Chapter 7

DISCONTINUITY SURVEYS

General

Physical properties of discontinuities generally control the engineering characteristics of a rock mass. Accurate and thorough description of discontinuities is an integral part of geological mapping conducted for design and construction of civil structures. It is improbable that any survey will provide complete information on all the discontinuities at a site. However, properly conducted surveys will furnish data with a high probability of accurately representing the site discontinuities. This chapter discusses discontinuity recording methodology. These recording methods can be applied to outcrops, drill holes, open excavations, and the perimeters of underground openings. The evaluation of discontinuity data is well described in the literature. For example, plotting discontinuity data on stereograms, contouring to determine prominent orientations, and subsequent wedge analyses are described in *Rock Slope Engineering* [1] and *Methods of Geological Engineering in Discontinuous Rock* and *Introduction to Rock Mechanics* [2,3]. Chapter 5, Terminology and Descriptions for Discontinuities, lists data that are typically recorded in discontinuity surveys.

It is extremely important that the actual discontinuity descriptors and measurement units be selected to support the anticipated rock mass classification system(s). Acquiring incomplete or excessive data may limit data usefulness in subsequent analyses, and result in excessive costs due to repeating surveys or from collecting more data than needed.

Empirical Methods for Rock Mass Classification

A number of empirical methods have been developed to predict the stability of rock slopes and underground openings in rock and to determine the support requirements of such features. A method for estimating steel-arch support requirements in tunnels was one of the first [4], and various methods which address open-cut excavations and existing rock slopes have been used since. The Geomechanical Classification (Rock Mass Rating [RMR]) [5,6] and the Norwegian Geotechnical Institute (NGI) (Q-system Classification [Q]) [7] are commonly used. Both of these methods incorporate Rock Quality Designation (RQD) [8]. Since both the RMR and Q-system are based on actual case histories, both systems can be somewhat dynamic, and refinements based on new data are widely suggested. Additional information on RQD, RMR, and the Q-system is provided in chapter 2.

Other predictive methods include the Rock Structure Rating (RSR) [9] and the Unified Rock Classification System (URCS) [10]. Keyblock analysis [11,12] is a means of determining the most critical or key blocks of rock formed by an excavation in jointed, competent rock. An excellent single source of information on the various classification systems is in American Society for Testing Materials Special Technical Publication 984, *Rock Classification Systems for Engineering Purposes*.

Data Collection

Discontinuity data can be collected using areal or detail line survey methods. The areal method, which consists of the spot recording of discontinuities in outcrops within an area of interest, is of limited use in geotechnical analyses. Areal surveys should be applied only for preliminary scoping of a site or in cases where the lateral extent of exposed rock is inadequate to perform detail line surveys. The detail line survey (DLS) method (DLS or line mapping) provides spacial control necessary to accurately portray and analyze site discontinuities. DLS mapping was originally a method of mapping road cuts and open pit excavations. DLS use has been expanded both in scope and types of exposures mapped. Each geologic feature that intercepts a usually linear traverse is recorded. The traverse can be a 100-ft (30 m) tape placed across an outcrop, the wall of a tunnel, a shaft wall at a fixed elevation, or an oriented drill core. In all cases, the alignment of the traverse and the location of both ends of the traverse should be determined. The mapper moves along the line and records everything, as noted in chapter 5, or as needed to support analyses. Feature locations are projected along strike to the tape, and the distance is recorded. Regardless of the survey method, the mapper must obtain a statistically significant number of observations. A minimum of 60 discontinuity measurements per rock type is suggested for confidence in subsequent analyses [14].

The orientation of a discontinuity can be recorded either as a strike azimuth and dip magnitude, preferably using the right-hand rule, or as a dip azimuth and magnitude (eliminating the need for dip direction and alpha characters required by the quadrant system). According to the right-hand rule, the strike azimuth is always to the left of the dip direction. When the thumb of the right hand is pointed in the strike direction, the fingers point in the dip direction. The selected recording method should be used consistently throughout the survey.

Data acquired in a single straight-line survey are inherently biased. The more nearly the strike of a discontinuity parallels the path of a line survey, the less frequently discontinuities with that strike will be recorded in the survey. This is called *line bias*. The number of intersecting discontinuities is proportional to the sine of the angle of intersection. In order to compensate for line bias, a sufficient number of line surveys at a sufficient variety of orientations should be conducted to ensure that discontinuities of any orientation are intersected by at least one survey at an angle of at least 30 degrees. Common practice is to perform two surveys at nearly right angles or three surveys at radial angles of 120 degrees. True discontinuity (set) spacing and trace lengths can be obtained by correcting the bias produced by line surveys [15, 16].

