SEMESTER-1 (HONS.)
GEO-A-CC-1-TH
GEOTECHTONICS AND GEOMORPHOLOGY
TOPIC :5

# DEGRADATIONAL PROCESSES


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- **Geomorphology :**
- •The word “**geomorphology**" comes from the Greek roots "geo,“ “morph,” and “logos,” meaning “earth,” “form,” and “study,” respectively. Therefore, geomorphology is literally “the study of earth forms.”

- **Importance of Geomorphology**

•To understand geomorphological processes of various environment.

•To detect natural and environmental hazards efficiently, e.g. earthquake, flooding, landslide, tsunami, volcanism etc.

•To identify various landform features and landscapes

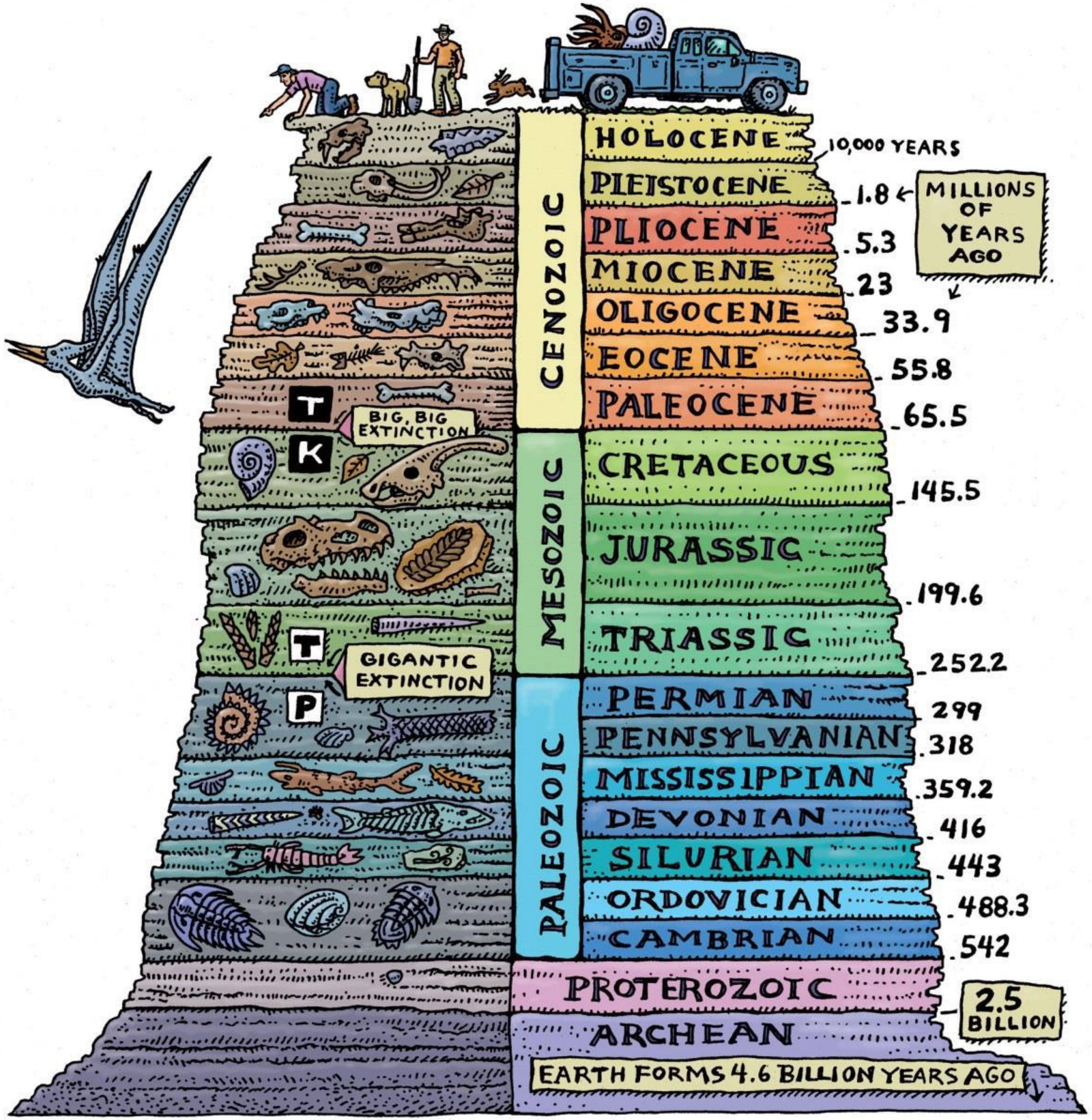
•To identify various landform features from satellite images

•Coastal and river research

•Vulnerability studies

•Geology, Geography, Archeology, Engineering, Planning, Mining, Construction, Urbanization etc……

# Geologic Timescale



# Geomorphic Processes

## Objectives:

- After attending this lesson, the learners would be able to know the mechanisms of weathering that are responsible for the dynamic changes of the landforms and their impacts on rocks.
- The geomorphic processes, that are responsible for landforms evaluation will be discussed.

