Introduction to Soil and Rock

- Soil: Unconsolidated agglomerate of minerals above solid Rock
- Rock: Hard and durable material that can not be excavated without blasting

Difference between Rock and Soil

- Rocks are generally cemented; soils are rarely cemented
- Rocks usually have much lower porosity than soils

Diff b/w Soil and Rock

- Rocks are more susceptible to weathering than soils
- Rocks are often discontinuous; soil masses usually can be represented as continuous
- Rocks have more complex and unknowable stress history than soils
- In Many rocks, minor principal stress is vertical but in most soils, this is horizontal.
- Stability of rock mass is controlled by the strength of discontinuities while in soil the strength of soil apply

Geotech studies for soil & rocks

- Geotechnical Investigation cover studies of soils as well as rocks
- In civil engineering construction, mostly more emphasis on soil than rocks
- Generally we construct more on soil than rocks, also rocks have more bearing capacity.
- For large projects like dams, rocks needs more investigation as they are more complex

ABOUT SOILS
Formation of Soil

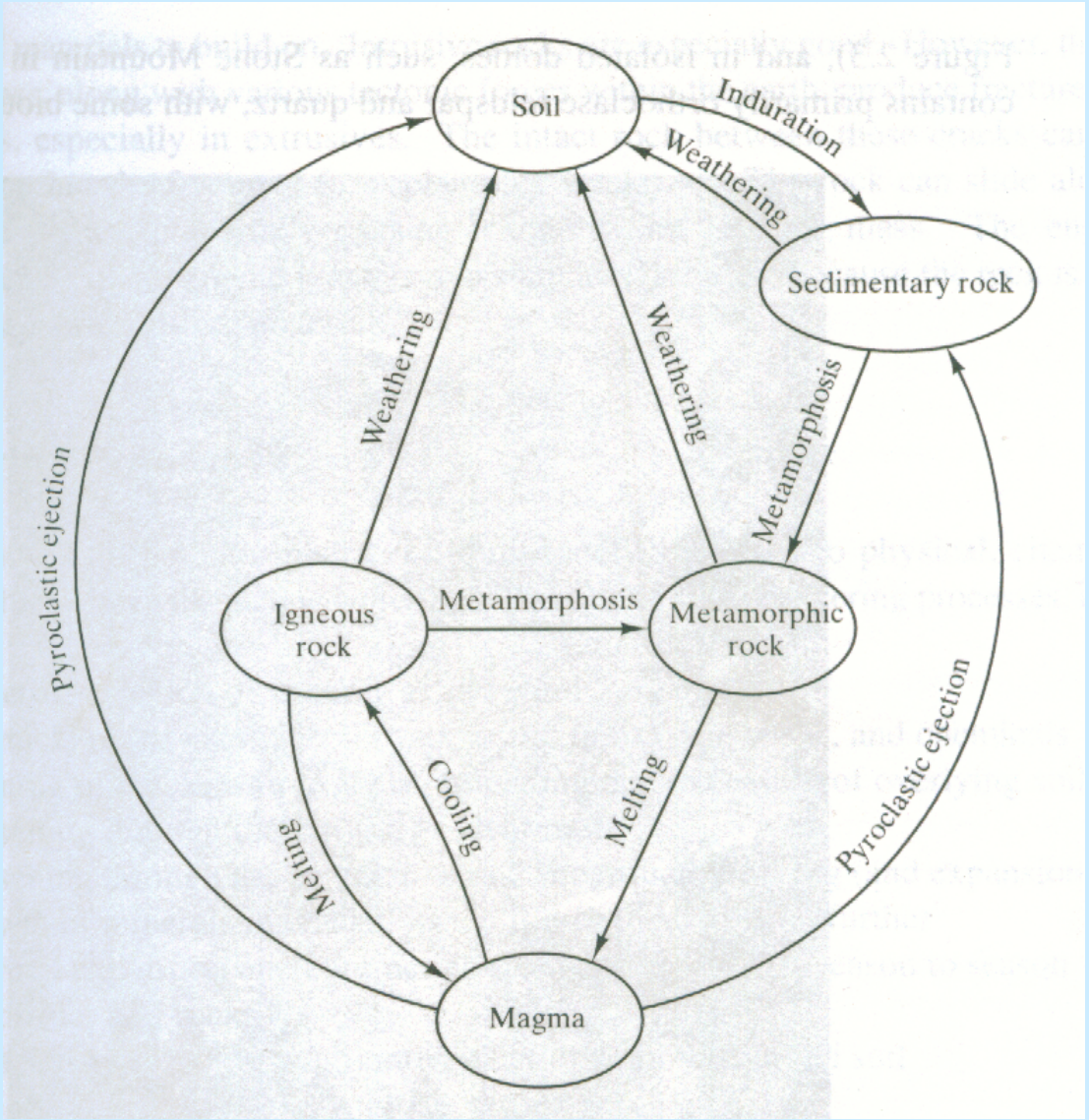
- Soil is formed as a result of weathering of rocks

- Weathering: is a process whereby an intact rock mass is decomposed or disintegrated by atmospheric agents

  - » Physical or Mechanical weathering agents
  - » Chemical weathering agents

Rock-Soil Cycle

- Weathering of all three kinds of rock form soil
- Pressure and cementation of sediments (soil) forms sedimentary rock
- Pressure, heat and solution of both igneous and sedimentary rock forms Metamorphic rocks
- Melting of rocks forms Magma
- Cooling of Magma forms igneous and pyroclastic soils



Mechanical Weathering Agents

- Temperature changes
- Freezing and thawing (vol of freezed water increases by 9%)
- Erosion/abrasion by flowing water, wind and ice
- Natural disasters, e.g. earthquakes, landslides etc.
- Activities by plants and animal including men

--Soil formed by mechanical weathering retains the minerals and material fiber of parent rock.

