4. 0.5-2.5 mm		4. 10 - 20 m	4. 20 - 60 cm	R3 25 - 50 MPa	4. OCCASIONAL DROPS
5. COMPLETELY	5. COMPLETELY	5. SCHISTOCITY	5. SWELLING CLAY	5. 2.5-10 mm	**SHAPE**	5. > 20 m	5. 0.6 - 2 m	R4 50 - 100 MPa	5. CONTINOUS FLOW
	6. MYLONITIC	6. CLEAVAGE	6. CEMENTED	6. > 10 mm	1. STEPPED		6. 2 - 6 m	R5 100 - 250 MPa	
	7. BRECCIATED	7. FOLIATION	7. MINERAL	7. 1 - 10 cm	2. UNDULATING		7. > 6 m	R6 > 250 MPa	
		8. VEIN		8. 10 - 100 cm	3. PLANAR				
		9. CONTACT		9. > 1m					

Rev. 0 - Issued for Maunual

TABLE 3.2

DESCRIPTION OF WEATHERING GRADES

M:\1\08\00014\03\A\Report\1-Geotech Manual\Tables\[Table 3.2_r0 Weathering Grades.xls]Weatherir
Print Nov/30/04 12:28:36
Rev'd Nov/24/04

Degree of Weathering	Symbol	Mineralogical Description	Mechanical Description
Fresh Rock	FR	No limonite staining on joints or in rock fabric, but coatings of chlorite, quartz, biotite, calcite, sulphides or clay on joints are common.	Rock not effected by weathering.
Slightly Weathered	SW	Some feldspar minerals show signs of decomposition. Limonite staining is on joints and, in places, throughout the rock. The rock may have a bleached appearance. The rock is slightly discolored and noticeably weakened or lower in strength than fresh rock.	Rings when struck with hammer; the strength approaches that of fresh rock.
Moderately Weathered	MW	Rock fabric visible; some minerals partly decomposed into clay materials; the rock is often limonite stained throughout its fabric. The rock is discolored and noticeably weakened, but 5 cm diameter drill cores cannot be broken up by hand across the rock fabric.	Cannot be broken by hand when struck with hammer, sound of impact is dull.
Highly Weathered	HW	Original rock fabric obscured; many minerals decomposed into clay materials. The rock is usually discolored and weakened to such an extent that 5 cm diameter cores can be broken up readily by hand across the fabric. Wet strength usually much lower than dry strength.	Can be broken and crumbled by hand. The material does not readily disintegrate in water.
Extremely Weathered	EW	Original rock fabric largely obscured. Most minerals other than quartz decomposed into clay minerals. The rock is discolored and completely changed to soil.	Can be broken and crumbled by hand, disintegrates when immersed in water.

Rev. 0 - Issued for Manual

Knight Piésold
CONSULTING

TABLE 4.1

ROCK MASS RATING CLASSIFICATION SYSTEM (RMR, 1989)

M:\1\08\00014\03\A\Report\1-Geotech Manual\Tables\[Table 4.1_r1 RMR Classification.xls]RMR_r1

Print Apr/24/07 10:50:20
Rev'd Apr/24/07

												VALUE	RATING
Intact Rock Strength	PLT, MPa	10	8	6.5	5.5	5	4.5	3	2	1	<1		
	UCS, MPa	250	200	160	140	125	110	75	50	25	< 25		
	Field Est.	chipped by hammer		many blows by hammer to break				single blow		pocket knife			
	RATING	15	14	13	12	11	10	8	6	4	< 3		
RQD	RQD, %	100	90	80	70	60	50	40	30	20	0		
	RATING	20	18	16	14	12	10	9	5	4	3		
Joint Spacing	Js, cm	> 200	160	130	90	60	40	20	15	10	< 6		
	RATING	20	18	16	14	12	10	9	8	7	5		

								Set 1	Set 2	Set 3	VALUE	RATING
							Orientation					
							J Spacing					
Joint Condition	**Persistence**	< 1 m	1 - 3m	3 - 10m	10 - 20 m	> 20m						
	RATING	6	4	2	1	0						
	Aperture	None	< 0.1 mm	0.1 - 1.0	1 - 5	5 - 10						
	RATING	6	5	4	1	0						
	Roughness	V Rough	Rough	SL Rough	Smooth	Slicks						
	RATING	6	5	3	1	0						
	Infilling	None	Hard Infilling		Soft Infilling							
			< 5 mm	> 5 mm	< 5mm	> 5 mm						
	RATING	6	4	3	2	0						
	Weathering	FRESH	SW	MW	HW	CW						
	RATING	6	5	3	1	0						
							Sub-Total					

							VALUE	RATING
Groundwater	**Inflow** l/min/10m	None	< 10	10 - 25	25 -125	> 125		
	General	Dry	Damp	Wet	Dripping	Flowing		
	RATING	15	10	7	4	0		

Adjustment for Joint Orientation	DIP OF ADVERSE JOINT SET			VALUE	RATING
	0 - 20	20 - 45	45 - 90		
Strike Perpendicular to Tunnel Axis drive with Dip	Unfavourable	Favourable	Very Favourable		
	-10	-2	0		
Strike Perpendicular to Tunnel Axis drive against Dip	Unfavourable	Unfavourable	Fair		
	-10	-10	-5		
Strike Parallel to Tunnel	Unfavourable	Fair	Very Unfavourable		
	-10	-5	-12		

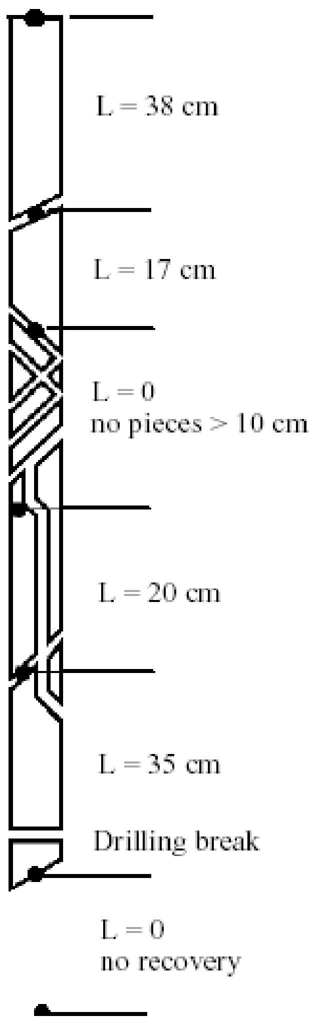
RMR RATING	80 - 100	60 - 80	40 - 60	20 - 40	0 - 20
DESCRIPTION	**VERY GOOD**	**GOOD**	**FAIR**	**POOR**	**VERY POOR**
ROCK CLASS	1	2	3	4	5