# What do you see on the earth's surface?

- **What are the processes work behind the landforms?**

- **Geomorphic Process**
- The process responsible for the formation and alteration of the earth's surface.
- The physical and chemical interactions between the earth's surface and the natural forces acting upon it to produce landforms.
- The processes are determined by such natural environmental variables as geology, climate, vegetation and base level, to say nothing of human interference.
- The geomorphic processes are all those physical and chemical changes which effect a modification of the earth’s surgical form *[W. D. Thornbury (1968): Principles of Geomorphology, pp. 34].*
- A process by which the earth’s land forms are changed or maintained [Jim Gardner (1979): Physical Geology]

# *Agent, Process & products*

## Process

Process includes three types of activities

**Erosion**

↓

**Transportation**

↓

**Deposition**

## Products of Geomorphic Processes

| **Process** | | ***Products*** |
|---|---|---|
| Erosion | → | Erosional landform features |
| Transportation | | Transportation |
| Deposition | → | Depositional landform features |

## Agent of Geomorphological Processes

- **River activities-** **Humid Geomorphic Environment**
- **Wind activities** **- Arid Geomorphic Environment**
- **Glacier activities** **- Glacial and Peri-Glacial Geomorphic Environments**
- **Wave activities** **- Marine and Coastal Geomorphic Environment**

Activities of the Agent of Geomorphic Processes *Three types of activities are* done Erosional activities Transportation Depositional activities.

## Agents of change

# Geomorphic Processes

## Terrestrial process

### Exogenic Processes

i. Weathering
ii. Erosion/Degradation
iii. Transportation
iv. Deposition/Aggradation
v. Mass movement

### Endogenic processes

i. Faulting and Folding
ii. Volcanism
iii. Earthquake
iv. Landslide
v. Diastrophism
vi. Metamorphism

## Extra -terrestrial

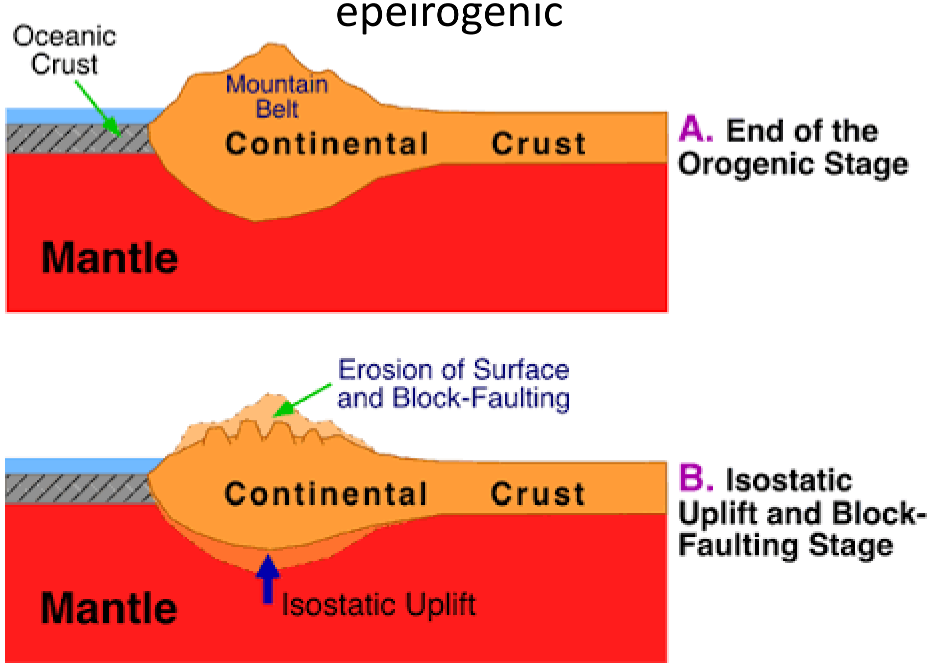
- **Degradation**
- •Degradation is the lowering of a bottomland surface through the process of erosion;
- •Conceptually it is the opposite of the vertical component of aggradation and is most frequently applied to sediment removed from a channel bed or other low-lying parts of a stream channel.

- **Aggradation**
- •Aggradation is the raising or elevating of a bottomland surface through the process of alluvial deposition;
- •Conceptually it is the vertical component of accretion and is most frequently applied to sediment deposition on a channel bed, bar or other near-channel surfaces, flood plain, or, less often, low-lying alluvial terrace.

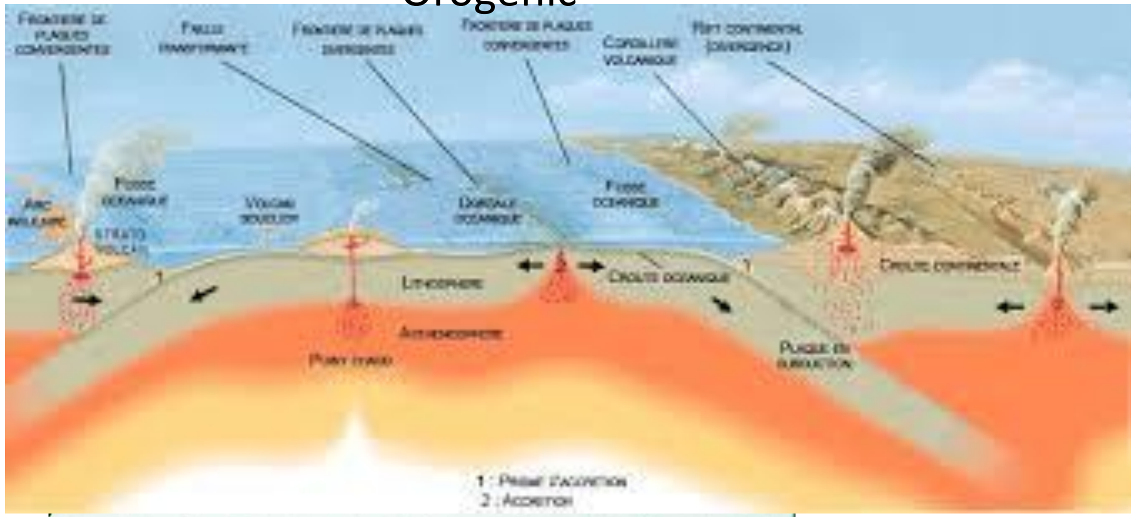
- Basic difference between the two process
- Processes that are caused by forces from within the Earth are **endogenous** processes.
- By contrast, **exogenous** processes come from forces on or above the Earth's surface.