--Coarse-grained soils such as gravels, sands and their mixtures

Chemical Weathering agents

--Chemical weathering results from reactions of rock minerals with oxygen, water, acids, salts etc. The various chemical weathering processes are

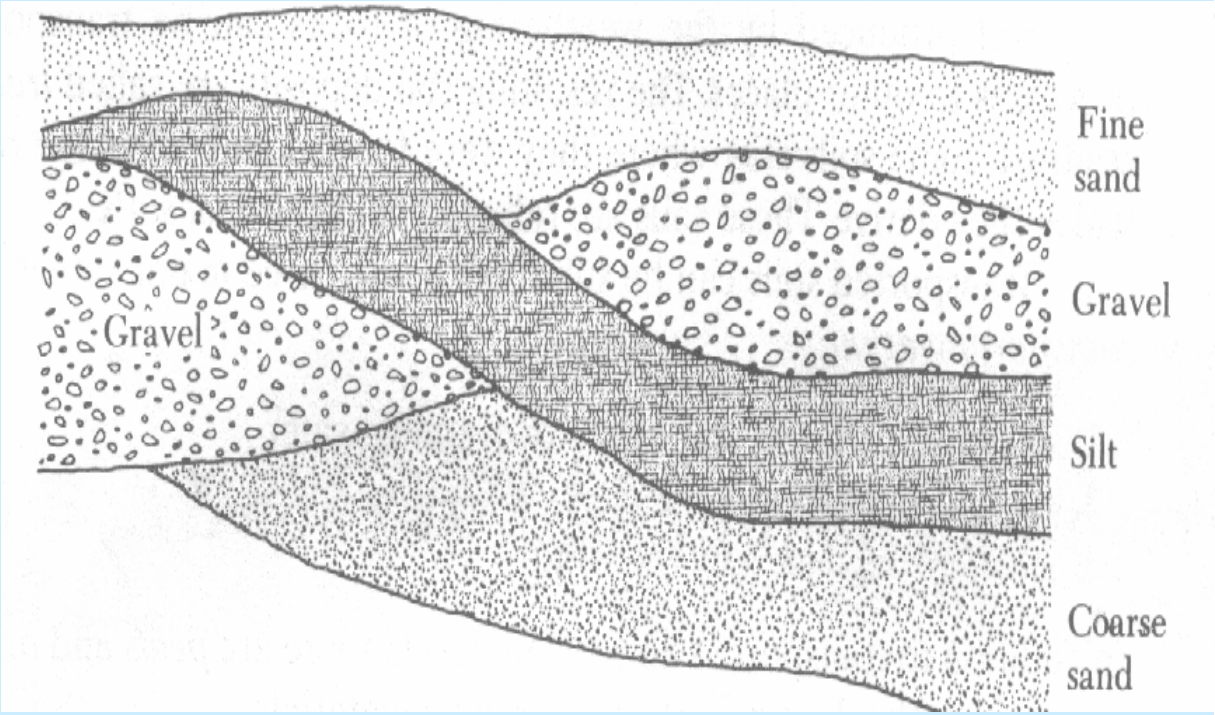
- »Oxidation
- »Carbonation
- »Hydration
- »Leaching
- »Solution

Soil Deposits

- Residual soils
- Transported soils
  - » Alluvial or fluvial or Alluvium
  - » Aeolian soil deposits
  - » Glacial soil deposits
  - » Colluvial or colluvium
- Organic soils
- Marine soils
- Pyroclastic soils

Alluvial Deposits

- Deposits from braided stream
- Are those with high gradient, rapidly flowing that are highly erosive
- A minor change in velocity will cause sediments to deposit
- They are complex in nature



Alluvial Deposits

- Meander Belt Deposits

Stream with winding Course

- Point par
- Natural levee
- Flood plain or backswamp deposit (highly plastic clay)
- Oxbow or channel fill