Reference: Bieniawski, 1989

Rev. 1 - Issued for Manual, Joint Spacing Rating Updated

FIGURES

Knight Piésold
CONSULTING
www.knightpiesold.com



Total length of core run = 200 cms

$$RQD = \frac{\Sigma \text{ Length of core pieces} > 10 \text{ cm length}}{\text{Total length of core run}} \times 100$$

$$RQD = \frac{38 + 17 + 20 + 35}{200} \times 100 = 55\ \%$$

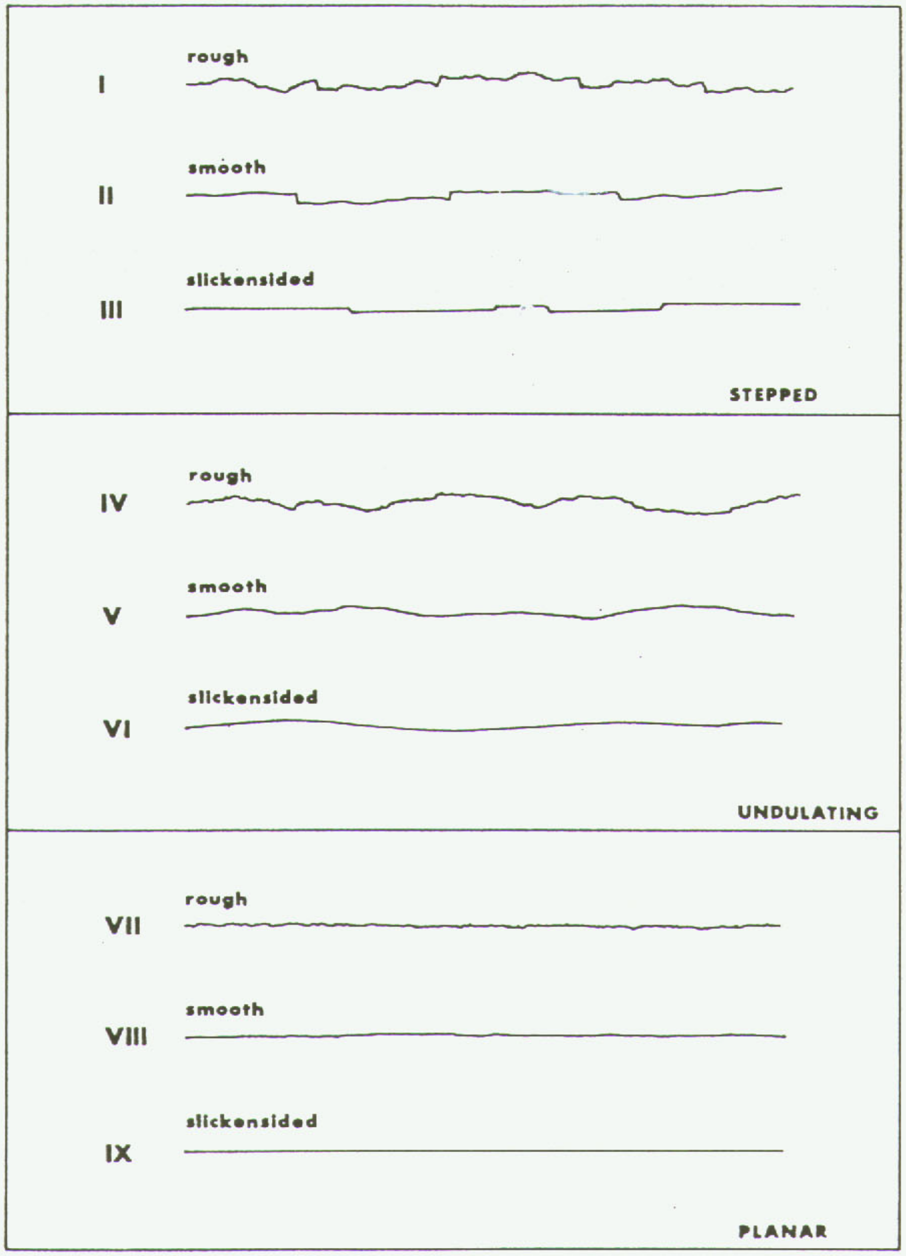
Note: After Deere, 1989.

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

ROCK QUALITY DESIGNATION (RQD)

Knight Piésold CONSULTING	PROJECT /ASSIGNMENT NO.	REF NO.	REV
	VA108-14/3	1	0
	FIGURE 2.1		

Rev. 0 - Issued for Manual



Note: Scale 1 – 10m

Reference: ISRM (1981)