| Endogenic Processes | Exogenic Processes |
| --- | --- |
| Originate in the interior of the earth. | Originate on the surface of the earth. |
| Causes sudden or rapid movements | Causes slow movements. |
| Eg: Earthquake, faulting, diastrophism | Eg: Erosional and Depositional |

epeirogenic




Orogenic



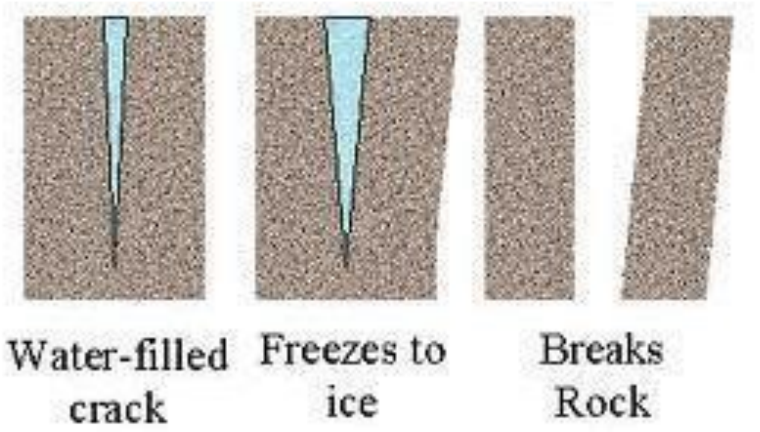
# Weathering:

"weathering is the breakdown and alteration of minerals near the earth's surface to products that are more in equilibrium with newly imposed Physico-chemical conditions" – C. D. Ollier(1969)

- **The weathering is a process by which the rocks on the surface of the earth is broken mechanically into pieces due to snow or frost, the variation of temperature and pressure or due to chemical (dissolution) action on the materials.**

- Even the rocks are dislodged by the animals. But the rocks weathered this way, are not transported elsewhere.

Weathering involves two types of changes in the rocks e.g.; (1) physical changes(rocks are disintegrated through different factors) (2) chemical changes (rocks are decomposed through chemical actions).




# Factors influencing weathering:

- Climate
- characteristics of rocks
- Organism

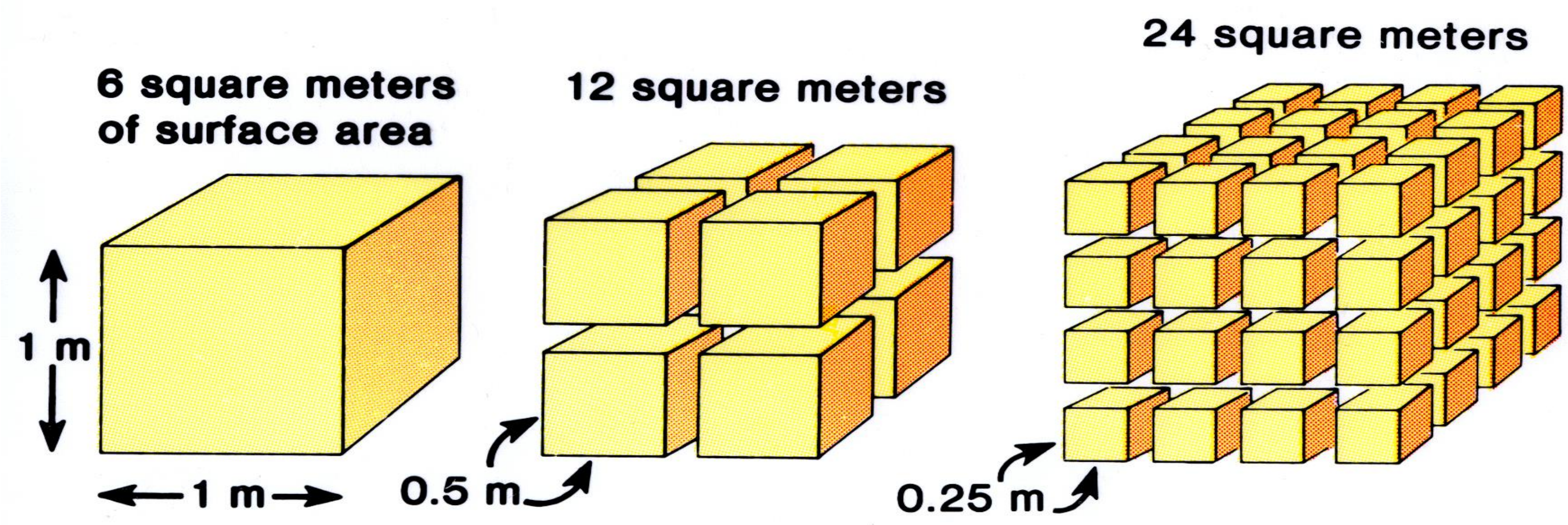
- **Climate:**
- Climate controls both the type of process involved in weathering as well the weathering rate.
- Temperature is a climatic factor that affects the reaction rate. Temperature influences the rate of weathering, but seldom the type of weathering.
- Chemical reactions need water to occur, but water is also crucial to many mechanical weathering processes.
- Mechanical weathering depends upon the presence of water but is very effective where repeated freezing and thawing occurs.
- **Rocks:**
- Mineral and chemical composition of the parent material are important for the rates of weathering.
- Different mineral composition might be expected to respond different to weathering processes.
- Limestones or marbles having more soluble elements are more affected by the chemical weathering.
- Well jointed rocks are more subjected to mechanical disintegration.
- **Organism:**
- The nature of weathering is largely determined by the presence or absence of vegetations in a particular region. Vegetation protect the ground surface from the direct impact of sun rays.
- Microorganisms associated with the roots of plants and trees encourage decomposition and disintegration of rocks through physico-biochemical weathering.