All discontinuities should be recorded regardless of subtlety, continuity, or other property until determined otherwise. Data collection should be as systematic as practicable, and accessible or easily measurable discontinuities should not be preferentially measured. Consistency and completeness of descriptions are also important. Consistency and completeness are best maintained if all measurements are taken by the same mapper and data are recorded on a form that prompts the mapper for the necessary descriptors. A form minimizes the probability of descriptor omission and facilitates plotting on an equal area projection, commonly the Schmidt net (figure 7-1), or entering data for subsequent analysis. Computer programs are available that plot discontinuities in a variety of projections and perform a variety of analyses. Whether the plot format is the equal area projection (Schmidt net) or equal angle projection (Wulff net), evaluation of the plotted data requires an understanding of the method of data collection, form of presentation, and any data bias corrections. References 2 and 3 in the bibliography are good sources of data analysis background information.

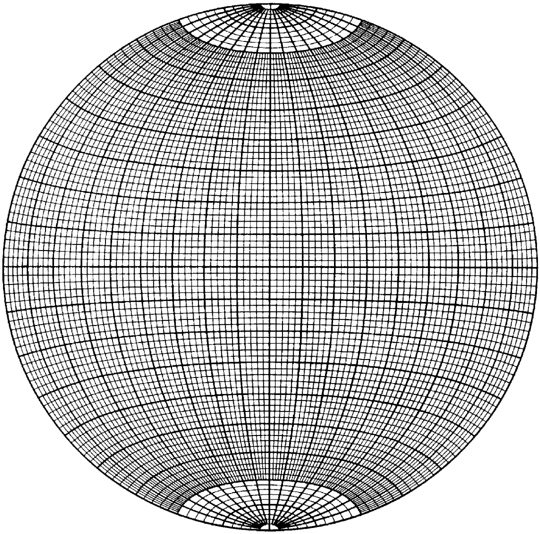

Figure 7-1. Equatorial equal area net (Schmidt net).

Different rock types in the same structural terrain can have different discontinuity properties and patterns, and the host rock for each discontinuity should be recorded. This could be an important factor for understanding subsequent evaluations of tunneling conditions, rock slopes, or the inplace stress field in underground openings.

Figure 7-2 is a form that can be used to record the data in an abbreviated or coded format. Recording these data will provide the necessary information for determining RMR and Q. These codes are derived from the descriptors for discontinuities presented in chapter 5.

DISCONTINUITY LOG

Project: ______________________ Sheet ____ of ____

Date: __________

Feature: ______________________ Location: ______________________ Recorded by: __________

Traverse Id.	Northing (start)	Easting (start)	Elevation (start)	Trend	Plunge	Traverse Length	Tl. No. Obs.	Recording Method: Strike Azimuth and Dip Magnitude * / Dip Azimuth and Dip Magnitude / Feet / Meters

Number	Distance	Rock	Azimuth	Dip	C	E	R	M	H	W	O	T	HL	Notes and Comments

Continuity
- C1 <3 ft. (<1 m)
- C2 3-10 ft (1-3 m)
- C3 10-30 ft (3-10 m)
- C4 30-100 ft (10-30 m)
- C5 >100 ft (>30 m)

Ends
- E0 No ends visible
- E1 One end visible
- E2 Both ends visible

Roughness
- R1 Stepped
- R2 Rough
- R3 Moderately rough
- R4 Slightly rough
- R5 Smooth
- R6 Polished

Moisture
- M1 Dry, not possible
- M2 Dry, no evidence
- M3 Dry, some evidence
- M4 Damp, no free water
- M5 Wet, some drops
- M6 Cont. flow, low pres.
- M7 Cont. flow, high pres.

Wall Hardness
- H1 Extremely hard
- H2 Very hard
- H3 Hard
- H4 Moderately hard
- H5 Moderately soft
- H6 Soft
- H7 Very soft

Wall Weathering
- W1 Fresh
- W2 Slightly weathered to fresh
- W3 Slightly weathered
- W4 Moderately to slightly weathered
- W5 Moderately weathered
- W6 Intensely to moderately weathered
- W7 Intense. weathered
- W8 Very intensely weathered
- W9 Decomposed

Openness
- O0 Tight
- O1 <0.003 ft (<1 mm)
- O2 0.003-0.01 ft (1-3 mm)
- O3 0.01-0.03 ft (3-10 mm)
- O4 0.03-0.1 ft (10-30 mm)
- O5 >0.1 ft (>30 mm)

Thickness
- T0 None
- T1 <0.003 ft (<1 mm)
- T2 0.003-0.01 ft (1-3 mm)
- T3 0.01-0.03 ft (3-10 mm)
- T4 0.03-0.1 ft (10-30 mm)
- T5 >0.1 ft (>30 mm)

Healing
- HL0 completely, to strength of wall rock
- HL2 >50%, or weaker than wall rock
- HL3 <50%
- HL5 No induration

* Dip magnitude follows right-hand rule

Discontinuity Log 14HL
Version 1.0

Figure 7-2. Discontinuity log field sheet.

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