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
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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
2.0 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.
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.


<table>
<thead>
<tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DISCONTINUITY DATA**

<table>
<thead>
<tr>
<th>Sampled?</th>
<th>Designation</th>
<th>Orientation of Slick wrt vertical (degrees) - clockwise from reference line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RMR DATA (BY RUN)**

<table>
<thead>
<tr>
<th>Depth Elev.</th>
<th>Date Core Gauge</th>
<th>UCS Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RMR CALCULATIONS (BY RUN)**

<table>
<thead>
<tr>
<th>Depth Elev.</th>
<th>UCS Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PLT STRENGTH DATA / CALCS.**

<table>
<thead>
<tr>
<th>Depth Elev.</th>
<th>UCS Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES**

- Table 2.1: Geotechnical Drillhole Logging Data Sheet
- ROCK MASS CLASSIFICATION - RMR, 1989

- Strength:
  - Weathered State
  - Structure
  - Color
  - Grain Size
  - Rock Material Strength
  - Rock Type

- DISCONTINUITY DATA:
  - Sampled
  - Designation
  - Orientation of Slick wrt vertical

- RMR DATA (BY RUN):
  - Depth Elev.
  - Date Core Gauge
  - UCS Value

- RMR CALCULATIONS (BY RUN):
  - Depth Elev.
  - UCS Value

- PLT STRENGTH DATA / CALCS:
  - Depth Elev.
  - UCS Value

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- Kni...........................................
- C O N S U L T I N G
- Rev. 0 - Issued for Manual
# TABLE 2.2

**DESCRIPTION OF SOIL AND ROCK STRENGTHS**

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

**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.
### TABLE 2.3

**JOINT CONDITION AND GROUNDWATER RATING**

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

<table>
<thead>
<tr>
<th>Description</th>
<th>Dry</th>
<th>Damp</th>
<th>Wet</th>
<th>Dripping</th>
<th>Flowing</th>
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<tr>
<td>RATING</td>
<td>15</td>
<td>10</td>
<td>7</td>
<td>4</td>
<td>0</td>
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<table>
<thead>
<tr>
<th>ROCK MATERIAL</th>
<th>STRUCTURE</th>
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<tr>
<td>CHAINAGE</td>
<td>TYPE</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1. FRESH</td>
<td>1. UNALTERED</td>
</tr>
<tr>
<td>2. SLIGHTLY</td>
<td>2. JOINTS ONLY</td>
</tr>
<tr>
<td>3. MODERATELY</td>
<td>3. DISCOLOURED</td>
</tr>
<tr>
<td>4. HIGHLY</td>
<td>4. PERSIS</td>
</tr>
</tbody>
</table>

WEATHERING ALTERATION TYPE INFILLING APERTURE ROUGHNESS PERSISTENCE SPACING STRENGTH WATER

Rev. 0 - Issued for Manual
### TABLE 3.2

**DESCRIPTION OF WEATHERING GRADES**

<table>
<thead>
<tr>
<th>Degree of Weathering</th>
<th>Symbol</th>
<th>Mineralogical Description</th>
<th>Mechanical Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh Rock</td>
<td>FR</td>
<td>No limonite staining on joints or in rock fabric, but coatings of chlorite, quartz, biotite, calcite, sulphides or clay on joints are common.</td>
<td>Rock not effected by weathering.</td>
</tr>
<tr>
<td>Slightly Weathered</td>
<td>SW</td>
<td>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.</td>
<td>Rings when struck with hammer; the strength approaches that of fresh rock.</td>
</tr>
<tr>
<td>Moderately Weathered</td>
<td>MW</td>
<td>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.</td>
<td>Cannot be broken by hand when struck with hammer, sound of impact is dull.</td>
</tr>
<tr>
<td>Highly Weathered</td>
<td>HW</td>
<td>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.</td>
<td>Can be broken and crumbled by hand. The material does not readily disintegrate in water.</td>
</tr>
<tr>
<td>Extremely Weathered</td>
<td>EW</td>
<td>Original rock fabric largely obscured. Most minerals other than quartz decomposed into clay minerals. The rock is discolored and completely changed to soil.</td>
<td>Can be broken and crumbled by hand, disintegrates when immersed in water.</td>
</tr>
</tbody>
</table>
### TABLE 4.1

