WEATHERING

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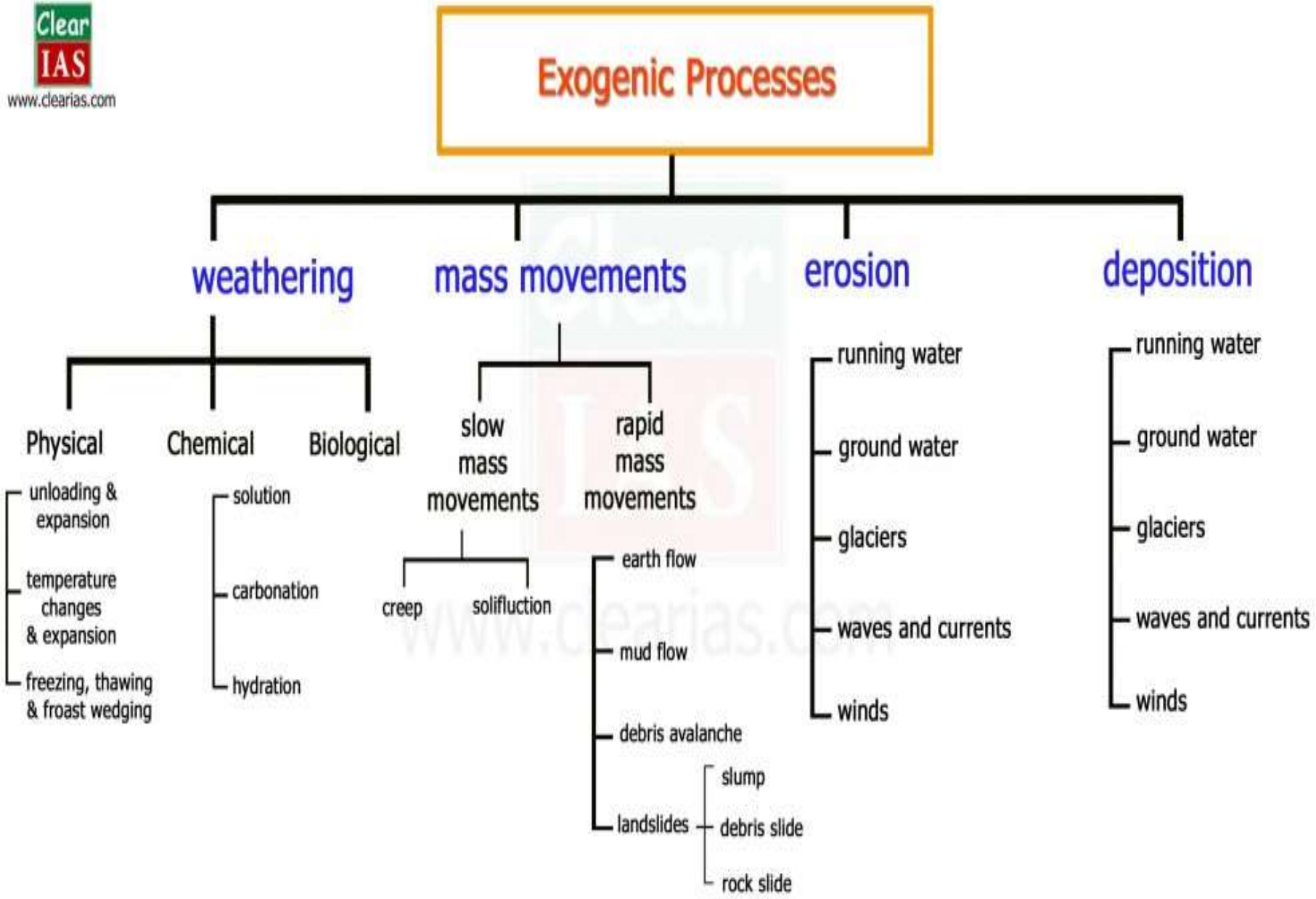
WEATHERING

Weathering

- It is a unique phenomena happening on the earth's surface
- Weathering is an important geomorphic mechanism which can destabilize the earth's surface materials and remove them by erosive processes.
- Weathering is the physical disintegration and chemical decomposition of a rock mass on the land.
- It happens 'In-situ'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hydration
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creep
solifluction
earth flow
mud flow
debris avalanche
landslides
slump
debris slide
rock slide
running water
ground water
glaciers
waves and currents
winds
running water
ground water
glaciers
waves and currents
winds