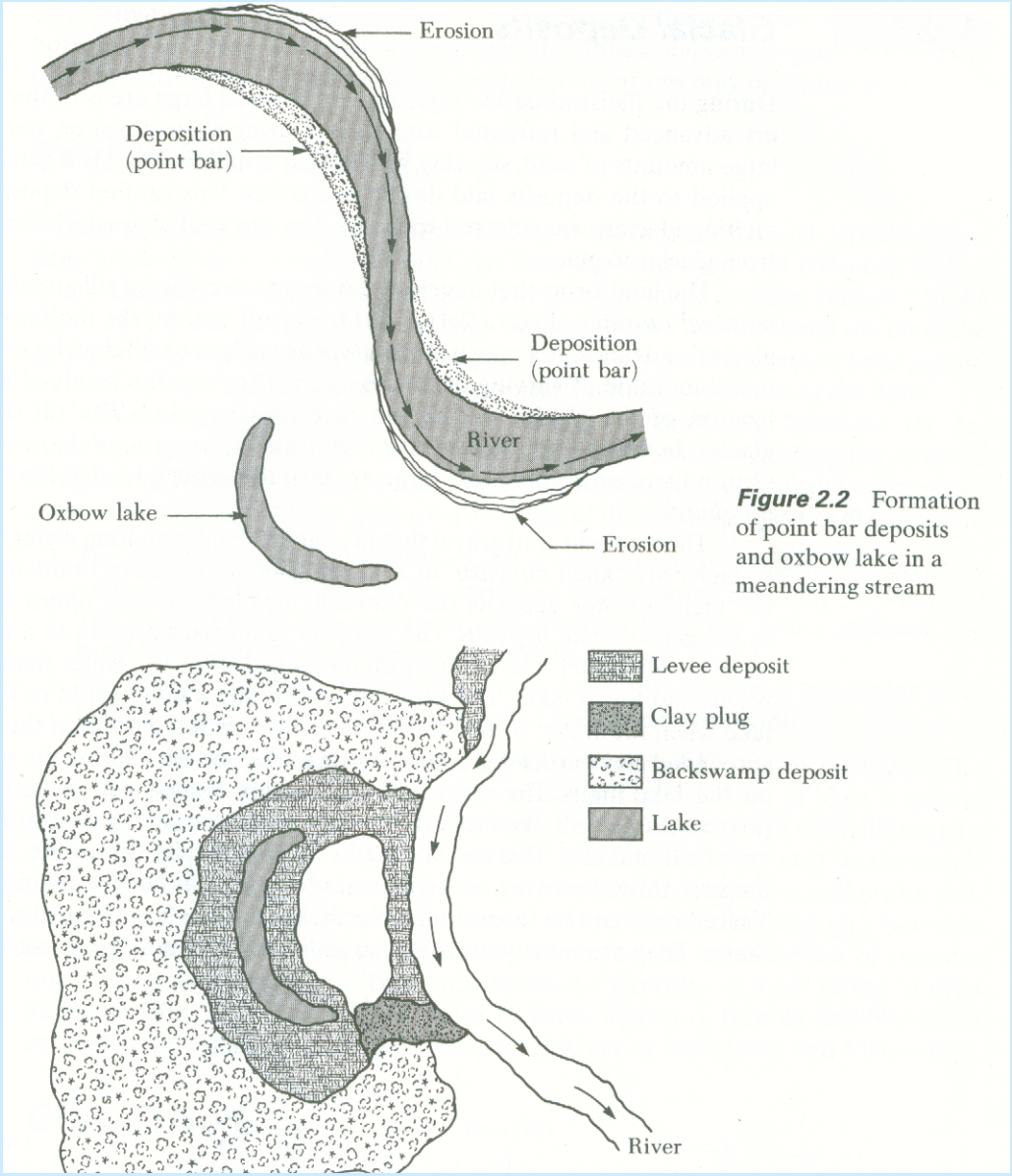


Figure 2.2 Formation of point bar deposits and oxbow lake in a meandering stream

Alluvial Deposits

- Alluvial Terrace deposits

Relatively narrow, flat-surfaced, river flanking remnant of flood plain deposit formed by entrenchment of river

- Alluvial fans

When a river channel widens significantly or its slope decreases substantially, coarse soil particles settle forming submerged, flat, triangular deposits known as Alluvial Fans

- Delta Deposit: soil deposited at mouth of river or stream entering a lake or reservoir.

Aeolian deposits

Soils transported and deposited by wind action; two type of soils are famous

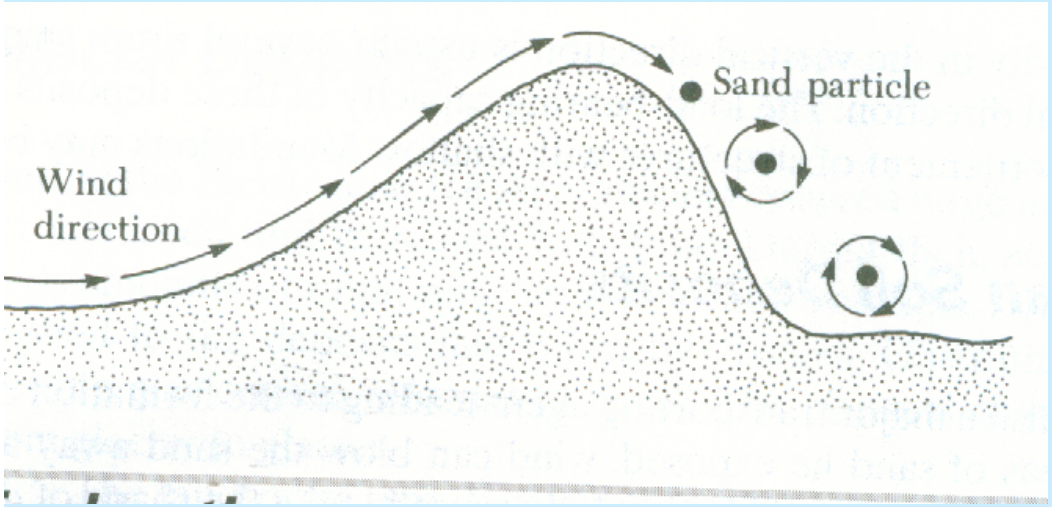
- Loess: is a soil consisting of silt and silt-size particles. The grain size tends to be uniform. Cohesion is developed by clay coating or by chemical leached by rainwater. Loess is quite stable under unsaturated condition. Its collapsible upon saturation.
- Sand Dune: Mounds ridges of uniform fine sand. They are formed when the sand is blown over the crest of the dune by wind action. Sand dunes have the properties:

  - Uniform in grain size

  - Relative density on windward side is more than leeward side

Aeolian deposits

Loess



Sand dune

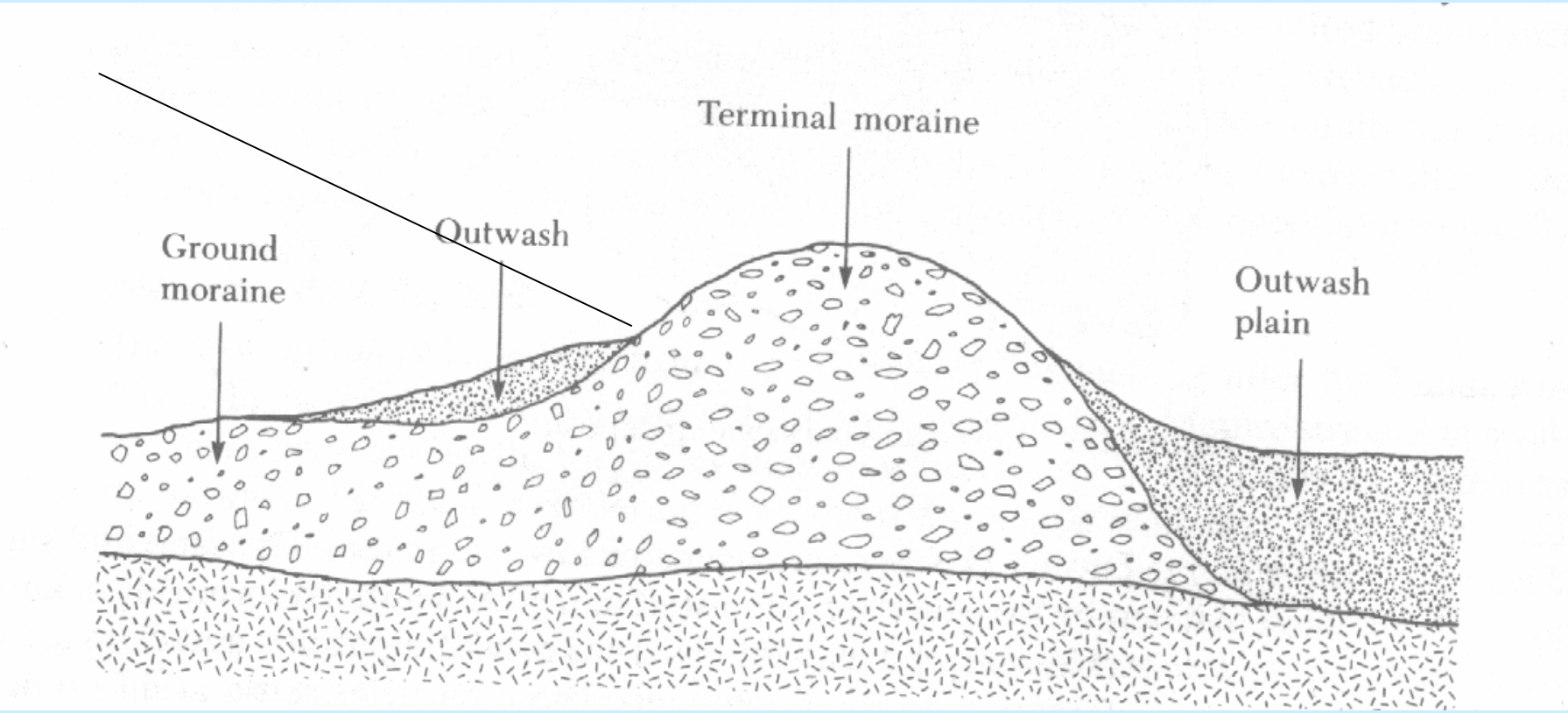
Glacial Deposits

They are transported and deposited by the movements of glaciers.

The general name is glacial till or Moraines.