# Types Of Weathering:

1. Physical weathering
2. Chemical weathering
3. Biological weathering

## Physical Weathering:

***Physical weathering*** is also called mechanical weathering. It is related to the physical breakup of rocks into small pieces and fragments. The disintegration of rocks take place due to temperature variations, frost action, wind action and unloading of pressure etc. In physical weathering, there is no change in the chemistry of the parent rock.



## Causes/processes Of Physical Weathering :

### *(a) INSOLATION*

1. Granular disintegration
2. Exfoliation/ onion weathering
3. Block disintegration
4. Dirt cracking
5. Boulder cleaving

### (b) *Unloading*

1. Spalling
2. sheeting

### ( c) *Crystallisation*

1. Frost
2. Salt

### (d) *Moisture*

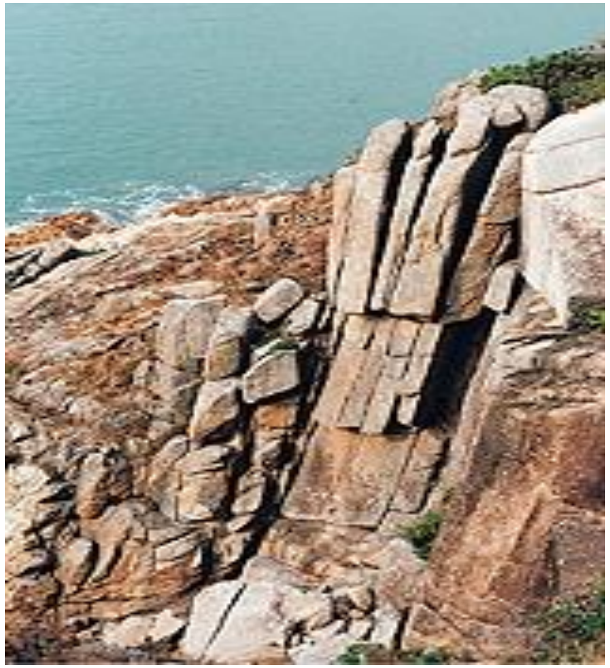
# Insolation:

**1.Granular disintegration:** the different part of the same rock mass receive and absorb different amount of insolation. consequently they are affected by differential expansion and contraction which cause stresses within the rock. Thus they get disintegrated into smaller particles.

**2.Exfoliation/ onion weathering:** The outer shells of rocks become loose due to alternate expansion and contraction.

Example of exfoliation of rock is kanki dome near ranchi.

**3. Disintegration:** When the difference between the day and night temperature is large, rocks expand and contract. They expand during the day, when the temperature is high and contract during the night when the temperature is extremely low. This results in the splitting of rocks.



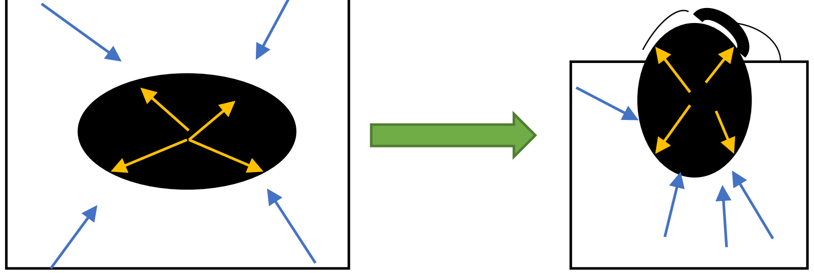
**4.Dirt cracking:** The boulders containing dirt are fractured and split due to thermal expansion and contraction.

**5.Boulder cleaving:**

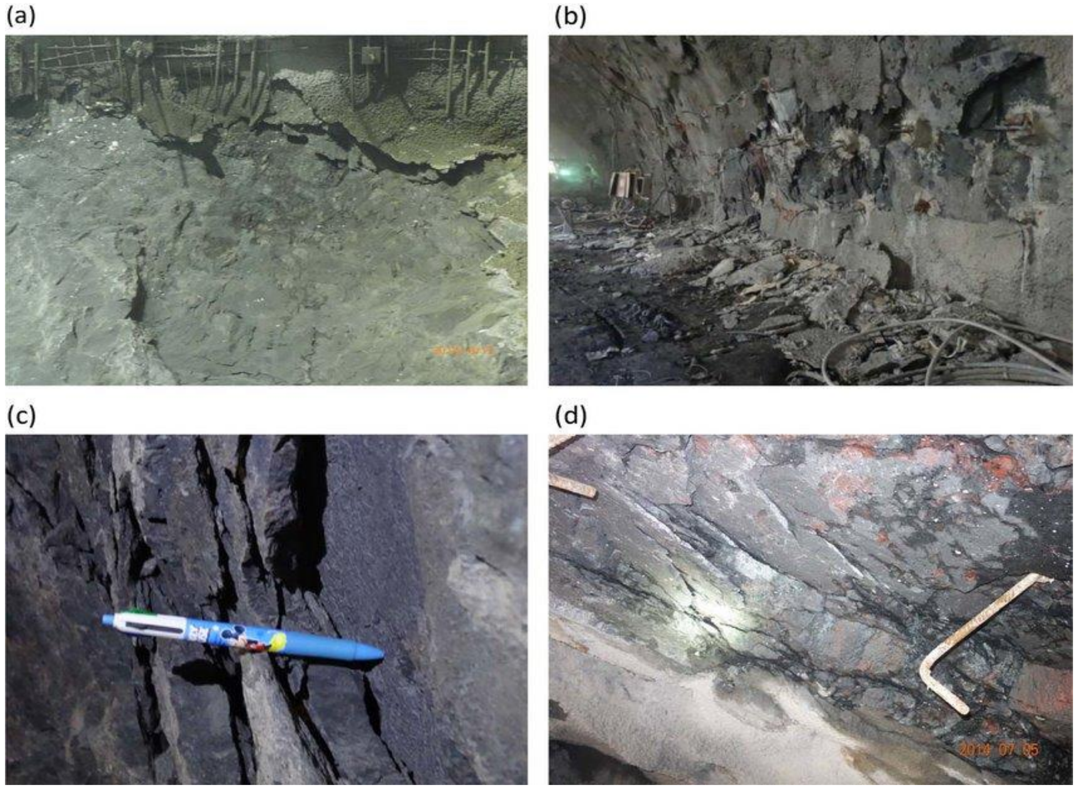
It refers to breaking and splitting of boulders of granites and basalts and complex boulders due to thermal expansion.