Factors Influencing Weathering

- Topography : Ground Slope, Aspect, Altitude
- Physical characteristics of rocks : Minerals, Joints, Layering, Folding, Faulting.
- Climatic Variations : Humid Tropics (CW>MW), Dry, semi-Arid (MW>CW), Permafrost, Monsoon.
- Vegetation (Flora) : Presence-Absence, Macro-Micro, Physical-Chemical. Weathering is In-situ and involves no agent of Transport

Geomorphic Importance of Weathering

- Lowering of Surfaces.
- Physical modification of pre-existing rocks.
- Modifications are made on the pre-existing rocks by mechanical forces, chemical reactions and biological interactions.
- Changes are expected in the pre-existing geologic materials that are exposed at or near the surface of the Earth. Destabilization of Geomorphic masses.
- Weathering creates both soils and other loose rock fragments.
- Weathering releases several chemical compounds from the parent rocks.
- Modification and Evolution of Landforms

Types of Weathering

- Physical (Mechanical)
- Chemical
- Biological
- Anthropogenic

Physical Weathering

- • Physical weathering is related to the physical breakup of rocks into small pieces and fragments. In physical weathering, there is no change in the chemistry of the parent rock. • It happens especially in places where there is little soil and few plants grow, such as in mountain regions and hot deserts. a large diurnal range of temperature or, temperatures fluctuating around 0 degrees Celsius. • The types/processes of physical weathering include; abrasion, crystallization, root wedging, insolation weathering, human mining, animal activity, tumbling, compressional stress, crushing waves, tensional stress.

Mechanisms of Physical Weathering

- • Freezing and thawing/ Frost weathering : acts on a wide range of spatial and temporal scales, from minutes to years. pronounced in high altitude and latitude areas. Block Disintegration • Root Wedging : Plants are effective agents of mechanical weathering. Roots can penetrate through the cracks of rocks to depths of several meters. • Heat spalling/ Thermal Weathering : sharp temperature fluctuations, dry air, absence or poorly developed vegetation cover. Heat from forest fires will cause the outer surface layers of rock to expand quickly and break away in spalls. Granular Disintegration • Exfoliation/ spheroidal weathering : separation of successive thin shells, or spalls happen from massive rocks

I. Mechanical Weathering

Mechanical weathering is the physical disintegration and reduction in the size of the rocks without changing their chemical composition.

- Exfoliation
- Frost Wedging
- Salt Wedging
- Temperature Changes
- Abrasion

Mechanical weathering processes disintegrate metamorphic rocks in South Carolina's Piedmont Region.

Photo courtesy of SCGS

PROCESSES OF MECHANICAL WEATHERING

- Mechanical or Physical--disintegration--smaller pieces
  - frost wedging--water freezes and expands in crack
  - salt wedging--water evaporates and crystals grow
  - exfoliation--rocks peel like an onion, especially intrusive igneous bodies; Stone Mountain, Georgia (accelerated by chemical weathering)
  - plant wedging--plant roots grow
  - differential heating; (fire)
  - granular disintegration

Mechanical Weathering: Exfoliation

- Exfoliation is a mechanical weathering process whereby pressure in a rock is released along parallel alignments near the surface of the bedrock and layers or slabs of the rock along these alignments break off from the bedrock and move downhill by gravity.
- Exfoliation primarily occurs on intrusive igneous or metamorphosed rocks that are exposed at the Earth's surface.
- Exfoliation can occur both very slowly or very rapidly as a form of mass wasting.
- Large rocks characterized by exfoliation are commonly referred to as exfoliation domes.
- Table Rock mountain in South Carolina, and Enchanted Rock in Texas are both examples of exfoliation domes with large slabs of rock exfoliating from the bedrock.

Enchanted Rock in the Texas Hill Country is an example of an exfoliation dome. As pressure is released from the surface layer, slabs of rock exfoliate from the dome and move down slope. As they are transported down slope, weathering and erosion processes break the rocks into progressively smaller fragments. Overtime, each new layer that is exposed will eventually exfoliate, from the bedrock.

