Rock Mechanics

Rock and Rock Mass

Introduction

What is Rock Mechanics?

Rock mechanics is a discipline that uses the principles of *mechanics* to describe the behaviour of *rock* of engineering scale.

Introduction

Rock at engineering scale is *D*iscontinuous, *I*nhomogeneous, *A*nisotropic, and *N*on-linearly *E*lastic.

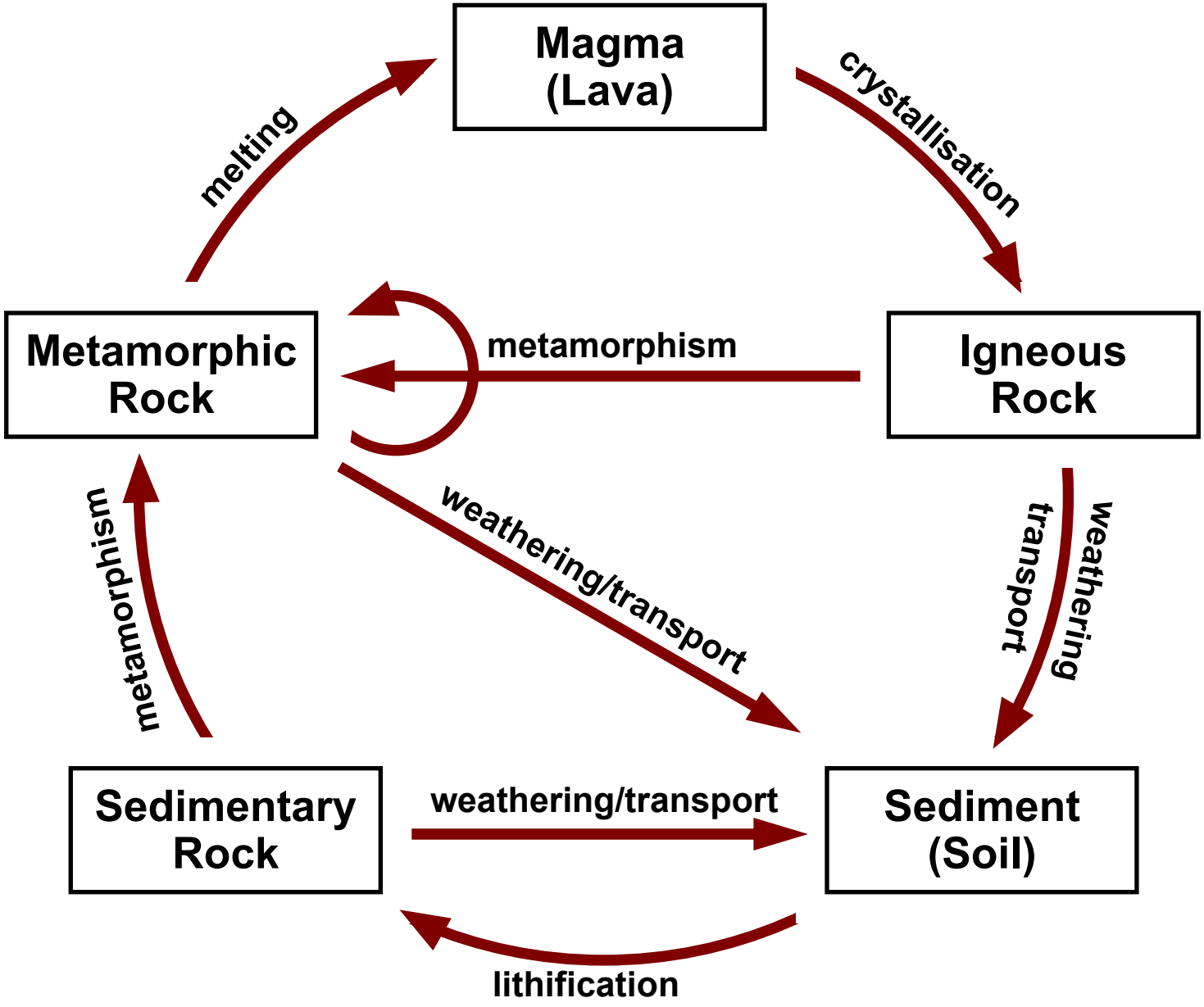
Rock mechanics deals with the response of rock when the boundary conditions are *disturbed* by engineering .

Rock Formation

Origin of Rock

Rock is a natural solid substance composed of minerals.

Rocks are formed by three origins: *igneous* rocks from magma, *sedimentary* rock from sediments lithification and *metamorphic* rocks through metamorphism, as illustrated by the rock cycle.