- Terminal moraine (Ablation till)
- Ground Moraine or lodgments till (hard pan)
- Lateral Moraine
- Glaciofluvial deposit or out wash
- Glacio-lacustrine deposit (varved clay)

Glacial Deposits



Colluvial deposits

Soils transported and deposited by the action of gravity.

- Talus: formed by gradual accumulation of unsorted rock fragments and debris at the base of cliffs
- Hill Wash:
- Fine colluvial consisting of clayey sand, sand silt or clay washed from top hills
- Landslide deposit:

  Large mass of soil or rock which have stepped down as a unit

Organic soil deposits

Formed by in-place growth and subsequent decay of animal and plant life

Peat: A fibrous aggregate of decaying vegetation matter with dark color and bad smell

MucK:

Peat with advanced stage of decomposition

Properties:

- NMC may range 200 to 300%
- Highly compressible
- Likely to undergo secondary consolidation
- Not suitable for engineering purposes.

Marine Deposits

Material transported and deposited by ocean waves and currents in shore and offshore areas:

- Shore deposits: deposits of sand and/or gravel by waves on the shoreline
- Marine clays: Organic and inorganic deposit of fine-grained soil at the bed of sea or lake.

Pyroclastic soil deposits

Materials ejected from volcanoes and transported by wind, air, gravity etc.

- Volcanic ash:

Lava thrown in air and subsequent cooling

- Pumice: is rock form by cooling of lava flow on earth surface during volcanic eruption. very porous, light weight material

Some Typical Soil Names

- Loam: mixture of sand, silt and clay
- Mud: a pasty mixture of soil and organic matter
- Caliche: cemented clay, sand gravel mixture. The cementing material is clacium carbonate deposited through evaporation
- Marl: Caly with calcareous material
- Boulder clay: clays containing wide range of particle sizes varying from boulder to very fine
- Bentonite: clays with main mineral of montmorrilonite formed by chemical weathering of volcanic ash
- Black cotton soils: Highly expansive and compressible clays of dark to black color commonly found in India

Soil Texture, Soil Structure & Clay Minerals

Soil texture is its appearance or feel and depends on relative sizes and shapes

- Coarse textured soil ---gravel, sand mixes
- Fine textured soil ---silt & clays

Soil Structure: geometric arrangement of particles and interparticle forces

- Single grained structure
- Honey combed structure
- Flocculent structure

Clay Minerals

-Kaolinites ---least expansive in nature
-Illites ----medium expansive in nature
-Montmorillonites ---highly expansive in nature

Classification of Soils

Classification Systems

For all engineering purposes, soils need to be classified according to various systems into various groups, mostly followed systems are:

-USCS system---mostly in foundation engg

-AASHTO system ---mostly in highway engg

Classification tests

- grain size analysis
- atterberg limits
- specific gravity

Rocks and Rock Minerals

- Rock Minerals: Minerals are naturally formed elements or compounds with specific structure and chemical properties. Minerals control the rock behavior; weaker or hard.

More than 2000 different mineral are present in earth crust. Few of them occur in large quantities. The most common include:

Rock Minerals

Feldspar:

- It is the most abundant mineral occurring in many kinds of rocks.
- Orthoclase Feldspar contain potassium and usually is white to pink
- Plagioclase Feldspar contain sodium, calcium or both and range from white to grey to black.
- Feldspars have a moderate hardness

Rock Minerals

Quartz

- Another very common rock mineral
- It is a silicate (SiO_2) and usually has a translucent to milky color
- It is harder than most mineral and thus very resistant to weathering.

Ferromagnesium Minerals

- A class of minerals containing both iron and magnesium
- They have dark grey, dark green, brown or black color

Rock Minerals

Iron oxides:

- A class of minerals, all of which contain iron (Fe_2O_3)
- Includes Limonite and magnetite
- Less common
- These minerals give distinctive rusty color to some rocks and soils, and can act as cementing agents

Rock Minerals

Calcite

- A mineral made of calcium carbonate ($CaCo_3$), usually white, pink or grey.
- It is soluble in water and can be transported by water into cracks in rock and soils where it precipitates out of solution acting as cementing agent
- It is much softer than quartz or feldspar
- Effervesces vigorously when treated with dilute hydrochloric acid.

Rock Minerals

Dolomite

- Similar to Calcite, with magnesium added
- Less vigorous reaction to dilute hydrochloric acid.

Mica

- Translucent thin sheets or flakes.
- Muscovite has silvery flakes while Biotite is dark gray or black
- These sheets have very low coeff. of friction, which can produce shear failure in certain rock, such as Schist

Rock Minerals

Gypsum:

- A very soft mineral occurring as a precipitate in sedimentary rocks, sometimes thick deposits
- It is colorless to white
- It is water soluble and can dissolve under the action of groundwater leading to problems.

Physical Properties of Minerals

- Hardness: what materials a mineral will scratch and what material will in turn scratch it.