Mechanical Weathering: Frost Wedging

- Frost wedging is a mechanical weathering process caused by the freeze-thaw action of water that is trapped between cracks in the rock.
- When water freezes, it expands and applies pressure to the surrounding rock forcing the rock to accommodate the expansion of the ice.
- This process gradually weakens, cracks, and breaks the rock through repetitive freeze-thaw weathering cycles.
- Frost wedging generally produces angular blocks and talus material. Talus is a term used to describe weathered [illegible] of a hill slope or

This example of frost wedging is from Pikes Peak in Colorado. The weathered fragments of rock break apart from the exposed rock from freeze-thaw action and collect as angular blocks of talus material

Temperature Changes

- Daily (diurnal) and seasonal temperature changes affect certain minerals and facilitates the mechanical weathering of bedrock.
- Warmer temperatures may cause some minerals to expand, and cooler temperatures cause them to contract.
- This gradual expansion and contraction of mineral grains weakens the rock causing it to break apart into smaller fragments or to fracture.
- This process is more common in desert climates because they experience extreme fluctuations in daily temperature changes.
- Temperature changes are often not the dominant form of weathering, but instead temperature changes tend to accelerate other forms of weathering already occurring.

The rock fragments in the lower right side of this image have weathered as a result of extreme fluctuations in day and night temperature changes.

Mechanical Weathering: Salt Wedging

- Salt wedging occurs when salts crystallize out of solution as water evaporates. As the salt crystals grow, they apply pressure to the surrounding rock weakening it, until it eventually cracks and breaks down, enabling the salt crystal to continue growing.
- Salt wedging is most common in drier climates, such as deserts.

These salt crystals were found growing between rock fractures in California's Death Valley.

Mechanical Weathering: Abrasion

- Abrasion occurs when rocks collide against each other while they are transported by water, glacial ice, wind, or gravitational force.
- The constant collision or gravitational falling of the rocks causes them to slowly break apart into progressively smaller particles.
- Flowing water is the primary medium of abrasion and it produces the 'rounded' shape of fluvial sediments.
- During abrasion, rocks may also weather the bedrock surface they are coming into contact with as well as breaking into smaller particles and eventually individual grains.
- In addition to the transported rocks being weathered by abrasion, the bedrock surface is also experiencing the effects of collision and mechanical weathering. This smoothes the surface of the bedrock and can also cause it to break apart.

Abrasion processes in creek beds produce rounded boulders and cobbles.
Over time, abrasion processes will eventually break these rocks into progressively smaller particle sizes, such as gravel, sand, silt, and clay.

CHEMICAL WEATHERING

2. Chemical Weathering

- Chemical Weathering is the process of decomposition of Earth's surface materials.
- Effectiveness of chemical weathering, is directly related to, Mineral stability, surface area exposed, which is related to the Density of fractures in a rock.
- Rate of Chemical weathering depends on Temperature, Availability of water or natural acid.

CHEMICAL WEATHERING

- Chemical--decomposition
  - carbonation--CO_2 + H_2 yields H_2CO_3 (carbonic acid)
  - oxidation
  - hydration--water joins to cause expansion or swelling
  - hydrolosis--water joins and weakens the rocks
  - solution (leaching)

Types of Chemical Weathering

Chemical weathering decomposes, dissolves, alters, or weakens the rock through chemical processes to form residual materials.

- Carbonation
- Hydrolysis
- Hydration
- Oxidation
- Solution

Stalactite and stalagmite joining together in Onondaga Cave State Park, Missouri.

Mechanisms of Chemical Weathering

- • Solution is the process of dissolving mineral constituents by water or acid. Some substances present in the rocks are directly soluble in water. Soluble substances are removed by the continuous action of water.
- • Hydration involves absorption of water. Soil forming minerals in rocks do not contain any water and they under go hydration when exposed to humid conditions. Upon hydration there is swelling and increase in volume of minerals.
- • Hydrolysis is also a process of chemical weathering. It is due to the dissociation of H2O into H+ and OH−ions which chemically combine with minerals and bring about changes. Hydrolysis of feldspar, produces clay