ROCK MASS RATING CLASSIFICATION SYSTEM (RMR, 1989)

<table>
<thead>
<tr>
<th>Value</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLT, MPa</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>6.5</td>
<td>8</td>
</tr>
<tr>
<td>5.5</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>4.5</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>&lt;1</td>
<td>3</td>
</tr>
</tbody>
</table>

| UCS, MPa          | 250    |
| 200               | 15     |
| 160               | 10     |
| 140               | 10     |
| 125               | 10     |
| 110               | 10     |
| 75                | 8      |
| 50                | 6      |
| 25                | 4      |
| <25               | 3      |

**Field Ekat:** chipped by hammer, many blows by hammer to break, single blow, pocket knife

**RATING:**
- Intact Rock Strength
- RQD
- Joint Spacing
- Joint Condition
- Groundwater
- Inflow
- General
- Groundwater
- Inflow
- General

### Orientation
- J Spacing

### Joint Spacing
- **Js, cm:** > 200, 160, 130, 90, 60, 40, 20, 15, 10, < 6

### Joint Condition
- **Persistence:** < 1 m, 1 - 3m, 3 - 10m, 10 - 20m, > 20m
- **Aperture:** None, < 0.1 mm, 0.1 - 1.0, 1 - 5, 5 - 10
- **Roughness:** V Rough, Rough, SL Rough, Smooth, Slicks
- **Infilling:** None, Hard Infilling, Soft Infilling
- **Weathering:** FRESH, SW, MW, HW, CW
- **Inflow:** None, < 10, 10 - 25, 25 - 125, > 125
- **General:** Dry, Damp, Wet, Dripping, Flowing

### Watering
- **RATING:**
- **Inflow:** None, < 10, 10 - 25, 25 - 125, > 125
- **General:** Dry, Damp, Wet, Dripping, Flowing

### Adjustment for Joint Orientation
- DIP OF ADVERSE JOINT SET
- 0 - 20
- 20 - 45
- 45 - 90

**Description:**
- Unfavourable
- Favourable
- Very Favourable

**Rock Class:**
- VERY GOOD
- GOOD
- FAIR
- POOR
- VERY POOR

**RMR Rating:**
- 80 - 100
- 60 - 80
- 40 - 60
- 20 - 40
- 0 - 20

Reference: Bieniawski, 1989

Rev. 1 - Issued for Manual, Joint Spacing Rating Updated
FIGURE 2.1

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

ROCK QUALITY DESIGNATION (RQD)

REV 0

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

FIGURE 2.1

Total length of core run = 200 cm

\[
RQD = \frac{\sum \text{Length of core pieces } > 10 \text{ cm length}}{\text{Total length of core run}} \times 100
\]

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

Note: After Deere, 1989.
GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS
LARGE SCALE JOINT SHAPE AND ROUGHNESS
PROFILES FOR SURFACE OUTCROP MAPPING

Knight Piésold
CONSULTING

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

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS
LARGE SCALE JOINT SHAPE AND ROUGHNESS
PROFILES FOR SURFACE OUTCROP MAPPING

Rev. 0 - Issued for Manual

FIGURE 3.1

Note: Scale 1 - 10m

Reference: ISRM (1981)
**FIGURE 4.1**

**GEOTECHNICAL DATA COLLECTION FOR EXPLORATION GEOLOGISTS**

**CONTOURED STEREONET OF ROCK JOINT DATA AND MAIN JOINT SETS**

*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
APPENDIX A

Drill Core Orientation
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.

<table>
<thead>
<tr>
<th>Orientation Quality</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Good</td>
<td>Marked reference line on core matches the reference line from the previous run.</td>
</tr>
<tr>
<td>Good</td>
<td>Reference line is identifiable on current run.</td>
</tr>
<tr>
<td>Fair</td>
<td>Reference line acquired by matching up joint surfaces with the previous orientable run.</td>
</tr>
<tr>
<td>Poor</td>
<td>No confidence in recorded orientation data.</td>
</tr>
<tr>
<td>None</td>
<td>No possibility of orientable discontinuities.</td>
</tr>
</tbody>
</table>
### BALLMARK CORE ORIENTATION METHOD