# Unloading

**1. Sheeting:** It refers to the development of cracks and fractures parallel to the ground surface caused by removal of superincumbent load resulting into reduction of confining pressure.



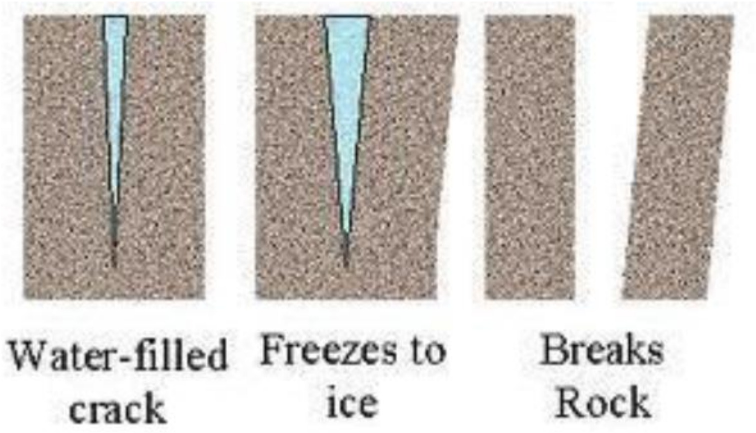
**2. Spalling:** It referrers to the development of platy rock fragments, lozenge shaped or irregular, in the rocks of cave or tunnel due to unloading of superincumbent load.



# Crystallisation

***Frost action***

Water occupying the pores and interstices within a soil or rock body expands by 9 per cent upon freezing. This expansion builds up stress in the pores and fissures, causing the physical disinte - gration of rocks. **Frost weathering** or **frost shattering** breaks off small grains and large boulders, the boulders then being fragmented into smaller pieces. It is an important process in cold environments, where **freeze–thaw cycles** are common.




***Salt-crystal growth***

In coastal and arid regions, crystals may grow in saline solutions on evaporation. Salt crystallizing within the interstices of rocks produces stresses, which widen them, and this leads to granular disintegration. This process is known as **salt weathering** or **haloclasty** (Wellman and Wilson 1965). When salt crystals formed within pores are heated, or saturated with water, they expand and exert pressure against the confining pore walls; this produces thermal stress or hydration stress respectively, both of which contribute to salt weathering.

# Moisture

***Wetting and drying***

Some **clay minerals,** including smectite and vermiculite, swell upon wetting and shrink when they dry out. Materials containing these clays, such as mudstone and shale, expand considerably on wetting, inducing microcrack formation, the widening of existing cracks, or the disintegration of the rock mass. Upon drying, the absorbed water of the expanded clays evaporates, and shrinkage cracks form. Alternate swelling and shrinking associated with wetting–drying cycles, in conjunction with the fatigue effect, leads to **wet–dry weathering**, or **slaking**, which physically disintegrates rocks.

## Chemical Weathering:

Chemical characteristics of minerals present in rocks are also expected to play a significant role in weathering. Decomposition and disintegration of rocks due to chemical reactions is called chemical weathering. It changes the composition of rocks.

**Six main chemical reactions are engaged in rock decomposition: solution, hydration, oxidation and reduction, carbonation, and hydrolysis.**

## *Solution*

Mineral salts may dissolve in water, which is a very effective solvent. The process, which is called **solution** or **dissolution**, involves the dissociation of the molecules into their anions and cations and each ion becomes surrounded by water.

## *Hydration:*

It occurs when minerals absorb water molecules on their edges and surfaces, or, for simple salts, in their crystal lattices, without otherwise changing the chemical composition of the original material. For instance, if water is added to anhydrite, which is calcium sulphate ($CaSO_4$), gypsum ($CaSO_4.2H_2O$) is produced. The water in the crystal lattice leads to an increase of volume, which may cause hydration folding in gypsum sandwiched between other beds. Under humid mid-latitude climates, brownish to yellowish soil colours are caused by the hydration of the reddish iron oxide hematite to rust-coloured goethite. The taking up of water by clay particles is also a form of hydration. Hydration assists other weathering processes by placing water molecules deep inside crystal structures.

