Observation of weakness zones

Fault is a major rupture zone ranging in width from decimetre to more than hundred metres, occasionally thousand metres. The walls are often striated and polished (slickensided) resulting from the shear displacement. Frequently rock on both sides of a fault is shattered and altered or weathered, resulting in fillings such as breccia and gouge.

To be characterised as 'fault' it is thus required that there is a proof of movement.

Fault zone is in this paper a fault of significant size, having marked impact of excavation and support in an underground construction.

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 fault zones, shear zones, thrust zones, weak rock or mineral layers, etc.

Gouge is clay-like material occurring between the walls of a fault as a result of the movements along the fault surfaces.

Most faults and fault zones are the result of numerous ruptures throughout geological time. Weathering, hydrothermal activity and alteration are also features that may have had a significant impact on the composition and properties of a zone. They often form characteristic patterns in the earth's crust consisting of several independent sets or systems, see Figure 1.

The fact that faults and weakness zones can have a major impact upon the stability as well as on the excavation process of an underground opening, necessitates special attention in investigations during planning to predict and, if possible, avoid such events.

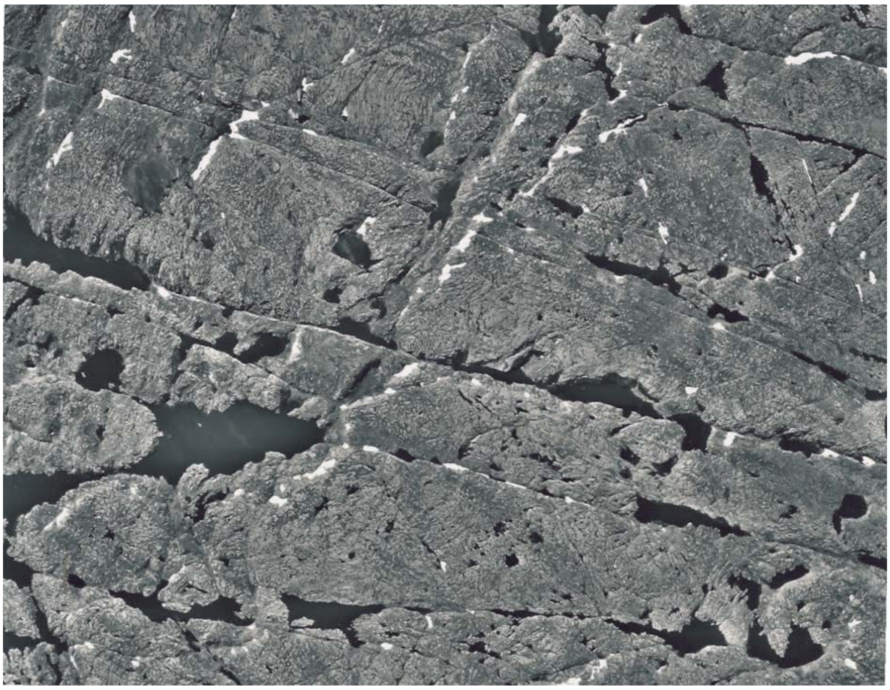
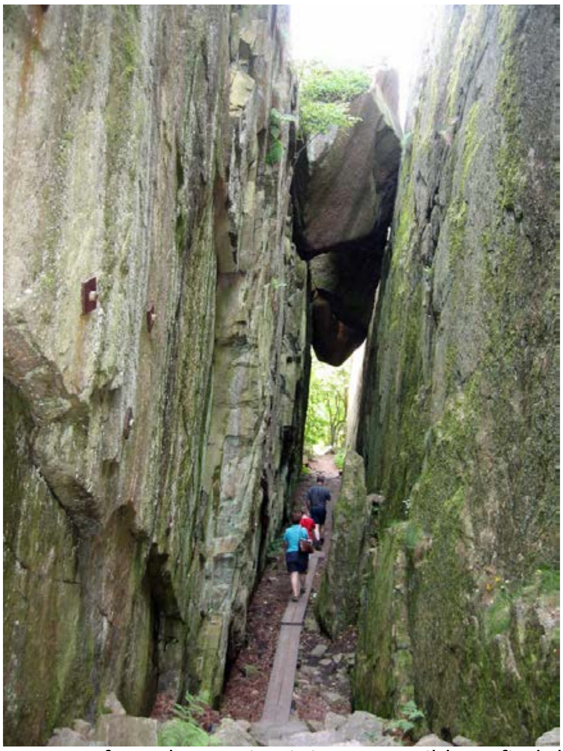


Figure 1:
Pattern of weakness zones (and singularities) occurring at the terrain surface. These are seen as distinct lines being more eroded than the surrounding rocks.

<u>Size</u>

Minor faults normally range in thickness from decimetre to a metre; major faults from several metres to hundreds of metres. The thickness of a weakness zone can be difficult to measure in the terrain surface as the zone is mostly covered and weathered, but an estimation may be possible from the topographical picture (see Figures 2 and 3).



Figures 2 and 3: A deep cleft eroded in a weakness zone. From surface observation it is not possible to find the composition of the zone. The width of the cleft indicates the approximate size (thickness) of the zone.

