CLASSIFICATION // CHARACTERIZATION OF SOME ROCK FEATURES

Engineering characteristics of main rock material:
- Geological name, (type of rock)
- Orientation of foliation/bedding/layering
- Anisotropy, (schistosity, foliation, bedding)
- Weathering or alteration
- Strength

Other characteristics of rocks:
- Folding, colour, mineral size and texture, porosity, density

Name the rock material is given according to the geological classification based on mineral content, texture, mineral size and origin (sedimentary, igneous, metamorphic). For various other purposes, including those for engineering usage, rocks have been classified on the basis of their properties, such as strength, void index, degree of weathering, etc.

Rock outlook

Colour is one of the most obvious characteristics of a rock stratum and therefore one of the most basic and useful in the description of a rock to both the specialist and layman alike. It often provides an excellent guide for rock strata correlation and may be used to identify various "marker" horizons. Colour variation is a primary indication of weathering.

The rock colour is can be described as its predominant colour i.e. brown, green, red, pink, khaki. Where a secondary colour is also evident this colour can be included in the description as an adjective i.e. reddish brown, greyish green, yellowish khaki. Where significant, the colour should be further amplified by using the following descriptions for value: very light, light, medium, dark, very dark i.e. dark reddish brown, light yellowish khaki.

The *schistosity* may be divided into:

1. Strong schistosity -well developed schistosity, less than 0.5 cm between schistose planes.
2. Moderate schistosity – 0.5-5.0 cm schistosity planes spaced.
3. Weak schistosity – schistosity weakly developed.

Minerals

Minerals can be classified according to their chemical composition or Moh's hardness scale, see Figure 1. Rocks are composed of assemblages of minerals. The arrangement and size of the individual grains of these minerals give the rock an individual form or *texture*. Figure 2 shows a classification of the mineral texture in rocks which may be useful in rock engineering.

Since the size or arrangement of the individual minerals can affect the physical properties of the rock such as permeability or angle of internal friction, it is necessary to describe them so that their engineer-log significance can be assessed.

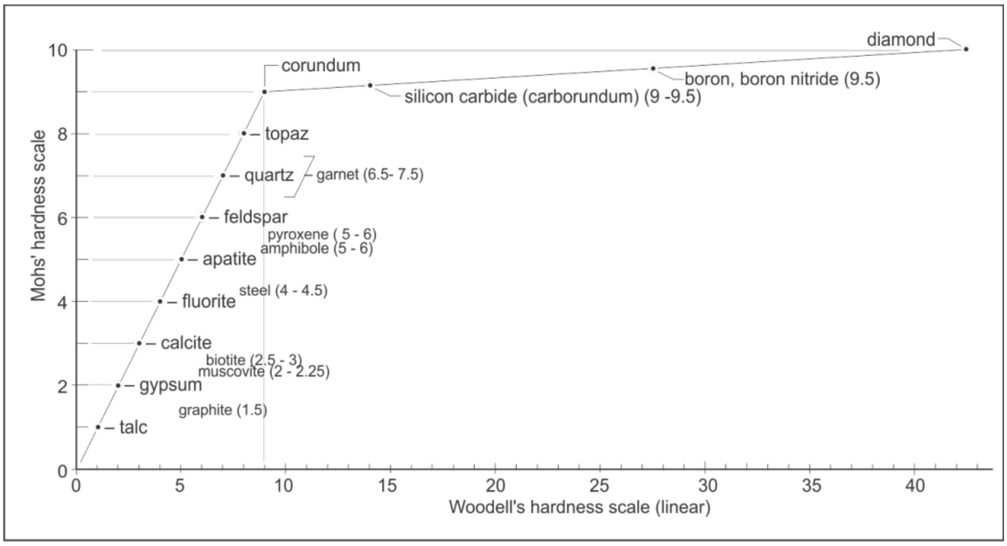

Figure 1: Hardness of some minerals. More can be found in textbooks, e.g. Dana's Manual of Mineralogy. John Wiley & sons, 609 p.