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

LARGE SCALE JOINT SHAPE AND ROUGHNESS PROFILES FOR SURFACE OUTCROP MAPPING

Knight Piésold CONSULTING

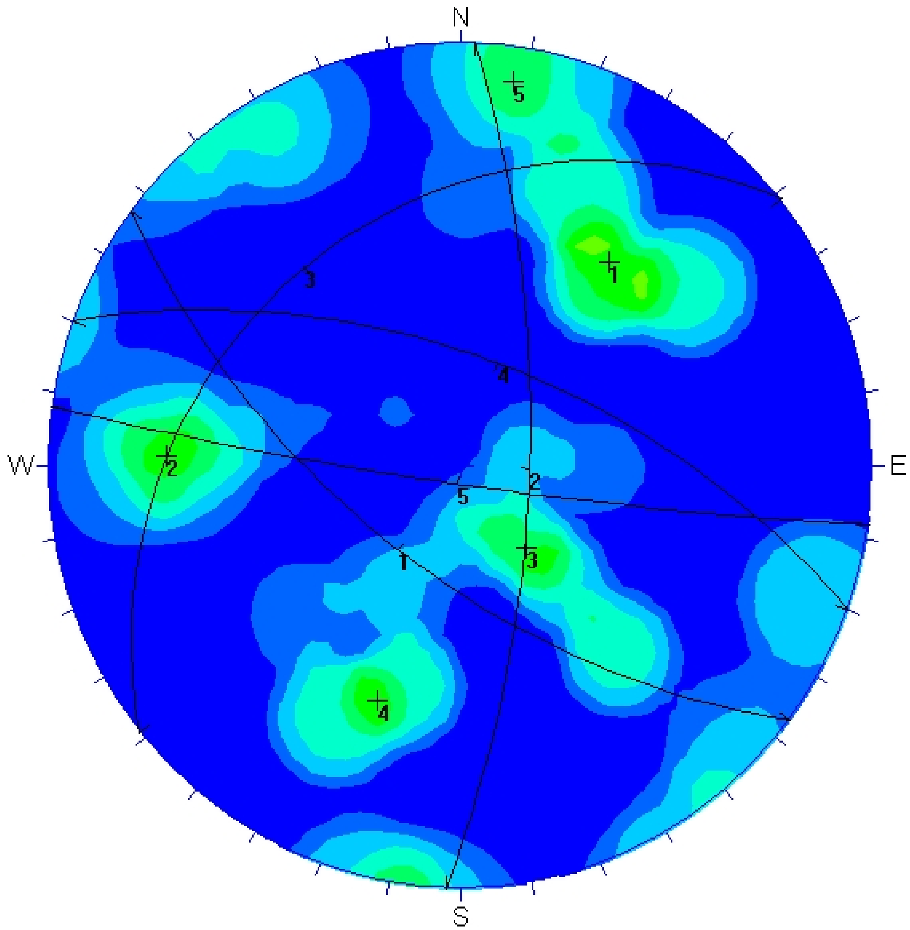
PROJECT NO.	REF. NO.	REV
VA108-14/3	1	0

FIGURE 3.1

Rev. 0 - Issued for Manual

M:\1\08\00014\03\A\Report\1-Geotech Manual\Figures\[Figure 4.1_r0 Stereographic Plot.xls]Dips

Print Nov/30/04 12:41:29
Rev'd Nov/24/04



Fisher
Concentrations
% of total per 2.0 % area

0.00 ~ 1.50 %
1.50 ~ 3.00 %
3.00 ~ 4.50 %
4.50 ~ 6.00 %
6.00 ~ 7.50 %
7.50 ~ 9.00 %
9.00 ~ 10.50 %
10.50 ~ 12.00 %
12.00 ~ 13.50 %
13.50 ~ 15.00 %

Terzaghi Correction
Min. Bias Angle = 15 deg
Max. Conc. = 10.0037%

Equal Angle
Lower Hemisphere
36 Poles
36 Entries

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

CONTOURED STEREONET OF ROCK JOINT DATA AND MAIN JOINT SETS

Knight Piésold CONSULTING

PROJECT NO.	REF. NO.	REV.
VA108-14/3	1	0

FIGURE 4.1

Rev. 0 - Issued for Manual

APPENDIX A

Drill Core Orientation

Knight Piésold
CONSULTING
ww.knightpiesold.com

APPENDIX A
DRILL CORE ORIENTATION

1. GENERAL

Drill core orientation methods are commonly employed where there is an absence of, or limited rock outcrops to allow for orientation of the main rock mass structure. The most common drill core orientation methods for use with exploration drilling are the following:

- Ballmark System;
- Ezy-Mark System;
- Clay Imprint Method;
- Craelius Method.

Information on all intersected discontinuities should be logged properly and filled into a geotechnical drill core logging data sheet (Table 2.1). Down hole surveys of the drillholes should be made and recorded at appropriate intervals to determine if drillhole has deviated.

2. DRILL CORE ORIENTATION METHODS

Ballmark System

The Ballmark system is a quick reliable core orientation method that goes down the hole with the core tube on each drill run and is available in NQ3 and HQ3 sizes. It comprises a spring-loaded extension to the core tube, with an inverted cup that retains a free-rolling, non-magnetic ball on an (consumable) aluminium disc. Tension exerted on the core tube back end during core breaking compresses the ball against the disk and leaves a mark on the disk that corresponds to the bottom edge of the drillhole. The Ballmark indentation process is illustrated in Figure A.1. The Ballmark system is applicable to core orientation in any competent rock formation and requires very little downtime for reading or resetting the device. Further information is available on the manufacturer's website at www.ballmark.com.au.

Ezy-Mark System

The Ezy-Mark system, similar to that of the Ballmark System, is also sent down the hole with the core tube and is available in NQ3 and HQ3 sizes. It comprises a tool that has approximately 12 finishing nails and 2 coloured pencils. They are held in place by O-rings and project from the front of the tool to take an impression of the core stub left from the previous run. The tool is inserted into the core lifter case and takes an impression of the hole bottom when the bit is lowered to start a run. The device then rises up into the split tube with core during drilling and is removed during extraction of the core from the tube at the end of the run. The core is oriented by aligning the shape of the top piece of core (the bottom of the hole prior to drilling the run) to the nails on the ezy-mark device which were compressed at the start of the run. A series of balls which lock when the device is pushed onto the bottom of the hole indicates the bottom edge of the core. The Ezy-Mark core orientation method is illustrated in Figure A.2. Further information is available on the manufacturer's website at www.2icaustralia.com.

Clay Imprint Method

The clay imprint method has been reported by Call et al. (1982) and comprises an eccentrically weighted down hole orientor which consists of a 1 m long inner core barrel that is half-filled with lead and a core lifter case at the end packed with modelling clay. The orientor is marked with a reference line opposite to the weighted side, which corresponds to the top of the core. Using the reference line on the orientor, a reference orientation line can be marked along the core pieces. An illustration of the components of the device is shown in Figure A.3. The device can be readily made from an old drill core barrel and core lifter cases of the same size as the proposed exploration drilling size. It is strongly suggested that at least two core lifter cases are made and provided in order that one is available for down hole testing while the other is used scribing the previous drill run.

The device is dropped through drilling mud or lowered to the bottom of the drill hole between drill runs to form an imprint of the core stub left by the previous drill run. The imprint can then be matched up with the subsequent drill run. Clay imprints are made as many times as necessary to produce a good quality imprint to maintain orientation of the drill core. Additional split tubes are typically used to facilitate the scribing of the reference line along the core as illustrated in the top photograph in Figure A.4.

With the clay imprint method the orientation of the joints can then be measured in terms of the relative alpha and beta angles. Alternatively, the true dip and dip direction/strike of rock joints can be measured directly from the core with the use of a NQ or HQ ruler or a core cradle/table in which the core pieces are set up in an assembly and oriented with the same inclination and direction as the drillhole as shown in the bottom photograph in Figure A.4.

