Classifications of some discontinuity features

Discontinuity is any structural or geological feature that changes or alters the homogeneity of a rock, which may be technically joints, bedding planes, minor faults, or other surfaces of weakness such as cleavage and schistosity planes. It excludes major faults, since they are considered as structural regions of their own.
Discontinuities constitute a tremendous range, from structures of up to several kilometres in extent down to a few centimetres, see Figure 1. The two main groups are joints and weakness zones. These are described in the following:

- *Joint* is a discontinuity plane of natural origin along which there has been no visible displacement. Joint is here used as a term for break, fracture, crack, as seen in Figure 1.
- *Singularity* is a small weakness zone or a seam.
- *Weakness zone* is a part or zone in the ground in which the mechanical properties are significantly lower than those of the surrounding rock mass. Weakness zones can be faults, shears / shear zones, thrust zones, weak mineral layers, etc.

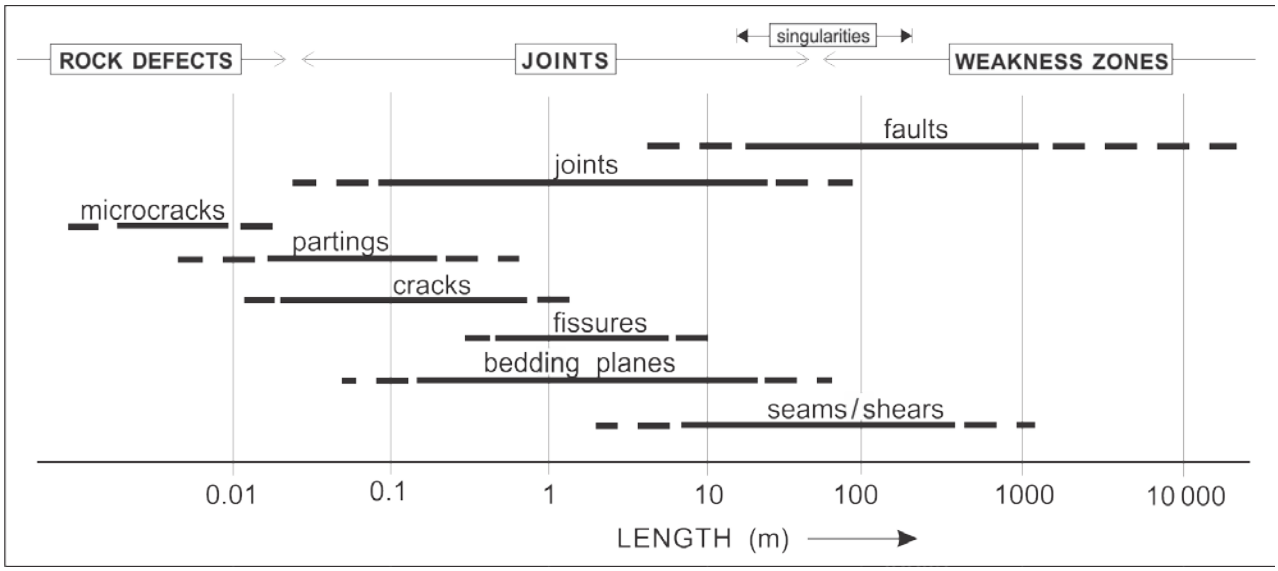

Figure 1: The main types of discontinuities according to size (revised from Palmström, 1995).

Condition of discontinuities includes roughness of the discontinuity surfaces, their separation (distance between the surfaces), their length or continuity (persistence), weathering of the wall rock of the planes of weaknesses, and the infilling (gouge) material. Some of these are classified in the following.

Classification of joint surface smoothness			
a	Very rough	Near vertical steps and ridges occur on the discontinuity surface	*Smoothness* or the nature of the asperities in the discontinuity surfaces.
b	Rough	Some ridge and side-angle steps are evident; asperities are clearly visible; discontinuity surface feels very abrasive	
c	Slightly rough	Asperities on the discontinuity surfaces are distinguishable and can be felt	
d	Smooth	Surface appears smooth and feels so to the touch	
e	Slickensided	Visual evidence of polishing exists	

Classification of joint waviness (undulation)			
a	Planar	Undulation u = a/L < 0.3 % *)	Waviness is defined as large scale undulations/roughness which, if interlocked and in contact, cause dilation during shear displacement since they are too large to be sheared off.
b	Slightly undulating	u = 0.3 – 1 %	
c	Moderately undulating	u = 1 – 3 %	
d	Strongly undulating	u > 3 %	
e	Discontinuous		
*) a = deviation from linear over length (L)			