Magma
(Lava)
crystallisation
Igneous
Rock
weathering
transport
Sediment
(Soil)
weathering/transport
Sedimentary
Rock
lithification
metamorphism
Metamorphic
Rock
melting
metamorphism
weathering/transport

Rock Formation

Minerals

Rocks are composed of minerals, primarily silicates. Important rock-forming silicates are feldspars, quartz, olivines, pyroxenes, amphiboles, garnets, and micas.

Minerals have different properties, crystal structure, hardness and cleavage influence rock properties.

In rock, mineral crystals are often massive, granular or compact, and only microscopically visible.

Rock Formation

Igneous Rocks

Igneous rocks are formed when molten rock (magma) cools and solidifies, with or without crystallization.

They can be formed (i) below the surface as intrusive (plutonic) rocks, or (ii) on the surface as extrusive (volcanic) rocks. Intrusive is generally coarse grained and extrusive fine grained.

They can also have different mineral contents.

	Granitic (acid) (felsic)	Andesitic (intermediate)	Basaltic (basic) (mafic)	Ultramafic (ultrabasic)
Intrusive (coarse grain)	Granite	Diorite	Gabbro	Peridotite
Extrusive (fine grain)	Rhyolite	Andesite	Basalt	None
Silica Content	>65% Silica	50-65% Silica	40-50% Silica	<40% Silica
Main Mineral Composition	Quartz Orthoclase N-Plagioclase	Amphibole Plagioclase Biotite	Ca-Plagioclase Pyroxene	Olivine Pyroxene
Minor Mineral Composition	Muscovite Biotite Amphibole	Pyroxene	Olivine Amphibole	Ca-Plagioclase
Colour	Light	→		Dark

Sedimentary Rocks

Sedimentary rock is formed in three main ways:
(i) deposition of the weathered remains of other rocks (known as 'clastic' sedimentary rocks);
(ii) deposition of the results of biogenic activity; and
(iii) precipitation from solution.

Clastic sedimentary rocks are commonly classified by grain size.

Particle size	Comments	Rock name
> 2 mm	Rounded rock fragment	Conglomerate
	Angular rock fragment	Breccia
1/16 - 2 mm	Quartz with other minerals	Sandstone
< 1/16 mm	Split into thin layers	Shale
	Break into clumps or blocks	Mudstone

Metamorphic Rocks

Metamorphic rock is a new rock transformed from an existing rock, through metamorphism – change due to heat and pressure.

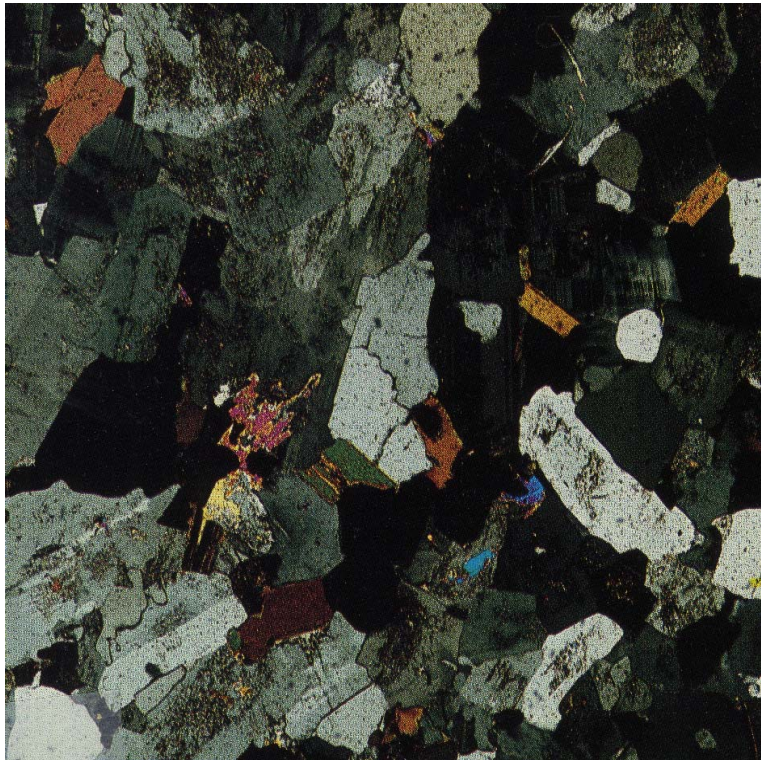
Metamorphic rocks can have foliated and non-foliated textures. Foliation is due to the re-orientation of mica minerals, creating a plane of cleavage or visible mineral alignment feature.