**Figure A.1**

**GEOTECHNICAL DATA COLLECTION FOR EXPLORATION GEOLOGISTS**

**PROJECT NO.** VA101-14/3  **REF NO.** 1  **REV.** 0

---

**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.

---

**Knight Piésold consulting**

**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.
Figure 1: Clay Core Orientation

Reference: Call et al. (1982)
GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS
CLAY IMPRINT DRILLCORE ORIENTATION TOOL, CORE CRADLE AND ACCESSORY EQUIPMENT

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FIGURE A.4
GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

CRAELIUS CORE ORIENTATION METHOD

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

Reference: Hoek and Bray (1981)
DEFINITION OF ALHA AND BETA ANGLES FOR CORE ORIENTATION DATA LOGGING

**CORE DIP DIRECTION ANGLE,** \( \beta \), measured clockwise relative to REFERENCE LINE looking down core axis in direction of drilling

**CORE DIP ANGLE,** \( \alpha \), measured relative to core axis
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**

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

**Date:**
Inclination 60°

**Drill Hole:**
DH-1

**Sample:**
DH1-SS1

**Core Size:**
NG3

**Core Length:**
150.5 mm

---

**DESCRIPTION OF SURFACE**

<table>
<thead>
<tr>
<th>Joint Surface Type</th>
<th>Joint Surface Type</th>
<th>Joint Surface Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth, Rough, Rugged</td>
<td>Smooth, Rough, Rugged</td>
<td>Smooth, Rough, Rugged</td>
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<tr>
<td>Planar</td>
<td>Planar</td>
<td>Planar</td>
</tr>
<tr>
<td>(Stepped, Unplanar, Planar)</td>
<td>(Stepped, Unplanar, Planar)</td>
<td>(Stepped, Unplanar, Planar)</td>
</tr>
<tr>
<td>Joint Surface Texture</td>
<td>Joint Surface Texture</td>
<td>Joint Surface Texture</td>
</tr>
<tr>
<td>Clastic, Tectic, etc.</td>
<td>Clastic, Tectic, etc.</td>
<td>Clastic, Tectic, etc.</td>
</tr>
<tr>
<td>Estimated Orientation (View)</td>
<td>Estimated Orientation (View)</td>
<td>Estimated Orientation (View)</td>
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<tr>
<td>90</td>
<td>90</td>
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</tr>
</tbody>
</table>

---

**SURFACE DIMENSIONS**

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<tr>
<th>Major Axis</th>
<th>Minor Axis</th>
<th>I/2 Dimension 125.5 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>51 mm</td>
<td>44 mm</td>
<td>25.5 mm</td>
</tr>
</tbody>
</table>

---

**TESTING DATA**

<table>
<thead>
<tr>
<th>Loading Cycle</th>
<th>Reading No.</th>
<th>Initial Normal Loading (kg)</th>
<th>Initial Displacement (mm)</th>
<th>Normal Displacement Dn (mm)</th>
<th>Normal Force Pn (kN)</th>
<th>Contact Area A (mm²)</th>
<th>Shear Force Ps (kN)</th>
<th>Shear Force Pn (kN)</th>
<th>t (MPa)</th>
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<tbody>
<tr>
<td>1</td>
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<td>0</td>
<td>0</td>
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</tbody>
</table>

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**REMARKS**

- Applied Normal Loading
- Normal Displacement
- Normal Force
- Contact Area
- Shear Force
- Shear Stress

---

**GRAPH DATA**

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<thead>
<tr>
<th>Graph Data</th>
<th>f(d)</th>
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<tr>
<td>Peak</td>
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<tr>
<td>Residual</td>
<td>0.140</td>
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</table>

---

**REFERENCES**

- Actual Shear Load: Re. = 0.83 x Gauge Reading (mm)
- Actual Area = 0.944 cm²
GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

POINT LOAD STRENGTH INDEX TEST MACHINE
FIGURE B.2

GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

SAMPLE SHAPE REQUIREMENTS FOR POINT LOAD STRENGTH INDEX TESTS

Reference: Franklin and Dusseault (1989)
GEOTECHNICAL DATA COLLECTION
FOR EXPLORATION GEOLOGISTS

PORTABLE DIRECT SHEAR TESTING MACHINE

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