The clay imprint method has been proven to be very successful with the use of good quality plasticine. The clay imprint method is considered to be successful in all rock types and is considerably less expensive than the Craelius method.

Craelius Method

The Craelius method was developed by Atlas Copco and is shown in Figure A.5. This method comprises an instrument with a spring-loaded conical probe and finger pins along one end that is connected to the core barrel and pushed down hole against the core stub left by the previous drill run. The finger pins form to the profile of the core stub and an indentation is made by a ball bearing against a soft aluminium ring thus marking the bottom of the hole position. The instrument is removed and fitted to the core from the subsequent drill run to allow for the scribing of the reference line representing the bottom of the core.

With the Craelius method, the orientation of the joints can then be measured in terms of the relative alpha and beta angles. Alternatively, the true dip and dip direction/strike can be measured directly from the core with the use of a NQ or HQ ruler or a core cradle/table in which the core pieces are set up in an assembly and oriented with the same inclination and direction as the drill hole. The Craelius method is considered to be best suited for use in hard rock.

3. ORIENTED DRILL CORE LOGGING

Discontinuity logging should be carried out for all intersected discontinuities from oriented drill core and the following information should be filled into an oriented drill core logging spreadsheet as shown on Table 2.1.

Depth of Discontinuity

The depth of each discontinuity should be recorded to facilitate sorting of data and domains of low rock quality, faults, shearing, etc.

Alpha and Beta Angles

The alpha and beta angles are measured, as shown in Figure A.6. The alpha angle is the angle of the maximum dip of the discontinuity with respect to the core axis. The beta angle is the radial angle measured between the intersection of the maximum dip and the reference line on the core. In situations or programs that do not allow for or require discontinuity orientation (beta angle), the alpha angle is still recorded.

Discontinuity Type

The type of discontinuity should be recorded and differentiated between open and healed joints, open and healed veining, bedding, shear, fault, foliation, schistocity, cleavage etc.

Aperture

The aperture is the distance between mating joint surfaces or “gap” of the particular joint.

Infilling Types and Thicknesses - Primary and Secondary

The type and thickness of primary and secondary infillings should be recorded for each discontinuity. Typical infilling types may include chlorite, quartz, calcite, clay gouge, pyrite, gypsum etc.

Joint Condition

A joint condition rating should be recorded for each discontinuity. The joint condition rating is based on the rock mass rating (RMR) classification by Bieniawski (1989) and is defined with joint condition descriptions for persistence (joint length), aperture, roughness, infilling and weathering. Typically, persistence is not recorded from drill core.

Orientation of Slickensides

Whenever possible the field engineer/geologist must determine the orientation of slickensides. Slickensides are oriented with respect to the vertical in a clockwise orientation.

Orientation Quality

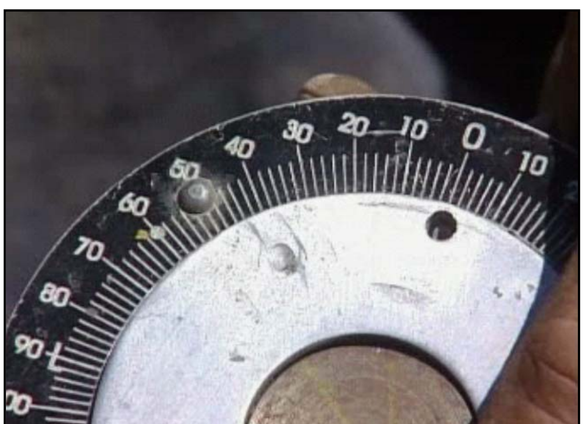
The quality of the oriented discontinuity is done qualitatively and ranges from no orientation to very good orientation. The table below summarizes the description of the discontinuity orientation qualities.

Orientation Quality	Description
Very Good	Marked reference line on core matches the reference line from the previous run.
Good	Reference line is identifiable on current run.
Fair	Reference line acquired by matching up joint surfaces with the previous orientable run.
Poor	No confidence in recorded orientation data.
None	No possibility of orientable discontinuities.

Ballmark backend

Non-magnetic ball settles to the lowest point in the track.

As the core is broken, a non-magnetic ball indents the aluminum disc, corresponding to the bottom of the hole. The pin location is the second (fixed with respect to the core barrel) point of reference used in determining the orientation of the core.



The angle between the pinhole and ballmark is transferred to the core after which the alpha and beta angles are determined.

Rev. 0 - Issued for Manual

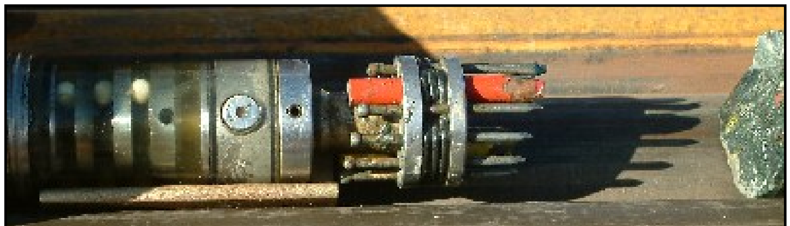
GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

BALLMARK CORE ORIENTATION METHOD

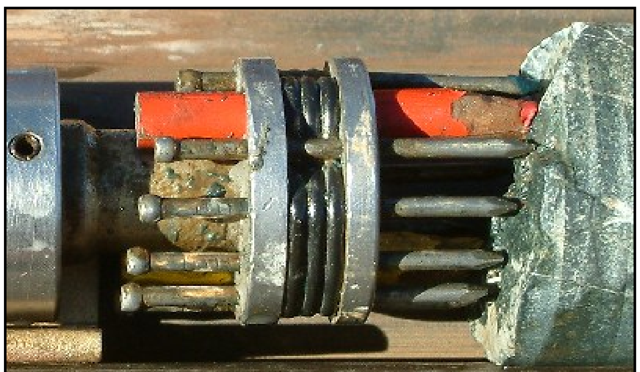
Knight Piésold CONSULTING	PROJECT NO.	REF NO.	REV.
	VA101-14/3	1	0
	FIGURE A.1		

Ezy-Mark lowers down with the core tube.

The Ezy-Mark head comes out with the core at the end of the run.



The head profile is then aligned with the face of the core.



Close-up of head-core alignment.

The gauge is aligned with the three orientation balls and the core is marked.