## *Oxidation and reduction*

Oxidation occurs when an atom or an ion loses an electron, increasing its positive charge or decreasing its negative charge. It involves oxygen combining with a substance. Oxygen dissolved in water is a prevalent oxidizing agent in the environment. **Oxidation weathering** chiefly affects minerals containing iron, though such elements as manganese, sulphur, and titanium may also be oxidized. The reaction for iron, which occurs mainly when oxygen dissolved in water comes into contact with iron-containing minerals, is written:

$4Fe2 + 3O2 + 2e \longrightarrow 2Fe2O3$ [*e* = electron]

If soil or rock becomes saturated with stagnant water, it becomes oxygen-deficient and, with the aid of **anaerobic bacteria**, reduction occurs.

**Reduction** is the opposite of oxidation, and the changes it promotes are called gleying. In colour, gley soil horizons are commonly a shade of grey. The propensity for oxidation or reduction to occur is shown by the redox potential, Eh. This is measured in units of millivolts (mV), positive values registering as oxidizing potential and negative values as reducing potential.

## *Carbonation*

**Carbonation** is the formation of carbonates, which are the salts of carbonic acid (H2CO3). Carbon dioxide dissolves in natural waters to form carbonic acid. The reversible reaction combines water with carbon dioxide to form carbonic acid, which then dissociates into a hydrogen ion and a bicarbonate ion. Carbonic acid attacks minerals, forming carbonates. Carbonation dominates the weathering of calcareous rocks (limestones and dolomites) where the main mineral is calcite or calcium carbonate (CaCO3). Calcite reacts with carbonic acid to form calcium hydrogen carbonate (Ca(HCO3)2) that, unlike calcite, is readily dissolved in water. This is why some limestones are so prone to solution.

$$CaCO_3 + H_2O + CO_2 \longleftrightarrow Ca_2+ + 2HCO_3-$$

## *Hydrolysis*

Generally, hydrolysis is the main process of chemical weathering and can completely decompose or drastically modify susceptible primary minerals in rocks. In hydrolysis, water splits into **hydrogen cations** (**H+**) and **hydroxyl anions** (**OH–)** and reacts directly with silicate minerals in rocks and soils. The hydrogen ion is exchanged with a metal cation of the silicate minerals, commonly potassium (K+), sodium (Na+), calcium (Ca2+), or magnesium (Mg2+). The released cation then combines with the hydroxyl anion. The reaction for the hydrolysis of orthoclase, which has the chemical formula KAlSi3O8, is as follows:

$$2KAlSi_3O_8 + 2H^+ 2OH^- \longrightarrow 2HAlSi_3O_8 + 2KOH$$

So the orthoclase is converted to aluminosilicic acid, HAlSi3O8, and potassium hydroxide, KOH.

## *Chelation:*

This is the removal of metal ions, and in particular ions of aluminium, iron, and manganese, from solids by binding with such organic acids as fulvic and humic acid to form soluble **organic matter metal complexes**. The chelating agents are in part the decomposition products of plants and in part secretions from plant roots. Chelation encourages chemical weathering and the transfer of metals in the soil or rock.

## Biological weathering

Some organisms attack rocks mechanically, or chemically, or by a combination of mechanical and chemical processes. Plant roots, and especially tree roots, growing in bedding planes and joints have a **biomechanical effect** – as they grow, mounting pressure may lead to rock fracture. Dead lichen leaves a dark stain on rock surfaces. The dark spots absorb more thermal radiation than the surrounding lighter areas, so encouraging **thermal weathering**.

Under some conditions, bacteria, algae, fungi, and lichens may chemically alter minerals in rocks. The boring sponge (*Cliona celata*) secretes minute amounts of acid to bore into calcareous rocks. The rock minerals may be removed, leading to **biological rock erosion**. In an arid area of southern Tunisia, weathering is concentrated in topographic lows (pits and pans) where moisture is concentrated and algae bore, pluck, and etch the limestone substrate.

Humans have exposed bedrock in quarries, mines, and road and rail cuts. They have disrupted soils by detonating explosive devices, and they have sealed the soil in urban areas under a layer of concrete and tarmac. Their agriculture practices have greatly modified soil and weathering processes in many regions.

**Question:**

1. Distinguish between hydration and carbonation.
2. Distinguish between hydration and hydrolysis.
3. Distinguish between oxidation and carbonation.

# WEATHERING PRODUCTS: LANDFORMS

(1) large-scale cliffs and pillars and (2) smaller scale rock-basins, tafoni, and honeycombs.

## Cliffs and pillars:

- Cliffs and crags are associated with several rock types, including limestones, sandstones, and gritstones.
- *sandstone cliffs and pillars are distinctive features of sandstone terrain. They are eye-catching in arid areas, but tend to be concealed by vegetation in more humid regions. Many cliffs are dissected by widened vertical joints that form open clefts or passageways. In Britain, such widened joints are called **gulls** or **wents.***
- Many sandstone cliffs, pillars, and boulders are undercut towards their bases. In the case of boulders and pillars, the undercutting produces **mushroom, perched**, or **pedestal rocks**.
- Processes invoked to account for the undercutting include (1) the presence of softer and more effortlessly weathered bands of rock; (2) abrasion by windblown sand.

## Rock-basins:

**Rock-basins**, also called **weathering pits**, **weatherpits** are closed, circular, or oval depressions, a few centimetres to several metres wide, formed on flat or gently sloping surfaces of limestones, granites, basalts, gneisses, and other rock types. They are commonly flat-floored and steep-sided, and no more than a metre or so deep, though some are more saucer-shaped.

## Tafoni:

**Tafoni** (singular **tafone**) are large weathering features that take the form of hollows or cavities on a rock surface, the term being originally used to describe hollows excavated in granites on the island of Corsica. They tend to form in vertical or near-vertical faces of rock. They can be as little as 0.1 m to several metres in height.