Hardness scale:

1-Talc (softest) 2-Gypsum 3-Calcite

4-Fluorite 5-Apatitie 6-Feldspar 7-Quartz

8-Topaz 9-Corundum 10 Diamond (Hardest)

Streak: the color of the line of mineral powder formed when the surface is scratched with a hard object

Luster: the appearance of a freshly broken surface as seen in reflected light

Cleavage: breaking along defined planes

Fracture: breakage along irregular fracture lines

Type of Rocks

Igneous Rocks

Formed by the cooling of molten magma

Two types of igneous rock

1. Intrusive (plutonic) form below the ground surface, where they cool slowly creating coarse crytal structure
2. Extrusive (volcanic): arrives at ground surface in a molten state and cool very rapidly

Common Igneous Rock

Granite:

- An intrusive, most common and familiar rock
- Granite contain primarily orthoclase feldspar and quartz
- Widely used for construction material and monuments

Basalt:

- An extrusive, fine-grained, dark colored rich in ferromagnesium minerals
- Very hard and forms excellent road construction material
- But rapid cooling creates joints in basalt, and slope made of basalt often fail along joints

Diorite:

- similar to granite, with plagioclase feldspar instead of orthoclase and little quartz
- moderate hardness

Common Igneous Rock

- Andesite: a very hard extrusive rock
- Rhyolite: The extrusive equivalent of granite
- Gabbro: The Intrusive equivalent to basalt. Dark in color than granite or diorite
- Pumice: porous, light-colored formed by volcanic eruption

Igneous Rocks being generally hard, dense and durable, igneous rocks often make good construction material and posses high bearing capacities

Weathered Igneous rocks are less desirable as they change into a more soil-like material

Sedimentary Rocks

- When the soil sediments are subjected to pressure and cementation (induration or lithification), sedimentary rocks are formed. The cementation comes from some type of minerals (calcium carbonate, iron oxide ect.)
- Sedimentary rocks are identified from their layered or stratified appearance.

Common Sedimentary Rocks

Shale

- The most abundant of the sedimentary rocks
- May be formed by clay or silt with principal induration agent being pressure
- Shale may be arenaceous, with large amount of sand, argillaceous, with large amount of clay, carbonaceous, with large amount of organic matter, calcareous, with large amount of lime as from shell life
- Calcareous shales are used in manufacturing of Portland cement
- Carbonaceous shale may yield petroleum or coal
- Shale may be called claystone or siltstone based on the primary constituent

Common Sedimentary Rocks

Sandstone

- Consisting of primarily of Quartz
- Formed by pressure and cementing action of calcite, iron oxide or clay
- Sandstone is used as abrasive, as building stone and for glass making
- Strength and durability depends on the kind of cementing material and degree of pressure involved.

Common Sedimentary Rocks

Conglomerate

- Rock composed of cemented pebbles intermixed with sand

Limestone

- Rock comprised primarily of calcite (calcium carbonate) hardened underwater by cementing agent.
- Limestone quickly react with dilute hydrochloric acid forming small white bubbles; this is identification test for limestone from Dolomite.
- Calcite is soluble in water, such rocks are prone to developing cave or caverns inside.

Common Sedimentary Rocks

Dolomite

- This is a lime stone in which some calcite is replaced with magnesium
- Very similar to limestone in color and grain structure
- Acid test is the identification from lime stone; no reaction-Dolomite, active reaction-limestone
- Color may be white to dark grey, including green, yellow etc., depending on mineral impurities

Common Sedimentary Rocks

Chalk

This is limestone consisting of calcareous shells of microorganisms

Coal

The carbonized plants remains; various stages include:

- Peat: decaying and semicompact organic matter
- Lignite: second stage, more compact, may be called brown coal
- Bituminous: soft coal
- Anthracite: hard coal and final stage

In general, the strength of sedimentary rocks is variable, therefore, their engineering use varies according.

Metamorphic Rocks

- Metamorphism of both sedimentary and igneous (less common) rocks through high temperature and pressure forms Metamorphic rocks
- During metamorphism, the original rock undergoes both chemical and physical alterations; change of texture, mineral type and chemical composition
- The rearrangement of rock minerals during metamorphism results in two rock texture: *foliated* and *nonfoliated*
- Foliation means becoming the rock minerals flattened or platy and arranged in parallel bands or layers

Common Metamorphic Rocks

Foliated rocks:

Slate:

- metamorphosed shale, a fine textured, splits into thin slab parallel to the foliation
- Typical colors are grey, black, red, green
- Widely used for roofing, blackboards, pool tables etc.

Schist:

- Mostly derived from shales or may be from igneous rocks, strongly foliated, with mica predominating mineral
- This type of foliation is called *schistosity*; prone to sliding along foliation planes

Common Metamorphic Rocks

Foliated rocks:

Gneiss: pronounced “nice”

- Generally derived from granite, coarse-grained and banded rock
- The band are typically folded and contorted, may resemble schist but cleavage is difficult than in schist.