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

EZY MARK CORE ORIENTATION METHOD

Knight Piésold
CONSULTING

PROJECT NO.	REF NO.	REV.
VA108-14/3	1	0

FIGURE A.2

Rev. 0 - Issued for Manual

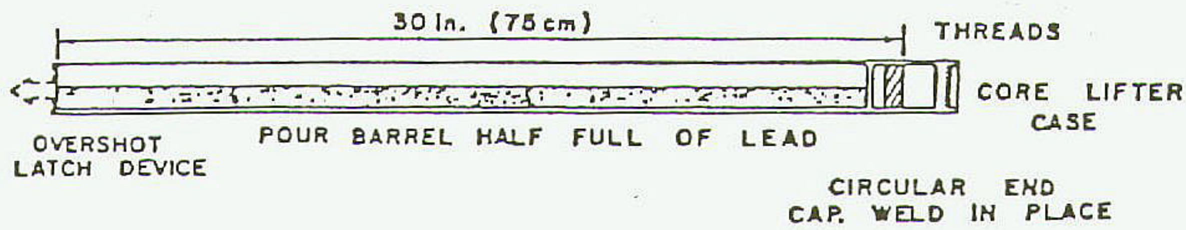
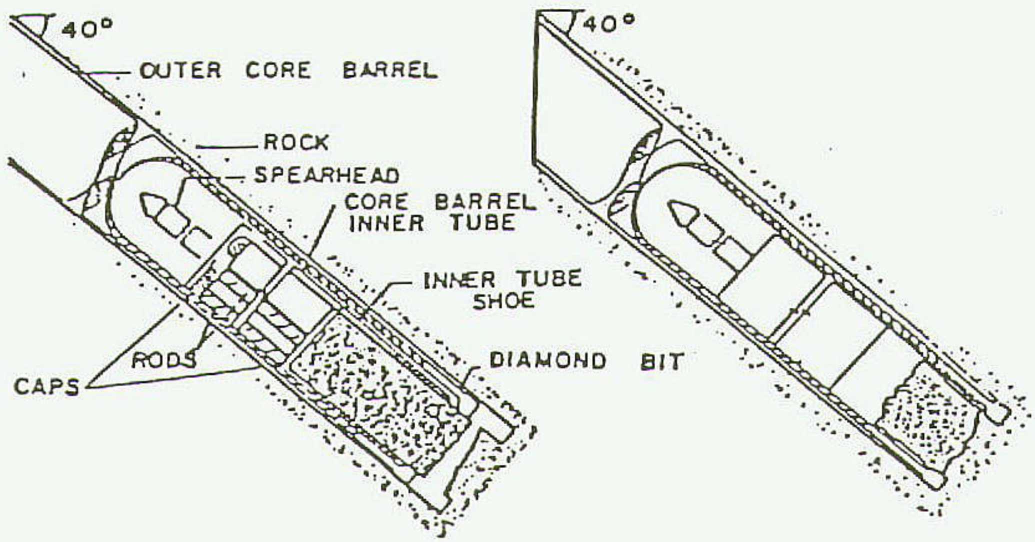


Figure 1: Clay Core Oriento:



PRIOR TO IMPRINT

IMPRINT

Reference: Call et al. (1982)

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

CLAY IMPRINT CORE ORIENTATION METHOD

Knight Piésold
CONSULTING

PROJECT NO.	REF NO.	REV
VA108-14/3	1	0

FIGURE A.3

Rev. 0 - Issued for Manual

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

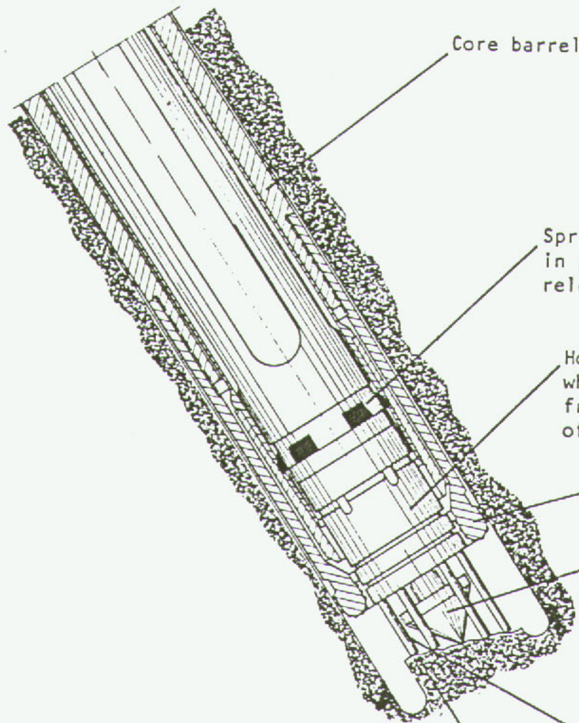
CLAY IMPRINT DRILLCORE ORIENTATION TOOL, CORE CRADLE AND ACCESSORY EQUIPMENT

Knight Piésold
CONSULTING

PROJECT NO.	REF. NO	REV
VA108-14/3	1	0

FIGURE A.4

Rev. 0 - Issued for Manual



Details and method of operation of the Craelius core orientator.
(Drawing from Craelius technical literature)

Reference: Hoek and Bray (1981)