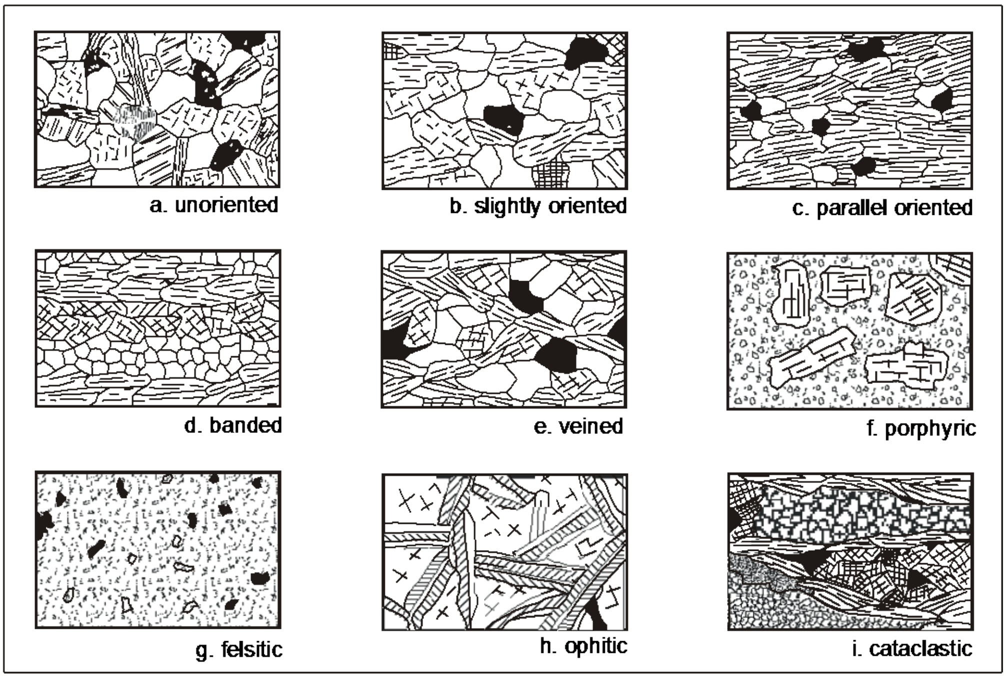

Figure 2: Characterization of mineral texture in rocks (from NBG (1985, 2000)

Mineral size, or grain size in sedimentary rocks, is a noticeable textural feature. The classification in Table 1 is been based on visual identification using a hand lens. For metamorphic and igneous rocks the same reasoning is applicable, with a grain size qualification only being necessary in the coarser grained rocks.

Table 1: Classification of mineral size (from 'A guide to core logging for rock engineering', 1976, 15 p.)

DESCRIPTION	SIZE IN mm	RECOGNITION	EQUIV. SOIL TYPE
Very fine grained	<0.06	Individual grains cannot be seen with a hand lens	Clays & Silts
Fine grained	0.06 - 0,2	Just visible as individual grains under hand lens	Fine sand
Medium grained	0.2 – 0.6	Grains clearly visible under hand lens, just visible to the naked eye	Medium sand
Coarse grained	0.6 – 2.0	Grains clearly visible to naked eye	Coarse sand
Very Coarse Grained	>2.0 -	Grains measureable	Gravel

Table 2: Goodman's engineering classification of rocks (from Goodman, 1989)

ENGINEERING CLASSIFICATION OF ROCKS	EXAMPLES
I Crystalline texture	
A. Soluble carbonates and salts	Limestone, dolomite, marble, rock salt, gypsum
B. Mica or other planar minerals in continuous bands	Mica schist, chlorite schist, graphite schist
C. Banded silicate minerals without continuous mica sheets	Gneiss
D. Randomly oriented and distributed silicate minerals of uniform grain size	Granite, diorite, gabbro, syenite
E. Randomly oriented and distributed silicate minerals in a background of very fine grain and with vugs	Basalt, rhyolite, other volcanic rocks
F. Highly sheared rocks	Serpentinite, mylonite
II Clastic texture	
A. Stably cemented	Silica-cemented sandstones and limonite sandstones
B. With slightly soluble cement	Calcite-cemented sandstone and conglomerate
C. With highly soluble cement	Gypsum-cemented sandstone and conglomerate
D. Incompletely or weakly cemented	Friable sandstone, tuff
E. Uncemented	Clay-bound sandstones
III Very fine-grained rocks	
A. Isotropic, hard rocks	Hornfels, some basalts
B. Anisotropic on a macro scale, but microscopically isotropic hard rocks	Cemented shales, flagstones
C. Microscopically anisotropic hard rocks	Slate, phyllite
D. Soft, soil-like rocks	Compaction shale, chalk, marl
IV Organic rocks	
A. Soft coal	Lignite and bituminous coal
B. Hard coal	
C. "Oil shale"	
D. Bituminous shale	
E. Tar sand	