Nonfoliated rocks

Quartzite:

- mainly composed of quartz, derived from sand stone, one of the most resistant of all rocks
- When formed pure quartz, color is white; impurities may give red, yellow or brown tints

Marble:

- Derived from limestone or dolomite, used for building stone, decorative purposes and monuments

Anthracite (hard coal):

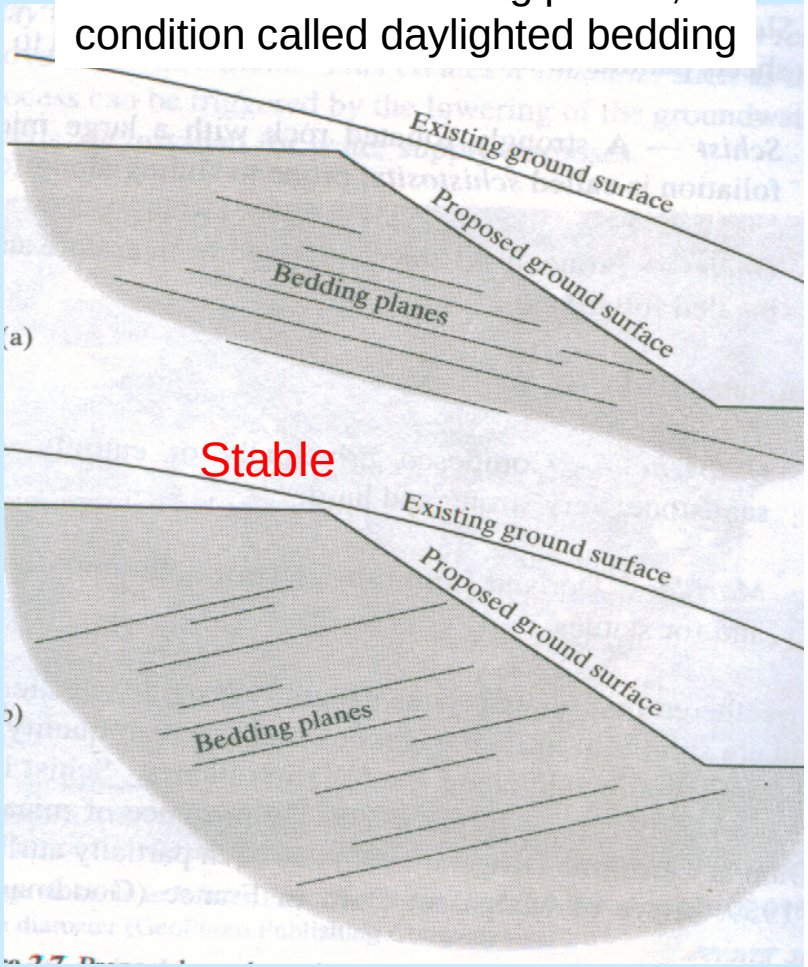
- This is metamorphosed bituminous or soft coal

Bedding Planes and Schistosity

- All sedimentary rocks are formed in horizontal or near horizontal layers and these layers often reflect alternating cycles of deposition
- Rocks have much less strength along bedding planes
- The orientation of bedding planes is very important in stability of rock slope and excavation in such rock

Schistosity: Metamorphic rocks have similar planes of weakness, called schistosity.

Unstable, as the excavation undermines the bedding planes, a condition called daylighted bedding



Folds and Fractures in Rocks

Folds: due to crustal movements, the rocks distort into a wavy pattern called folds.

- When folds are oriented concave downward they are called Anticlines
- When concave upward, called synclines

Fractures: fractures are cracks in rock mass. The shear strength along fractures is much less, their orientation is important

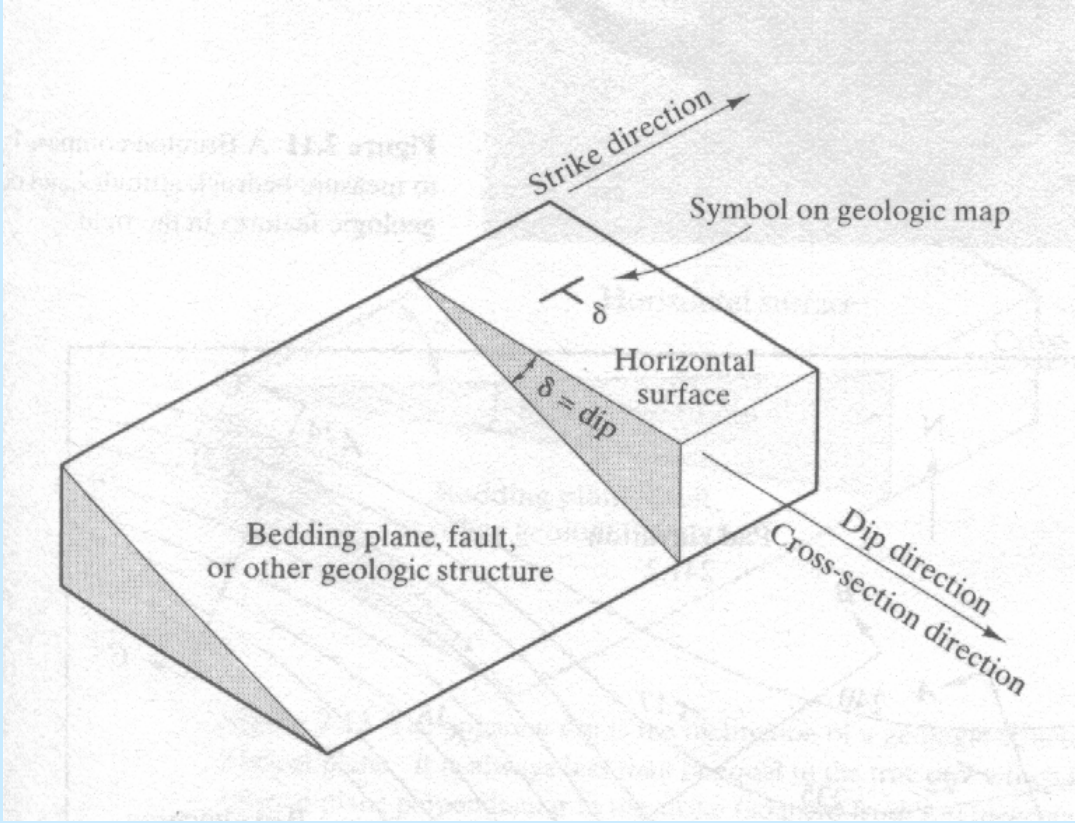
Types of fractures:

- Joint: fractures that have experiences no shear movement
- Shear zones: are fractures that have experienced small shear movement. They are conduits for groundwater
- Faults: fractures similar to shear zones, except they have experienced much greater shear displacement, generally more than 1 m

Strike and Dip

Strike: is the compass direction of the intersection of the plane and the horizontal

Dip: is the angle between the geological surface and the horizontal.



Types of Fault

Dip-slip fault:

Those whose movement is along the dip

- Normal fault:

If the overhanging part moves downward

- Reverse fault:

If the overhanging part moves up

- Thrust fault: a reverse fault with a very small angle

Strike-slip fault:

Those whose movement is along the strike

Left lateral: if movement is towards left

Right lateral: if movement is towards right w.r.t overhanging part

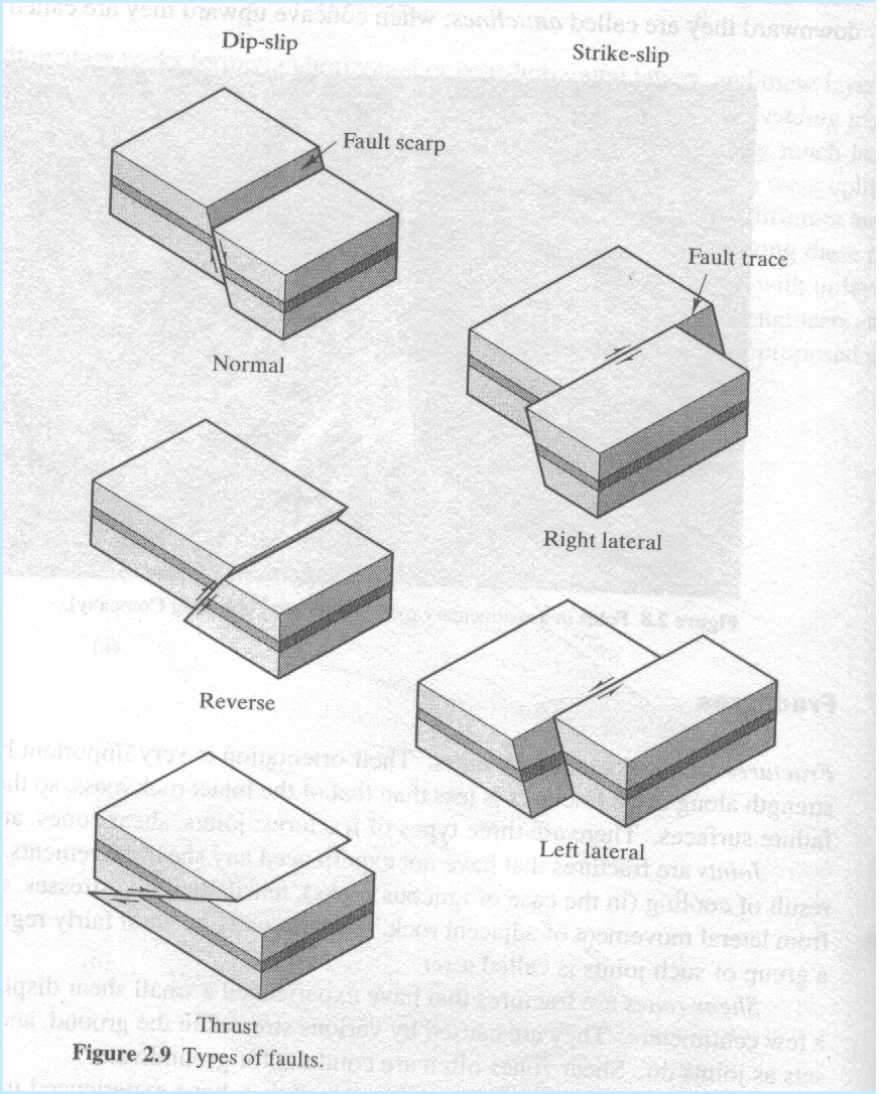


Figure 2.9 Types of faults.