Rock	Texture	Metamorphic grade	Original parent rock
Slate	Foliated	Low grade	Shale (clay minerals)
Phyllite	Foliated	Low to intermediate grade	Shale
Mica schist	Foliated	Low to intermediate grade	Shale
Chlorite schist	Foliated	Low grade	Basalt
Gneiss	Foliated	High grade	Granite, shale, andesite
Marble	Non-foliated	Low to high grade	Limestone, dolomite
Quartzite	Non-foliated	Intermediate to high grade	Quartz sandstone

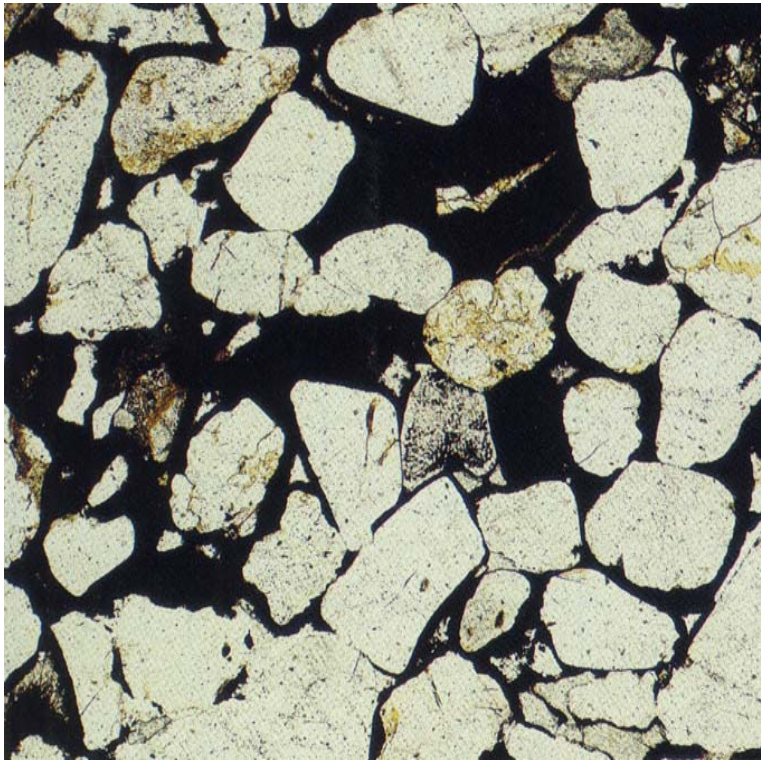
Rock Textures

The interlocking microstructures of igneous and metamorphic rocks lead to generally high strength of rock material, while the clastic microstructures of sedimentary rocks often lead to low rock material strength, particularly when cementation is weak.

Any existing weakness in a rock material matrix (microcracks, pores, and weak grains and cementation) also weakens the rock material.



Interlocking structure of a granite



Clastic structure of a sandstone

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Rock Discontinuities

Rock Joints

Joints are the most common rock discontinuity. They are normally in parallel sets.

They are generally considered as part of the rock mass. The spacing of joints is usually in the order of a few to a few ten centimetres. For engineering, joints are constant features of the rock mass.

Rock Discontinuities

Faults

Faults are planar rock fractures which show evidence of relative movement. Faults have different scale and the largest faults are at tectonic plate boundaries. Faults usually do not consist of a single, clean fracture, they often form fault zones.

Large scale fault, fault zone and shear zone, are large and localised features. They are often dealt separately from the rock mass.

Folds

Fold is the bended originally flat and planar rock strata, as a result of tectonic force or movement.

Folds are usually not considered as part of the rock mass. They are often associated with high degree of fracturing and relatively weak and soft rocks.

Bedding Planes

Bedding plane is the interface between sedimentary rock layers.

Bedding planes are isolated geological features to engineering activities. It mainly creates an interface of two rock materials. However, some bedding planes could also become potential weathered zones and groundwater pockets.

Rock Material and Rock Mass

Rock in an engineering scale is generally a mass of rock at the site. This mass of rock, often termed as rock mass, is the whole body of the rock in situ, consists of intact rock blocks and all types of discontinuities (joints, faults etc).