Mechanisms of Chemical Weathering

- . • Oxidation of Minerals and Rocks is an effective process in de-coloration and decomposition of materials. atmospheric oxygen combines with the metal ions of minerals to form oxides.
- • Carbonation is the reaction of carbonate or carbonate ions with minerals. Carbonic acid is the principal weak acid- responsible for chemical weathering.
- • Chelation is a biological process where organisms produce organic substances, known as chelates, that have the ability to decompose minerals and rocks by the removal of metallic cations

Chemical Weathering: Hydrolysis

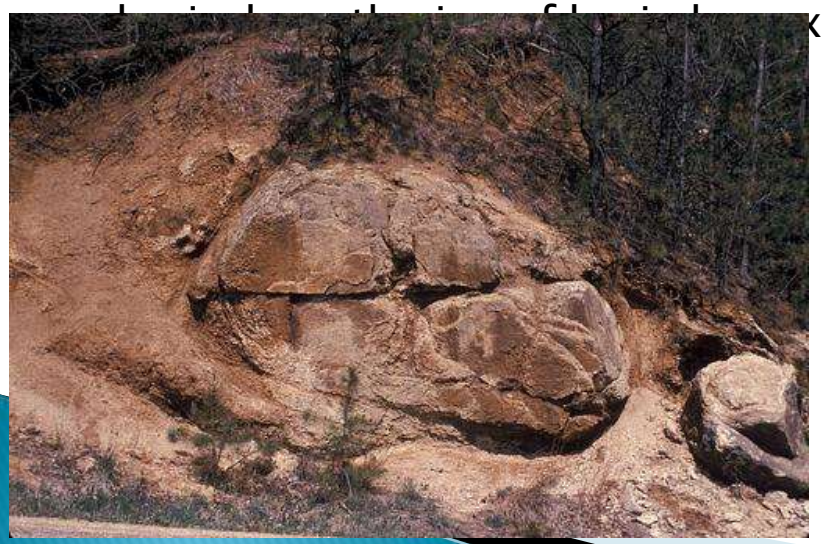
- Hydrolysis is a chemical reaction between H^+ and OH^- ions in water and the minerals in the rock. The H^+ ions in the water react with the minerals to produce weak acids.
- The reaction creates new compounds which tend to be softer and weaker than the original parent rock material.
- Hydrolysis can also cause certain minerals to expand, which also facilitates mechanical weathering processes.
- Hydrolysis commonly affects igneous rocks because they are composed of silicate minerals, such as quartz and feldspar, which readily combine with water.
- Hydrolysis may also be accompanied by hydration and oxidation weathering
- es kaolinite, which is a clay.

Photo Source: Dr. Hugh Mills, Technical University

The weathering rinds shown on this sample of amphibolite illustrate the effects of hydrolysis weathering on deposited rock fragments. Geologists measure the 'thickness' of the weathering rinds on in-situ rock fragments to estimate the relative age of depositional landforms such as river terraces or alluvial fans. The thicker the weathering rinds, the older the landform.

Chemical Weathering: Hydration

- Hydration is a process where mineral structure in the rock forms a weak bond with H_20 which causes the mineral grains to expand, creating stress which causes the disintegration of the rock.
- Hydration often produces a new mineral compound that is larger than the original compound. The increased size expanse the rock and can lead to decay.
- Hydration can also lead to color changes in the weathered rock surface.
- Once hydration begins, it accelerates other weathering processes and may also be accompanied by hydrolysis and oxidation.
- An example of hydrolosis: Anhydrite ($CaSO_4$) can absorb two water molecules to become gypsum ($CaSO_4 \cdot 2H_2O$).
- Hydration in granite transforms feldspar minerals to clay and accelerates the [illegible] exposed rocks.



This boulder is surrounded by saprolitic soils formed by the weathered rock. Hydration processes cause the formation of clays and contribute to the reddish-tan color of the saprolite.

Chemical Weathering: Oxidation

- Oxidation occurs when oxygen and water react with iron-rich minerals and weaken the structure of the mineral.
- During oxidation the minerals in the rock will change colors, taking on a 'rusty', reddish-orange appearance.
- Similar to other chemical weathering processes, oxidation accelerates rock decay, rendering it more vulnerable to other forms of weathering.