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

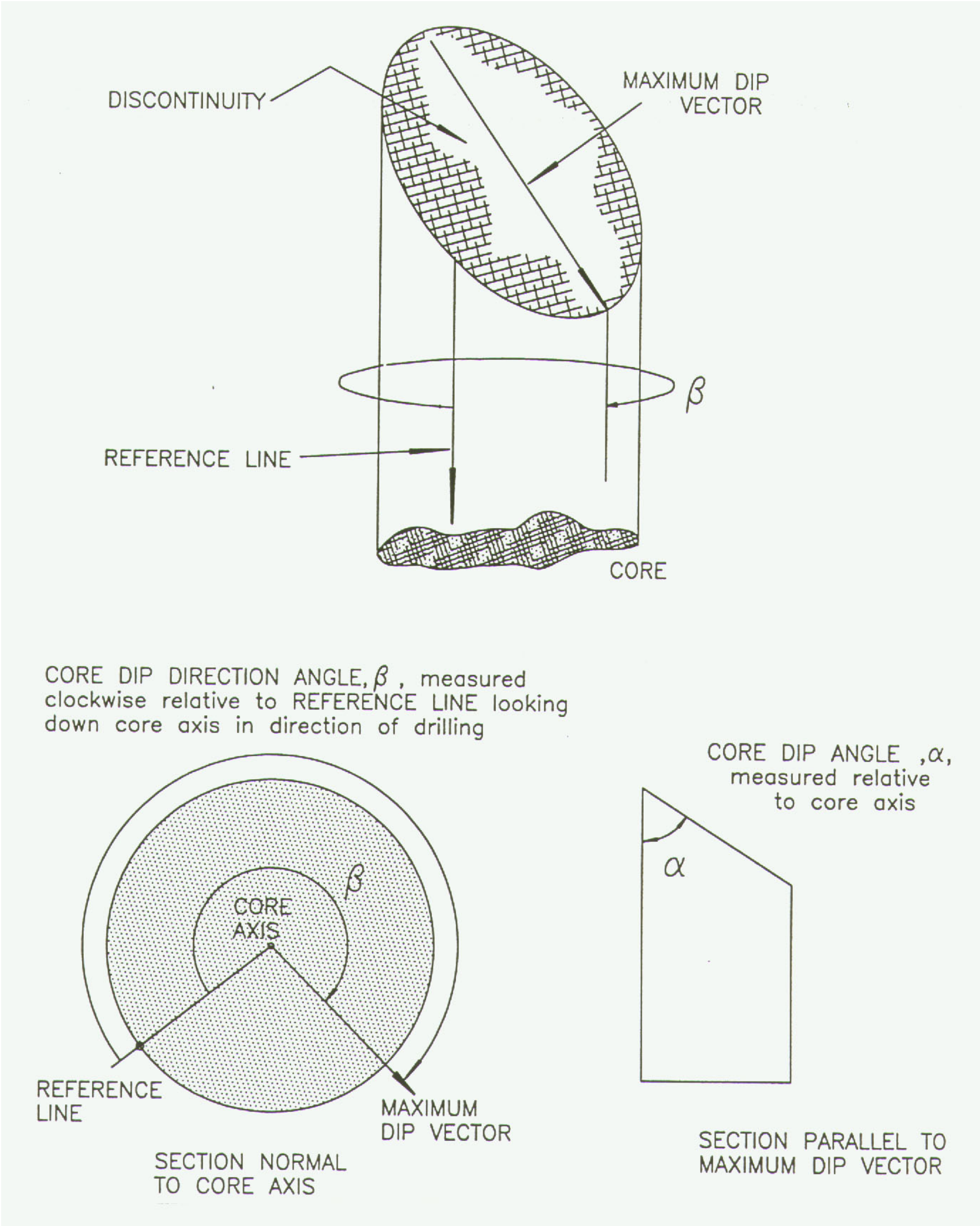
CRAELIUS CORE ORIENTATION METHOD

Knight Piésold
CONSULTING

PROJECT NO.	REF. NO.	REV.
VA108-14/3	1	0

FIGURE A.5

Rev. 0 - Issued for Manual



GEOTECHNICAL DATA COLLECTION			
FOR EXPLORATION GEOLOGISTS			
DEFINITION OF ALHA AND BETA ANGLES FOR CORE ORIENTATION DATA LOGGING			
Knight Piésold CONSULTING	PROJECT NO. VA108-14/3	REF. NO. 1	REV. 0
	FIGURE A.6		

Rev. 0 - Issued for Manual

APPENDIX B

Field Testing

APPENDIX B
FIELD TESTING

Field geotechnical testing of drill core may comprise point load strength index test and direct shear test on rock joints

Point Load Test

Point load test (PLT) provides a quick determination of intact rock strength on the field. A portable point load test machine with calibrated gauges is shown on Figure B.1. Information to be included as part of all point load strength index tests is the nature of the failure and whether it occurred through intact rock or pre-maturely along a healed joint or vein. The testing data can be filled into a geotechnical drill core logging spreadsheet (Table 2.1) or a PLT recording sheet. The PLT strength index and unconfined compressive strength (UCS) will be calculated. In order to calibrate the correlation between PLT strength index and UCS, PLTs are carried out both directly above and below a sample that has been removed for laboratory UCS test. It is noted that point load strength index tests may be carried out on non-drill core samples but should meet the sample shape requirements for testing as shown in Figure B.2.

Direct Shear Test

Direct shear tests of rock joints should be carried out using a portable direct shear test machine with calibrated pressure and dial-meter gauges. A direct shear machine for field testing is shown in Figure B.3. Information included as part of the direct shear test is a full description of the joint surface, drill hole information, surface dimensions as well as the corresponding readings. The electronic direct shear calculation spreadsheet used in the field is illustrated in Table B.1. Direct shear testing of rock joints can be carried out in a lab to confirm results from field tests. The purpose of the direct shear test is to determine the peak and residual friction angles for use in slope design and or wedge analysis.

TABLE B.1
DIRECT SHEAR TEST CALCULATION SHEET

Knight Piésold
CONSULTING

PROJECT
PORTABLE DIRECT SHEAR TESTING OF ROCK JOINT SURFACES FROM DRILL CORE

M:\1\08\00014\03\A\Report\1-Geotech Manual\Appendices\[Table B.1_r0 Shear Test Data Sheet.xls]Shear Test

Print Nov-30-2004 12:59
Rev'd: Nov 24, 2004

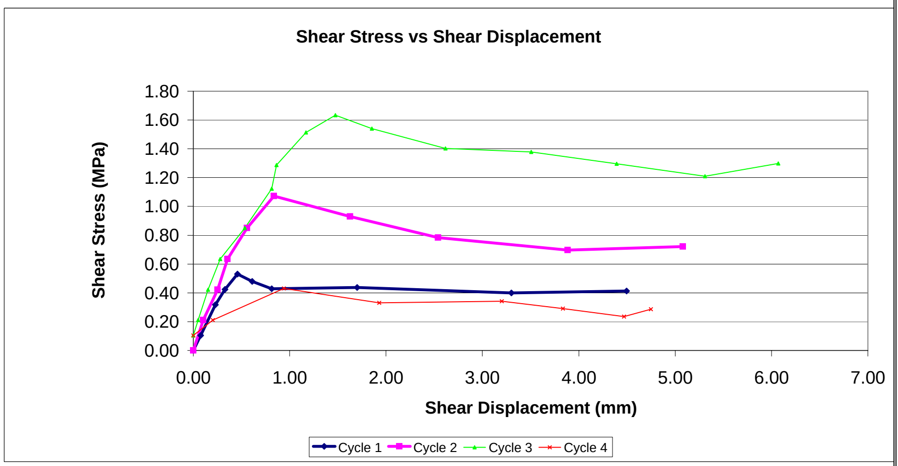
Date:		**Inclination**	60	**Core Size:**	NQ3
Drill Hole:	DH-1	**Azimuth**	180	**HQ-3 = 61.1mm**	
Sample	DH1-SS1	**Joint Set No**		**NQ-3 = 45.0 mm**	
Depth, m	150.5	**Description**	Monzodiorite, Jc = 18, Pyrite infills, 0.5mm aperature	**Inspector:**	