Composition of Rock Mass

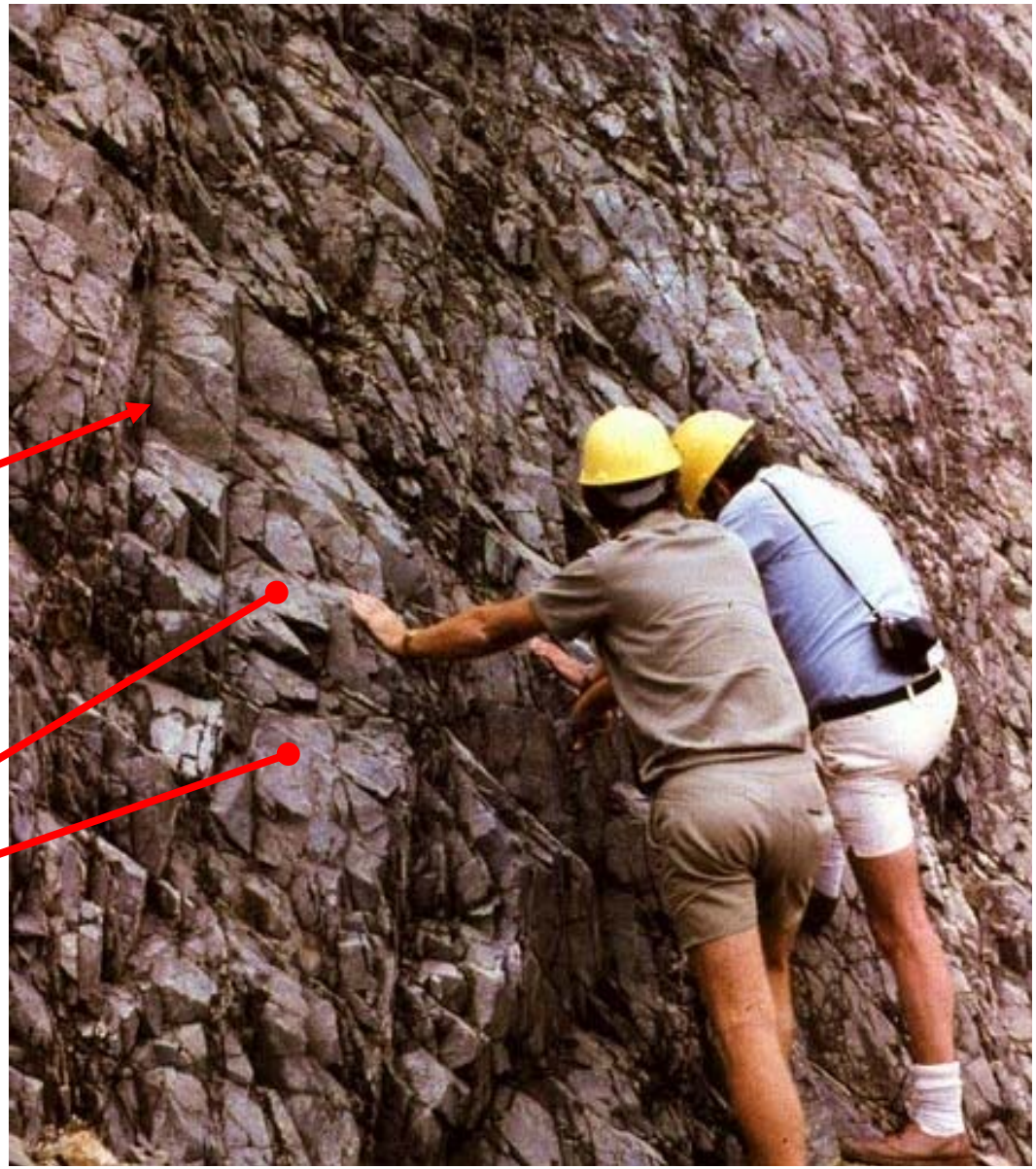
A rock mass contains (i) rock material, in the form of intact rock blocks of various sizes, and (ii) rock discontinuities that cuts through the rock, in the forms of fractures, joints, faults, bedding planes, and dykes.

Rock mass = Rock materials + Rock discontinuities


A borehole 10 cm.
A tunnel of 10 m diameter.
An excavated quarry slope of about 30 m high.

Discontinuities

Rock material



Rock Material and Rock Mass

Roles of Rock Joints in Rock Mass Behaviour

- **Cuts rock into slabs, blocks and wedges, to be free to fall and move;**
- **Acts as weak planes for sliding and moving;**
- **Provides water flow channel and creates flow networks;**
- **Gives large deformation;**
- **Alters stress distribution and orientation;**

Rock mass behaviour is largely governed by joints.

Inhomogeneity and Anisotropy

Inhomogeneity of Rock Material

Inhomogeneity represents property varying with locations. Many construction materials have varying degrees of inhomogeneity. Rock is formed by nature and exhibits great inhomogeneity, due to:

(i) different minerals in a rock,
(ii) different bounding between minerals,
(iii) existence of pores,
(iv) existence of microcracks.

Inhomogeneity is the cause of fracture initiation leading to the failure of a rock material. If some elements in the rock material matrix are very weak, they will start to fail early and usually lead to low overall strength of the rock material.

Inhomogeneity and Anisotropy

Inhomogeneity of Rock Mass

Inhomogeneity of a rock mass is primarily due to the existence of the various discontinuities.

Rock masses are also inhomogeneous due to the mix of rock types, interbedding and intrusion.

Anisotropy

Anisotropy is defined as properties are different in different direction. It occurs in both rock materials and rock mass.

Rock with obvious anisotropy is slate. Metamorphic phyllite and schist and sedimentary shale also exhibit anisotropy.

Rock mass anisotropy is controlled by
(i) joint set, and
(ii) sedimentary layer.