Figure 4: A small coarse fragmented weakness zone in a tunnel wall. White traces are filling of clay material.

Figure 5: Weakness zone encountered in a core drill hole. There is limited information on the structure of the zone, but in this case the material in the zone has been recovered. Part of the zone contains crushed material, other part (at the end in the box filling of soft material.

<u>Filling</u>

The filling includes materials derived from breakage of the country rock due to movements (as in crushed zones and breccias), in situ weathered or altered materials (i.e. alteration products), infilling materials deposited between the structural planes (such as calcite), and also intruded igneous materials which are different from the host rock. A filling can, therefore, consist of several different minerals and materials. The main groups of filling materials are shown in Table 1. Figures 4 and 5 show examples of weakness zones with filling.

Table 1: Main types of coating and filling materials in joints and seams and their properties.

FILLING MATERIALS IN JOINTS		PROPERTIES
FRICTIONAL MATERIALS	Calcite	May dissolve, particularly when being porous or flaky.
	Gypsum	May dissolve.
	Epidote, quartz	May cause healing or welding of the joint.
	Zeolite	May slake.
	Sandy or silty materials	Cohesionless, friction materials.
COHESIVE MATERIALS	Chlorite, talc, graphite	Very low friction materials, in particular when wet.
	Inactive clay materials	Weak, cohesion materials with low friction properties.
	Swelling clay	Exhibits a very low friction and loss of strength together with high swelling pressure.

Table 2: The division of weakness zones applied in the Q-system

Single shear zone
Multiple clay-free shear zones
Single weakness zone with clay
Multiple, complex weakness zones
Loose, open crushed zones
Heavily jointed ("sugar cube")

Table 3: Qualitative classification of weakness zones (revised from Palmstrom, 1995)

TYPES OF WEAKNESS ZONES	OCCURRENCE AND FORMATION
I. Zones of weak materials	Many of the zones of weak materials are only regarded as weakness zones if they are surrounded by other, stronger rock masses.
A. Layers of soft or weak minerals and rocks - clay materials - mica, talc, or chlorite layers and lenses - coal seams	The (weak) material in these zones may consist of clay, pegmatite, mica or chlorite, poorly cemented sedimentary layers (for example tuff layers in basalts), or coal layers. The zone has often a sharp boundary to the adjacent stronger rocks.
B. Weathered rock mass	Also weathered rock mass belong to this group. The weathering process has often acted along rock layers, dykes or rock contacts, or along joints, seams, and crushed zones to form zones, layers or pockets of weathering products with low mechanical properties.
II. Faults and fault zones	These zones are the result of numerous ruptures throughout geological time and that their composition and magnitude may vary largely.
C. Tension fault zones - feather joints and filled zones,	Tension fault zones are often developed with a filling of soft minerals between parallel walls. The filling material can be chlorite, (swelling) clay, porous calcite, silt etc. Such zones are named according to the dominant filling. Feather or pinnate zones ("*fiederspalten*") belong to this group. There is generally a sharp boundary to the adjacent rocks.
D. Shear fault zones - coarse-fragmented, crushed zones - small-fragmented, crushed zones - sand-rich crushed zones - clay-rich, crushed zones - foliation shears	Shear fault zones are crushed and brecciated by many intersecting joints and/or seams. Their central part may sometimes be weathered or completely altered to clay. These zones can vary in width from a few centimetres to several metres. Where shear zones occur parallel with the foliation, typically along weak mica-rich schist layers, they are often termed *foliation shear zones*.
E. Altered faults - altered, clay-rich zones - altered, leached (crushed) zones - altered veins/dykes	Alteration of faults may take place in most types of the zones described above. The alteration processes may occur during the formation of the zone and/or later.
F. Recrystallized and cemented or welded zones	Recrystallization may cause significant changes to the composition, properties and behaviour of a weakness zone. These types, which probably earlier have been crushed zones, are still geologically named faults or thrust zones. They often have some slickensided and clay filled joints, with secondary formed minerals of epidote, quartz, feldspar, etc. which have "welded" the blocks and 'reinforced' the zone.

Types of weakness zones

There are numerous occurrences of weakness zones, often with complex composition and structure. Tables 2 and 3 present crude classifications, only of a few of the many variations of weakness zones.

Description of weakness zones

It is very important to make a good description of a weakness zone where it can be observed and studied in the tunnel or in a cutting. The reason is that this description often forms a major part in stability evaluations and the required rock support. The main features are:

- Composition of the zone: its centre part, the transition part, plus the adjacent rockmasses
- Geometry and structure
- Filling materials and properties (strength, swelling, slaking, etc.) of these
- Alteration of central part and of adjacent rockmasses
- Size (thickness)
- Interlocking
- Orientation
- Type of zone

The Rock Engineering book presents more on weakness zones.

References

Palmström A. (1995): RMi - a rock mass characterization system for rock engineering purposes. Ph.D. thesis Univ. of Oslo, 400 p. http://www.rockmass.net

Selmer-Olsen R. (1971): Engineering geology. Part 1 (in Norwegian). Tapir publishers, Trondheim, Norway, 230 p.