## Honeycomb weathering:

**Honeycomb weathering** is a term used to describe numerous small pits or **alveoli**, no more than a few centimetres wide and deep, separated by an intricate network of narrow walls and resembling a honeycomb. They are often thought of as a small-scale version of multiple tafoni.

## Joints and weathering:

All rocks are fractured to some extent. A broad range of fractures exists, many of which split rock into cubic or quadrangular blocks. All **joints** are avenues of weathering and potential seats of erosion. The geomorphic significance of a set of joints depends upon many factors, including their openness, pattern and spacing, and other physical properties of the rock mass.

If granite has a high density of fractures, the many avenues of water penetration promote rapid rock decay that, if rivers are able to cut down and remove the weathering products, may produce a plain of low relief. This has happened on many old continental shields, as in the northern Eyre Peninsula, Australia.

The weathering of granite with moderately spaced joints produces distinctive landforms. The weathering of the joint-defined blocks proceeds fastest on the block corners, at an average rate on the edges, and slowest on the faces. This differential weathering leads to the rounding of the angular blocks to produce rounded kernels or **core stones** surrounded by weathered rock. The weathered rock or **grus** is easily eroded and once removed leaves behind a cluster of rounded boulders that is typical of many granite outcrops.

A similar dual process of weathering along **joints and grus** removal operates in other plutonic rocks such as diorite and gabbro, and less commonly in sandstone and limestone. It also occurs in rocks with different fracture patterns, such as gneisses with well-developed cleavage or foliation, but instead of producing boulders it fashions slabs known as **penitent rocks**, **monkstones**, or **tombstones.**

Another common feature of granite weathering is a bedrock platform extending from the edge of inselbergs (island mountains). These platforms appear to have formed by etching. Inselbergs come in three varieties: **bornhardts**, which are dome-shaped hills;**nubbins** or **knolls**, which bear a scattering of blocks; and small and angular **castle koppies**.

## *Etch plains and etched surfaces*

Traditional models of landscape evolution assumed that mechanical erosion predominates. It was realized that chemical weathering reduces the mass of weathered material, but only on rocks especially vulnerable to solution (such as lime stones) were chemical processes thought to have an overriding influence on landscape evolution. However, it now seems that forms of chemical weathering are important in the evolu tion of landscapes. **Groundwater sapping**, for instance, shapes the features of some drainage basins (e.g. Howard *et al*. 1988). And the solute load in three catchments in Australia comprised more than 80 per cent of the total load, except in one case where it comprised 54 per cent (Ollier and Pain 1996, 216).

What makes these figures startling is that igneous rocks underlay the catchments. Information of this kind is making some geo morphologists suspect that chemical weathering plays a starring role in the evolution of nearly all landscapes. In tropical and subtropical environments, chemical weathering produces a thick regolith that

erosion then strips (Thomas 1989a, 1989b, 1994). This process is called **etch planation**. It creates an **etched plain** or **etch plain**. The interface between the weathered saprolite and the un weathered bedrock is the **etch surface**, which is exposed after stripping takes place. The etch plain is largely a production of chemical weathering.

