

On weathering and alteration of rocks

Weathering refers to the various processes of physical disintegration and chemical decomposition that occur when rocks at the Earth's surface are subjected to physical, chemical, and biological processes induced or modified by wind, water, and climate. These processes produce soil, unconsolidated rock detritus, and components dissolved in groundwater and runoff.

Alteration is a process, which involves changes in the composition of the rock, most often caused by hydrothermal solutions or chemical weathering.

Both processes, which generally first affect the walls of the discontinuities, lead to deterioration of the rock material with a reducing effect on its strength and deformation properties, may completely change the mechanical properties and behaviour of rocks. The main results of rock weathering and alteration are:

1. Mechanical *disintegration* or breakdown, by which the rock loses its coherence, but has little effect upon the change in the composition of the rock material. The results of this process are:
 - The opening up of joints.
 - The formation of new joints by rock fracture, the opening up of grain boundaries.
 - The fracture or cleavage of individual mineral grains.

Disintegration involves the breakdown of rock into its constituent minerals or particles with no decay of any rock-forming minerals. The principal sources of physical weathering are thermal expansion and contraction of rock, pressure release upon rock by erosion of overlaying materials, the alternate freezing and thawing of water between cracks and fissures within rock, crystal growth within rock, and the growth of plants and living organisms in rock. *Rock alteration* usually involves *chemical weathering* in which the mineral composition of the rock is changed, reorganized, or redistributed. The rock minerals are exposed to solution, carbonation, hydration, and oxidation by circulating waters. These effects on the mineral decomposition are added to the effects of living organisms and plants as nutrient extraction to alter rock. Several factors control the type of weathering and

2. Chemical *decomposition*, which involves rock decay accompanied by marked changes in chemical and mineralogical composition. It influences the joints as well as the rock material and results in:
 - Discolouration of the rock.
 - Decomposition of complex silicate minerals (feldspar, amphibole, pyroxene, etc) eventually producing clay minerals; some minerals, notably quartz, resist this action and may 'survive' unchanged.
 - *Leaching* or solution of calcite, anhydrite and salt minerals.

Both weathering and alteration produce changes of the mineralogical composition of a rock that result in reduction of the mechanical properties of a rock. Deterioration from weathering and alteration generally affects the walls of the discontinuities more than the interior of the rock (Piteau, 1970).

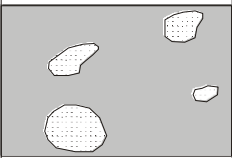
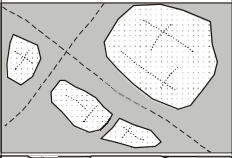
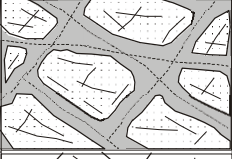
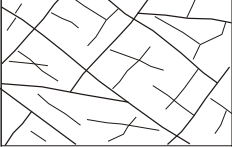
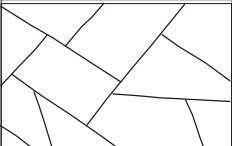
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In general, the degree of weathering is usually estimated from visual observations. The tables below show different classifications of weathering/alteration. A more precise characterization of alteration and weathering can be found from analysis of thin sections in a microscope.

From Geoguide 3: Guide to rock and soil descriptions, Hong Kong, 1988

Grade		Rock characteristics	Ground behaviour
VI	Residual soil	Original rock texture completely destroyed Can be crumbled by hand and finger pressure into constituent grains	soil
V	Completely decomposed	Original rock texture preserved Can be crumbled by hand and finger pressure into constituent grains Easily indented by point of geological pick Slakes when immersed in water Completely discoloured compared with fresh rock	soil, probably with clay properties
IV	Highly decomposed	Can be broken by hand into smaller pieces Makes a dull sound when stuck by geological pick Does not slake when immersed in water Completely discoloured compared with fresh rock	mixed ground
III	Moderately decomposed	Cannot usually be broken by hand; easily broken by geological hammer Makes a dull or slight ringing sound when stuck by geological hammer Completely stained throughout	
II	Slightly decomposed	Not broken easily by geological hammer Makes a ringing sound when stuck by geological hammer Fresh rock colours generally retained but stained near joint surfaces	rock mass
I	Fresh	Not broken easily by geological hammer Makes a ringing sound when stuck by geological hammer No visible signs of decomposition (i.e. no discolouration)	

Partly from Zulfu Gurocak and Recep Kilic (2005): Effect of weathering on the geomechanical properties of the Miocene basalts in Malataya, Eastern Turkey. Bull. Eng.Geol. Env. 64: (373-381)

		ISRM (1981)	
ROCK AND SOIL		V	Completely weathered
		IV	Highly weathered
		III	Moderately weathered
ROCK		II	Slightly weathered
		I	Unweathered (fresh)

Engineering classification of the weathering of rocks (from Lama and Vutukuri, 1978)

CLASSIFICATION	DESCRIPTION
Unweathered	No visible signs of weathering. Rock fresh, crystals bright. Few discontinuities may show slight staining.
Slightly weathered	Penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material. Discontinuities are discoloured and discoloration can extend into rock up to a few mm from discontinuity surface.
Moderately weathered	Slight discoloration extends through the greater part of the rock mass. The rock is not friable (except in the case of poorly cemented sedimentary rocks). Discontinuities are stained and/or contain a filling comprising altered materials.
Highly weathered	Weathering extends throughout rock mass and the rock material is partly friable. Rock has no lustre. All material except quartz is discoloured. Rock can be excavated with geologist's pick.
Completely weathered	Rock is totally discoloured and decomposed and in a friable condition with only fragments of the rock texture and structure preserved. The external appearance is that of a soil.
Residual soil	Soil material with complete disintegration of texture, structure and mineralogy of the parent rock.

Weathering/alteration (from ISRM, 1978)

GRADE and TERM	DESCRIPTION (from ISRM, 1978)
I Fresh	No visible sign of rock material weathering.
II Slightly weathered	Discolouration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker externally than in its fresh conditions.
III Moderately weathered	Less than half the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.
IV Highly weathered	More than half the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

From Geoguide 3: Guide to rock and soil descriptions, Hong Kong, 1988

Grade	Rock characteristics	Ground behaviour
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Terminology for Classification of Rock Weathering

Terminology of weathering and alteration recommended by the Geological Society of London (1970) and accepted by U.S. Task Committee for Foundation design Manual (1972))

Term	Description
Unweathered, or Fresh	No visible sign of weathering. Rock fresh, crystals bright. A few discontinuities may show slight staining.
Slightly weathered	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material. Discontinuities are discoloured and discolouration can extend into rock up to a few millimetres from discontinuity surface.
Moderately weathered	Slight discolouration extends through greater part of rock mass. The rock is not friable. Discontinuities are stained and/or contain a filling comprising altered material.
Highly (or severely) weathered	Weathering extends throughout rock mass and the coloured material is partly friable. Rock has no lustre. All material except quartz is discoloured. Rock can be excavated with geologist's pick.
Completely weathered	Rock is totally discoloured and decomposed and in a friable condition with only fragments of rock texture and structure preserved. The external appearance is that of a soil.
Residual Soil	Soil material with complete disintegration of texture, structure and mineralogy of parent rock.