Weathering / alteration of rock

The process of weathering/alteration is by means of mechanical, chemical and biological action which drastically affects the engineering properties of both the rock material and the rock mass. Some of the more important effects of weathering/alteration on rock are the decrease in strength, density and volumetric stability and the increase in deformability, porosity and weatherability.

Table 3: The classification of weathering/alteration is as follows:

Term *)	**Description**
Unweathered/unaltered	No visible signs of alteration in the rock material out fracture planes may be stained or discoloured.
Slightly weathered /altered	Fractures are stained or discoloured and may contain a thin filling of altered material. Discolouration may extend into the rock from the fracture planes to a distance of up to 20% of the fracture spacing (i.e. less than 4o% of the core is discoloured).
Medium weathered/altered	Slight discolouration extends from fracture planes for a distance greater than 20% of the fracture spacing (i.e. generally greater part of the rock). Fractures may contain filling of altered material. The surface of the core is not friable (except in the case of poorly cemented sedimentary rocks) and the original texture of the rock has been preserved. Partial opening of grain boundaries may be observed.
Highly weathered/altered	Discolouration extends throughout the rock. The surface of the core is friable and usually pitted due to washing out of highly altered minerals by drilling water. The original texture of the rock has mainly been preserved but separation of grains has occurred.
Completely weathered/altered	The rock is totally discoloured and the external appearance of the core is that of a soil. Internally the rock texture is partly preserved but grains have completely separated.

The term "weathered" (decay caused by influence from weather (at the surface)) is often used where the correct term is "altered".

Table 4 may be used to find the approximate degree of weathering / alteration.

Table 4. Guide to describe the degrees of weathering

DIAGNOSTIC FEATURE / DESCRIPTION TERM	DISCOLOURATION EXTENT	FRACTURE CONDITION	SURFACE CHARACTERISTICS	ORIGINAL TEXTURE	GRAIN BOUNDARY CONDITION
UNWEATHERED	NONE	CLOSED OR DISCOLOURED	UNCHANGED	PRESERVED	TIGHT
SLIGHTLY WEATHERED	20% OF FRACTURE SPACING ON BOTH SIDES OF FRACTURE	DISCOLOURED MAY CONTAIN THIN FILLING	PARTIAL DISCOLOURATION	PRESERVED	TIGHT
MEDIUM WEATHERED	20% OF FRACTURE SPACING ON BOTH SIDES OF FRACTURE	DISCOLOURED MAY CONTAIN THICK FILLING	PARTIAL TO COMPLETE DISCOLOURATION NOT FRIABLE EXCEPT POORLY CEMETED ROCKS	PRESERVED	PARTIAL
HIGHLY WEATHERED	THROUGHOUT	-	FRIABLE AND POSSIBLY PITTED	MAINLY PRESERVED	PARTIAL SEPARATION
COMPLETELY WEATHERED	THROUGHOUT	-	RESEMBLES A SOIL	PARTLY PRESERVED	COMPLETE SEPARATION

<u>An example</u>:
Grey, slightly weathered fine grained, medium jointed hard dolerite rock. (Core loss and fracture filling suggest rock mass is highly weathered to spheroidal boulders. 50% boulders + 50% matrix not recovered)

The *secondary colouration* of the rock can be an indicator of the degree of weathering/alteration. It has usually a characteristic geometric pattern which may be described by one of the following terms:

banded	approximately parallel bands of varying colour.
streaked	randomly orientated streaks of colour
blotched	large irregular patches of colour (>75 mm ø)
mottled	irregular patches of colour
speckled	very small, less than 10 mm diameter, patches of colour
stained	local colour variations associated with other features, i.e. bedding, joints, etc.