DESCRIPTION OF SURFACE

Joint Surface Type (Bedding, Toppling, Other)	Joint
Description (Rough, Smooth Slickensided)	Rough
Profile (Stepped, Undulating, Planar)	Planar
Joint Surface Texture (Chloritic, Talc, etc.)	n/a
Estimated Orientation (Dip/Dip Direction)	90
Small Scale JRC (0 - 20):	15
Infilling Type	pyr
Infilling Thick.	1.0

SURFACE DIMENSIONS

Major Axis	51	mm
l/2 Dimension	25.5	mm
Minor Axis	44	mm
l/2 Dimension	22	mm
Area:	0.00176	m^2
	2.730	in^2



TESTING DATA

Loading Cycle	Reading No.	Applied Normal Loading (kg) Initial kg	Additional Loading	Total Load, kg	Normal Displacement D_n Dial Reading	Increment (mm)	Applied Shear Force P_s Gauge Pressure, psi	Force (kN)	Shear Displacements D_s Dial Reading	Increment (mm)	Total (mm)	Contact area A (corrected) mm^2	Normal Force, P_N (kN)	S_n (MPa)	Shear Force, P_S (kN)	t (MPa)
	0	1.76	10	11.76	314.0	0.000	0	0.00	452.0	0.000	0.000	1762.4	1.39	0.791	0.00	0.000
	1	1.76	10	11.76	314.0	0.000	50	0.18	449.0	0.076	0.076	1759.1	1.39	0.793	0.18	0.105
	2	1.76	10	11.76	314.0	0.000	150	0.55	443.0	0.152	0.229	1752.4	1.39	0.796	0.55	0.316
	3	1.76	10	11.76	314.0	0.000	200	0.74	439.0	0.102	0.330	1747.9	1.39	0.798	0.74	0.423
	4	1.76	10	11.76	314.0	0.000	250	0.92	434.0	0.127	0.457	1742.3	1.39	0.800	0.92	0.531
1	5	1.76	10	11.76	314.0	0.000	225	0.83	428.0	0.152	0.610	1735.6	1.39	0.803	0.83	0.479
	6	1.76	10	11.76	314.0	0.000	200	0.74	420.0	0.203	0.813	1726.7	1.39	0.808	0.74	0.428
	7	1.76	10	11.76	314.0	0.000	200	0.74	385.0	0.889	1.702	1687.6	1.39	0.826	0.74	0.438
	8	1.76	10	11.76	314.0	0.000	175	0.65	322.0	1.600	3.302	1617.2	1.39	0.862	0.65	0.400
	9	1.76	10	11.76	314.0	0.000	175	0.65	275.0	1.194	4.496	1564.9	1.39	0.891	0.65	0.413
	0	1.76	20	21.76	294.0	0.000	0	0.00	465.0	0.000	0.000	1762.4	2.58	1.464	0.00	0.000
	1	1.76	20	21.76	294.0	0.000	100	0.37	461.0	0.102	0.102	1758.0	2.58	1.468	0.37	0.210
	2	1.76	20	21.76	294.0	0.000	200	0.74	455.0	0.152	0.254	1751.3	2.58	1.473	0.74	0.422
	3	1.76	20	21.76	294.0	0.000	300	1.11	451.0	0.102	0.356	1746.8	2.58	1.477	1.11	0.635
	4	1.76	20	21.76	295.0	0.025	400	1.48	443.0	0.203	0.559	1737.8	2.58	1.485	1.48	0.851
2	5	1.76	20	21.76	294.0	0.025	500	1.85	432.0	0.279	0.838	1725.6	2.58	1.495	1.85	1.071
	6	1.76	20	21.76	304.0	0.254	425	1.57	401.0	0.787	1.626	1690.9	2.58	1.526	1.57	0.929
	7	1.76	20	21.76	304.0	0.000	350	1.29	365.0	0.914	2.540	1650.7	2.58	1.563	1.29	0.784
	8	1.76	20	21.76	304.0	0.000	300	1.11	312.0	1.346	3.886	1591.6	2.58	1.621	1.11	0.697
	9	1.76	20	21.76	304.0	0.000	300	1.11	265.0	1.194	5.080	1539.3	2.58	1.676	1.11	0.721
	0	1.76	30	31.76	290.0	0.000	50	0.18	333.0	0.000	0.000	1762.4	3.77	2.137	0.18	0.105
	1	1.76	30	31.76	290.0	0.000	100	0.37	331.0	0.051	0.051	1760.2	3.77	2.140	0.37	0.210
	2	1.76	30	31.76	290.0	0.000	200	0.74	327.0	0.102	0.152	1755.7	3.77	2.145	0.74	0.421
	3	1.76	30	31.76	290.0	0.000	300	1.11	322.0	0.127	0.279	1750.1	3.77	2.152	1.11	0.634
	4	1.76	30	31.76	289.0	0.025	400	1.48	312.0	0.254	0.533	1739.0	3.77	2.166	1.48	0.850
	5	1.76	30	31.76	288.0	0.025	525	1.94	301.0	0.279	0.813	1726.7	3.77	2.181	1.94	1.124
	6	1.76	30	31.76	291.0	0.076	600	2.22	299.0	0.051	0.864	1724.4	3.77	2.184	2.22	1.286
3	7	1.76	30	31.76	313.0	0.559	700	2.59	287.0	0.305	1.168	1711.0	3.77	2.201	2.59	1.513
	8	1.76	30	31.76	313.0	0.000	750	2.77	275.0	0.305	1.473	1697.6	3.77	2.218	2.77	1.633
	9	1.76	30	31.76	313.0	0.000	700	2.59	260.0	0.381	1.854	1680.9	3.77	2.241	2.59	1.540
	10	1.76	30	31.76	313.0	0.000	625	2.31	230.0	0.762	2.616	1647.4	3.77	2.286	2.31	1.403
	11	1.76	30	31.76	313.0	0.000	600	2.22	195.0	0.889	3.505	1608.3	3.77	2.342	2.22	1.379
	12	1.76	30	31.76	313.0	0.000	550	2.03	160.0	0.889	4.394	1569.3	3.77	2.400	2.03	1.296
	13	1.76	30	31.76	313.0	0.000	500	1.85	124.0	0.914	5.309	1529.3	3.77	2.463	1.85	1.209
	14	1.76	30	31.76	313.0	0.000	525	1.94	94.0	0.762	6.071	1496.0	3.77	2.518	1.94	1.298
	0	1.76	10	11.76	331.0	0.000	50	0.18	321.0	0.000	0.000	1762.4	1.39	0.791	0.18	0.105
	1	1.76	10	11.76	331.0	0.000	100	0.37	313.0	0.203	0.203	1753.5	1.39	0.795	0.37	0.211
	2	1.76	10	11.76	331.0	0.000	200	0.74	284.0	0.737	0.940	1721.1	1.39	0.810	0.74	0.430
4	3	1.76	10	11.76	339.0	0.203	150	0.55	245.0	0.991	1.930	1677.5	1.39	0.831	0.55	0.331
	4	1.76	10	11.76	339.0	0.000	150	0.55	195.0	1.270	3.200	1621.7	1.39	0.860	0.55	0.342
	5	1.76	10	11.76	339.0	0.000	125	0.46	170.0	0.635	3.835	1593.8	1.39	0.875	0.46	0.290
	6	1.76	10	11.76	339.0	0.000	100	0.37	145.0	0.635	4.470	1566.0	1.39	0.891	0.37	0.236
	7	1.76	10	11.76	339.0	0.000	120	0.44	134.0	0.279	4.750	1553.7	1.39	0.898	0.44	0.286