Photo: SCGS

The reddish-orange color of this sandstone is a result of oxidation processes weathering the rock.

Chemical Weathering: Solution

- Solution occurs when minerals in rock dissolve directly into water.
- Solution most commonly occurs on rocks containing carbonates such as limestone, but may also affect rocks with large amount of halite, or rock salt.
- Solution of large areas of bedrock may cause sinkholes to form, where large areas of the ground subside or collapse forming a depression.

Subsurface dissolution of halite has caused overlying rocks to collapse and form crater-like features.

This is an example of a limestone solution karst feature found in Florida's Everglades National Park.

Chemical Weathering: Carbonation

- Carbonation is a process by which carbon dioxide and rainwater or moisture in the surrounding environment chemically react to produce carbonic acid, a weak acid, that reacts with carbonate minerals in the rock.
- This process simultaneously weakens the rock and removes the chemically weathered materials.
- Carbonation primarily occurs in wet, moist climates and effects rocks both on and beneath the surface.
- Carbonation occurs with limestone or dolomite rocks and usually produces very fine, clayey particles.

Limestone weathered by carbonation processes

Photo source: Wikipedia GNU Free Documentation License

BIOLOGICAL WEATHERING

Biological Weathering

Biological weathering is the disintegration or decay of rocks and minerals caused by chemical or physical agents of organisms.

- Organic activity from lichen and algae
- Rock disintegration by plant growth
- Burrowing and tunneling organisms
- Secretion of acids

Biological Weathering

- • Floral Weathering
- • Faunal Weathering
- • Anthropogenic Weathering

Lichen, Algae, and Decaying Plants

- Organisms such as lichen and algae often live on bare rock and extract minerals from the rock by ion-exchange mechanisms.
- This bio-chemical weathering process leaches minerals from the rock causing it to weaken and breakdown.
- The decaying of plant materials can also produce acidic compounds which dissolve the exposed rock.
- The presence of organisms growing, expanding, or moving across the surface of the rock also exerts a small amount of abrasion and pressure that gradually cause the mechanical weathering of the rock as the organisms extract various minerals.

Photo: SCGS

This is an example of biological weathering that is caused by mosses and lichen growing on the face of a rock.

Plant Roots

- The most common form of biological weathering is when plant roots penetrate into cracks and crevices of rocks and cause the rock to split or break into smaller particles through mechanical weathering.
- Although, this process is gradual, it can be fairly effective at breaking apart rocks that may already have a pre-existing weaknesses such as fractures, faults, or joints.

This is an example of a tree that is growing between a crevasse in a rock. The tree is splitting the rock along parallel planes of alignment that are already weakened by foliation processes, a form of mechanical weathering.

Organism Activity

- Burrowing, tunneling, and acid-secreting organisms are another form of biological weathering that chemically or mechanically contribute to weathering.
- Some animals may burrow or tunnel into rocks or cracks in rocks and cause the rock to break down and disintegrate. Small animals, worms, termites, and other insects, often contribute to this form of biological weathering.
- Some organisms, such as snails, barnacles, or limpets, attach themselves to rocks and secrete acid acids that chemically dissolve the rock surface.

oto: D. Kroessig

The periwinkle snails on this rock are secreting acids that dissolve the rock. This picture is taken from a volcanic shoreline in Hawaii.

Differential Weathering

- Weathering rates will not only vary depending on the type of weathering process, whether it is mechanical, chemical, or biological, but they will also vary depending on the rock material that is being weathered.
- Some rocks are harder than other rocks, and will weather slower than softer rocks.
- The differences in rates of weathering due to different types of rocks, textures, or other characteristics is referred to as differential weathering.
- Differential weathering processes contribute to the unique formation of many landforms, including pedestals, waterfalls, and monadnocks.
- Climate can also produce differential weathering responses for the same rock type. For example, limestone weathers more quickly in wet climates than dry

Image source: SCDNR, Heritage Preserves

Peachtree Rock's unique pyramidal shape is a result of differential weathering associated with the different sedimentary sandstone rock components. The top portion of the outcrop consists of hard, coarse-grained sandstone, while the lower part of the rock consist of a less cohesive, sandstone layer. The lower portion of the rock has weathered more quickly than the upper portion ultimately producing its unique pyramidal shape.