Examples of rock descriptions are:

- Light yellowish green streaked grey**,** unweathered intensely laminated widely fractured medium hard rock mudstone
- Dark greyish green speckled white**,** slightly weathered very fine grained medium fractured very hard rock amygdaloidal andesite

Where ***slaking*** of the core is observed or suspected, its nature and degree should be recorded after the description of the basic parameters.

Intact rock strength

The uniaxial compressive strength of a rock material constitutes the highest strength limit of the rock mass of which it forms a part. It is determined in accordance with the standard laboratory procedures. For the purpose of rock mass classification, the use of the well-known point load strength index can be useful as the index can be determined in the field on rock core retrieved from borings and the core does not require any specimen preparation.

Knowing the rock type and rock material hardness, it is possible for the experienced engineer or engineering geologist to make fairly accurate estimates on rock material strength. These can be readily verified by uniaxial compressive strength or point load tests. A simple estimate can be made from the field test in Table 5. The hammer tests should be made with a 2-lb hammer on pieces about 4 in. (10 cm) thick placed on a solid, hard surface, and tests with the hands should be made on pieces about 1.5 in. (4 cm) thick. The pieces must not have incipient fractures, and therefore several should be tested. The sound tests, which are only accessory, should be made on solid outcrops or on fragments thicker than 1 ft (0.3 m).

Table 5. Field classification of rock hardness

CLASSIFICATION	FIELD TEST	RANGE OF COMPRESSSIVE STRENGTH (MPa)
Very soft rock	Can be peeled with a knife, material crumbles under firm blows with the sharp end of a geological pick.	1 - 3
Soft rock	Can just be scraped with a knife, indentations of 2 to 4 mm with firm blows of the pick point.	3 - 10
Medium hard rock	Cannot be scraped or peeled with a knife, hand held specimen breaks with firm blows of the pick.	10 - 25
Hard rock	Point load tests must be carried out in order to distinguish between these classifications. These results may be verified by uniaxial compressive strength tests on selected samples.	25 - 70
Very hard rock		70 - 200
Extremely hard rock		>200

Table 6: The classification of rock strength used by Bieniawski (1989)

Intact rock strength (MPa)	extremely low	very low	low	moderate	medium	high	very high
Uniaxial compr. strength σ_c =	< 1	1 - 5	5 - 25	25 - 50	50 - 100	100 - 250	> 250
Point load strength Is =				1 - 2	2 - 4	4 - 10	> 10

It should be noted that the boundary between rock and soil is defined in terms of the uniaxial compressive strength and not in terms of weathering. A material with the strength ≤ 1 MPa is considered as a rock.

A SCALE OF STRENGTH

1. *Loose.* Sediment flows when dry and thus cannot be sampled in aggregate.
2. *Very friable.* Sediment crumbles so easily that pieces are difficult to collect intact.
3. *Friable.* Sediment crumbles under light pressure in the hands.
4. *Somewhat friable.* Rock breaks in the hands under moderate pressure.
5. *Firm, slightly friable.* Rock breaks with difficulty in the hands but readily by hammer blows, sounding a dull "whop"
6. *Weak, nonfriable.* Rock cannot be broken in the hands but breaks under light hammer blows, sounding "whop"
7. *Moderately strong.* Rock breaks under moderate hammer blows, sounding "whap"
8. *Strong.* Rock breaks under hard hammer blows, sounding "whack," with a ring.
9. *Very strong.* Rock difficult to break with hammer, sounding "boink."
10. *Unusually strong.* Rock impossible to break with hammer, sounding like steel.

A SCALE OF ROCK HARDNESS

1. *Soft.* All rocks weaker than 5 on the scale-of-strength above.
2. *Moderately hard.* Slightly friable or nonfriable rocks consisting mainly of soft minerals, as carbonates, sulfates, micas, and clays.
3. *Hard.* Nonfriable rocks consisting almost entirely of minerals with hardnesses of 4, 5, or 6 on the Mohs scale, and quartz-rich rocks with strength of 6 or 7.
4. *Very hard.* Rocks stronger than 7 on the scale above and consisting mainly of minerals harder than 6 on the Mohs scale.

Table 7: 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 swelling pressure.