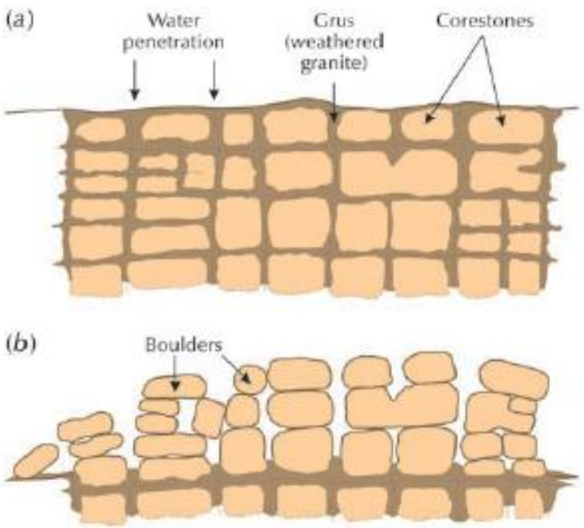



**Plate 7.10** Granite tor, Haytor, Dartmoor, England. (*Photograph by Tony Waltham Geophotos*)

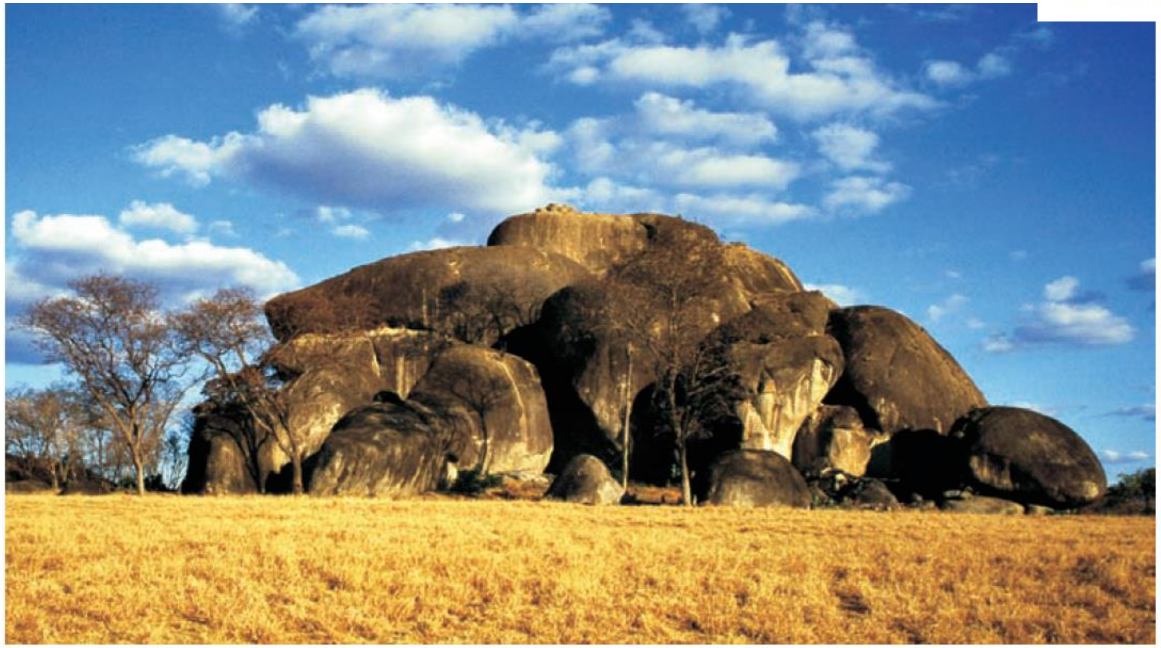


**Plate 7.8** Bornhardt granite block standing out by differential weathering, Iuiu, Minas Gerais, Brazi (*Photograph by Tony Waltham Geophotos*)

**Plate 7.9** Nubbin weathering remnants in massive sandstone, Hammersley Ranges, Pilbara, Western Australia. (*Photograph by Tony Waltham Geophotos*)

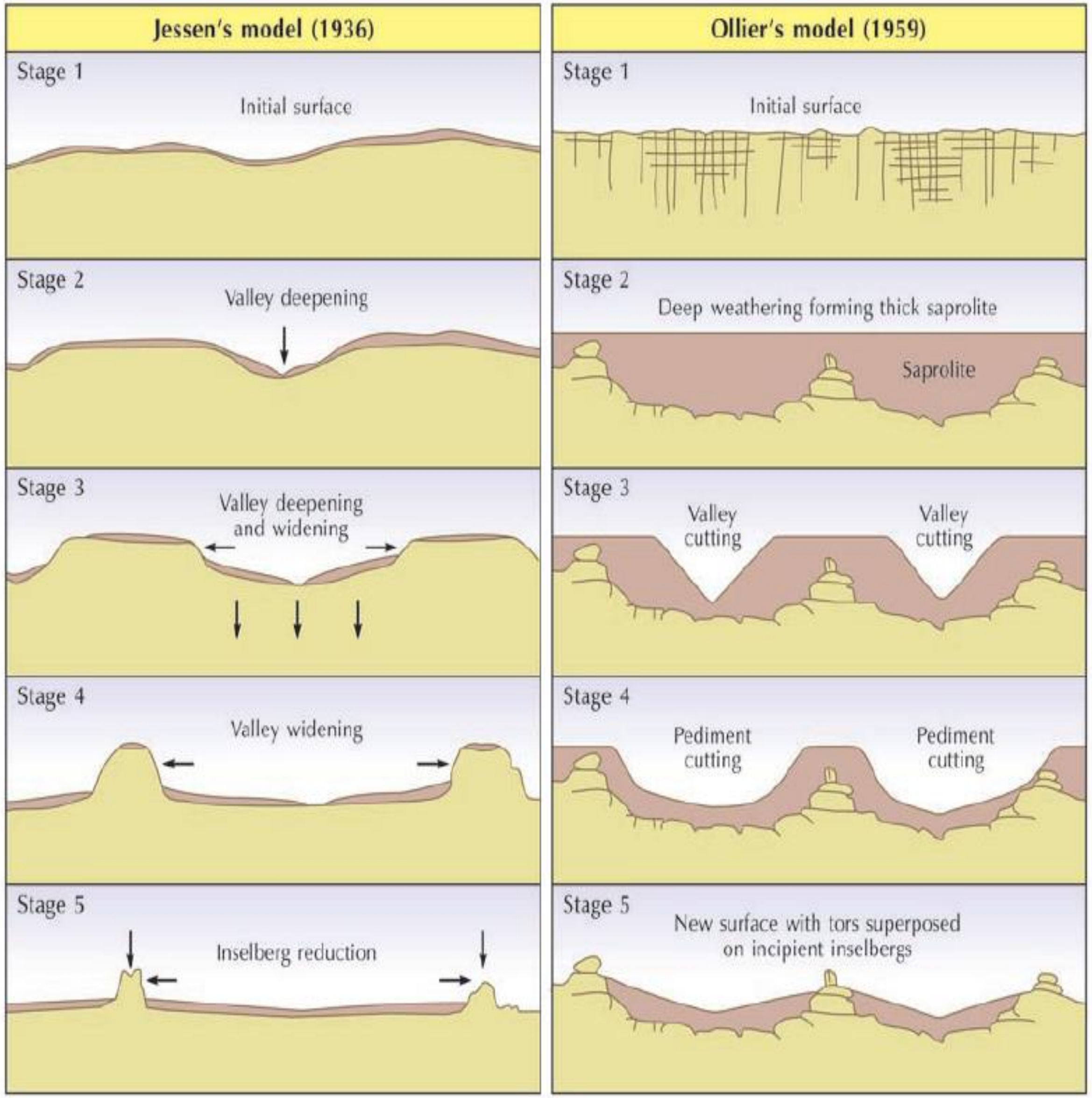



**Figure 15.6** Theories of etchplanation. *Source:* Adapted from Jessen (1936) and Ollier (1995)

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**FURTHER REFERENCES:**

RICHARD JOHN HUGGETT: FUNDAMENTALS OF GEOMORPHOLOGY
KALE & GUPTA: INTRODUCTION TO GEOMORPHOLOGY