Calibration data — Dial Readings in 0.001"

****** Lever Arm Ratio = 12.1*** — Actual Shear Load (lbs.) = 0.83 x Gauge Reading (psi)

Ram Area = 0.994 in^2

REMARKS

Graph Data

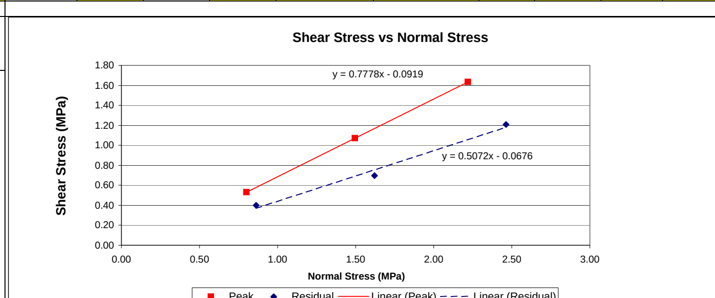
Peak	s	t
Trial 1	0.800	0.531
Trial 2	1.495	1.071
Trial 3	2.218	1.633
Trial 4	0.810	0.430

f_{peak}(deg)= 38

Graph Data

Residual	s	t
Trial 1	0.862	0.400
Trial 2	1.621	0.697
Trial 3	2.463	1.209
Trial 4	0.891	0.236

f_r(deg)= 27



Rev. 0 - Issued for Manual

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

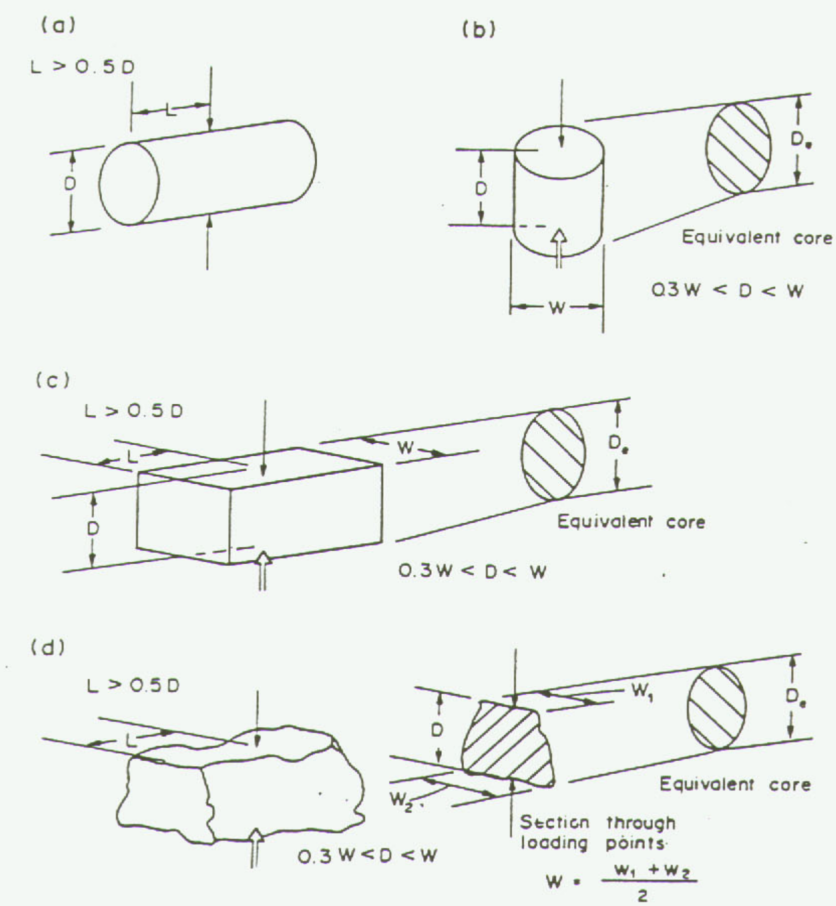
POINT LOAD STRENGTH INDEX TEST MACHINE

Knight Piésold
CONSULTING

PROJECT NO.	REF. NO.	REV
VA108-14/3	1	0

FIGURE B.1

Rev. 0 - Issued for Manual



Reference: Franklin and Dusseault (1989)

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

SAMPLE SHAPE REQUIREMENTS FOR POINT LOAD STRENGTH INDEX TESTS

Knight Piésold CONSULTING

PROJECT NO.	REF. NO.	REV
VA108-14/3	1	0

FIGURE B.2

Rev. 0 - Issued for Manual

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

PORTABLE DIRECT SHEAR TESTING MACHINE

Knight Piésold
CONSULTING

PROJECT NO.	REF. NO.	REV
VA108-14/3	1	0

FIGURE B.3

Rev. 0 - Issued for Manual