Classification of joint separation (aperture)			
a	Very tight	A < 0.1 mm	*Separation* is the distance between the discontinuity surfaces. Note that where the separation is more than 25 mm, the discontinuity should be described as a singularity (or major discontinuity).
b	Tight	0.1 – 1 mm	
c	Open	1 – 5 mm	
d	Very open	> 5 mm	

(Infilling material (gouge) prevents the interlocking of the fracture asperities when the thickness of the filling increases to more than approx. 10 mm)

Classification of joint alteration and weathering			
CLEAN OR UNFILLED JOINTS		FILLED JOINTS	
a	Healed or welded joints	g	Friction materials (silt, sand, etc.)
b	Unweathered, fresh joint walls //no filling	h	Hard, cohesive materials (clay, talc, chlorite)
c	Slightly altered joint walls (coloured, stained)	i	Soft, cohesive materials (soft clay)
d	Altered joint wall (no loose material)	j	Swelling clay materials
e	Highly altered // Coating of friction materials (silt, sand, etc.)		
f	Decomposed // Coating of cohesive materials (clay, chlorite, etc.)		

Several joints (jointing)

- *Jointing* is the occurrence of joint sets forming the system or pattern of joints as well as the amount or intensity of joints.
- *Detailed jointing* is the network of joints in the massifs between weakness zones.
- *Degree of jointing / density of joints* is used as the general term for the amount of joints in a rock mass. This includes block size, joint set spacing, joint frequency, rock quality designation (RQD).

Joint spacing and degree of jointing

Joints are found in certain, preferred directions as *joint sets* forming the *jointing pattern*. One to three prominent joint sets and one or more minor sets often occur; in addition several individual or *random joints* may be present.

Joint set spacing is the distance between individual joints within a joint set.

Joint spacing and *average joint spacing* are often used in the description and assessments of rock masses. Note: The term "joint spacing" does not clearly indicate whether it is the "joint intercept" or the "joint set spacing". Thus, there is often much confusion related to the use of joint spacing, which often leads to errors or inaccurate description / characterization and hence on the calculation results.

Joint intercept is drill lengths of core pieces between the joint. This is seldom true joint set spacings, as joints of different sets are included in the measurement. In addition, random joints, which do not necessarily belong to any joint set, may occur.

Classification of density of joints, volumetric joint count, and block volume, related to particle size of soil							
DEGREE OF JOINTING (or DENSITY OF JOINTS)	**VOLUMETRIC JOINT COUNT**		**BLOCK VOLUME**		**SOIL PARTICLES** *)	
	TERM	Jv	TERM	Vb	TERM	VOLUME
Massive / no joints	extremely low	< 0.3	extremely large	>1000 m^3		
Massive / very weakly jointed	very low	0.3 - 1	very large	30 - 1000 m^3		
Weakly jointed	low	1 - 3	large	1 - 30 m^3		
Moderately jointed	moderately high	3 - 10	moderate	0.03 - 1 m^3	blocks	> 0.1 m^3
Strongly jointed	high	10 - 30	small	1 - 30 dm^3	boulder	5 - 100 dm^3
Very strongly jointed	very high	30 - 100	very small	0.03 - 1 dm^3	cobbles	0.1 - 5 dm^3
Crushed	extremely high	> 100	extremely small	< 30 cm^3	coarse gravel	5 - 100 cm^3

*) $V = 0.58\ d^3$ has been applied for the correlation between particle volume and particle diameter

Classification of RQD			
TERM		**RQD**	RQD is mainly a measure for the degree of jointing, originally linked to drill core logging. Although RQD is a quick and inexpensive index, it has limitations such as the disregarding of joint orientation, tightness, and gouge (infilling) material. Consequently, while it is a practical parameter for core quality estimation, it is not sufficient on its own to provide an adequate description of a rock mass.
a	Very poor	< 25	
b	Poor	25-50	
c	Fair	50-75	
d	Good	75-90	
e	Excellent	90-100	

Classification of the block shape factor				
Type of block		**Block shape factor**	(average)	The block shape factor is a numerical indication of the block shape; whether it is flat, long or cubical
a	Cubical (equidimensional) blocks	β = 27 - 32	(30)	
b	Slightly long or flat blocks	β = 32 - 50	(40)	
c	Moderately long or flat blocks	β = 50 - 100	(72)	
d	Very long or flat blocks	β = 100 - 500	(270)	
e	Extremely long or flat blocks	β > 500	(720)	