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GEOMORPHOLOGY
SEDIMENTOLOGY
SEQUENCE STRATIGRAPHY

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1. Approaches to geomorphology

Geomorphology is the study of the shape of the earth's land surface and of the processes that are create them. These processes continually shape the earth's surface, and generate the sediments that circulate in the rock cycle. Landforms are the result of the interactions among the geosphere, atmosphere and hydrosphere.

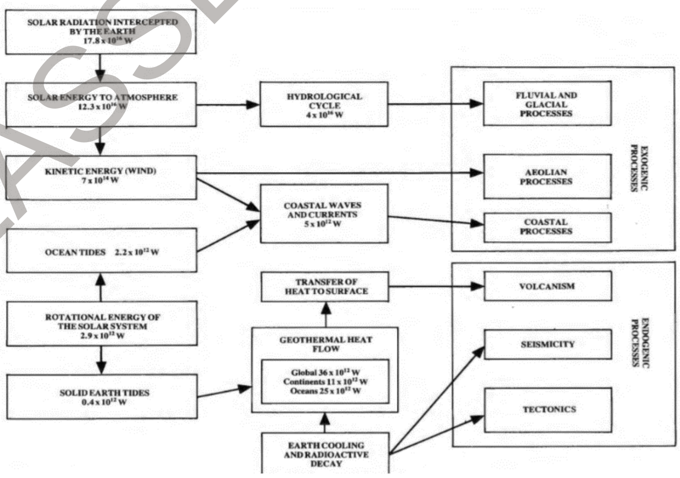
Geomorphic processes:

Exogenic Processes

External, or generated from outside also termed exogenic processes, including the action of water, ice and wind, predominantly involve denudation, that is, the removal of material, and thus generally lead to a reduction in elevation and relief. Denudation can involve the removal of both solid particles and dissolved material. Lowering of relief by erosion.

The two sources of energy which power the various exogenic processes:

- **Potential energy** arising from the gravitational attraction of the earth which, in the absence of sufficient resisting forces, causes the downslope movement of water, ice and particles of rock and soil.
- **Solar radiation** acts in diverse ways, providing the energy for biological activity, the evaporation of water and the functioning of the earth's atmospheric circulation.



Endogenic processes

These are an example of a closed system driven by earth's internal heat, which drives plate tectonics through deep convection of the planet's mantle.

Major three processes:

- **Igneous activity -** movement of molten rock, or magma, on to, or towards, the earth's surface.
- **Orogenesis (orogeny)-** formation of linear mountain belts in plan form.
- **Epeirogenesis (epeirogeny)** – upliftment of earth's surface without significant folding or fracture.

The broad structures of the earth's crust and the processes of deformation and faulting which give rise to them are described by the term tectonics.

- **Morphotectonics** is applied to the interaction between tectonics and landform genesis.
- **Neotectonics** refers to the processes and effects of recent tectonic activity and is usually applied to late Cenozoic events.

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MORPHOCLIMATIC ZONE	MEAN ANNUAL TEMPERATURE (°C)	MEAN ANNUAL PRECIPITATION (mm)	RELATIVE IMPORTANCE OF GEOMORPHIC PROCESSES
Humid tropical	20–30	>1500	High potential rates of chemical weathering; mechanical weathering limited; active, highly episodic mass movement; moderate to low rates of stream corrasion but locally high rates of dissolved and suspended load transport
Tropical wet–dry	20–30	600–1500	Chemical weathering active during wet season; rates of mechanical weathering low to moderate; mass movement fairly active; fluvial action high during wet season with overland and channel flow; wind action generally minimal but locally moderate in dry season.
Tropical semi–arid	10–30	300–600	Chemical weathering rates moderate to low; mechanical weathering locally active especially on drier and cooler margins; mass movement locally active but sporadic; fluvial action rates high but episodic; wind action moderate to high
Tropical arid	10–30	0–300	Mechanical weathering rates high (especially salt weathering); chemical weathering minimal; mass movement minimal; rates of fluvial activity generally very low but sporadically high; wind action at a maximum
Humid mid–latitude	0–20	400–1800	Chemical weathering rates moderate, increasing to high at lower latitudes; mechanical weathering activity moderate with frost action important at higher latitudes; mass movement activity moderate to high; moderate rates of fluvial processes: wind action confined to coasts
Dry continental	0–10	100–400	Chemical weathering rates low to moderate; mechanical weathering, especially frost action, seasonally active; mass movement moderate and episodic; fluvial processes active in wet season; wind action locally moderate
Periglacial	<0	100–1000	Mechanical weathering very active with frost action at a maximum; chemical weathering rates low to moderate; mass movement very active; fluvial processes seasonally active; wind action rates locally high
Glacial	<0	0–1000	Mechanical weathering rates (especially frost action) high; chemical weathering rates low; mass movement rates low except locally; fluvial action confined to seasonal melt; glacial action at a maximum; wind action significant
Azonal mountain zone	Highly variable	Highly variable	Rates of all processes vary significantly with altitude; mechanical and glacial action become significant at high elevations

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Geomorphic system:

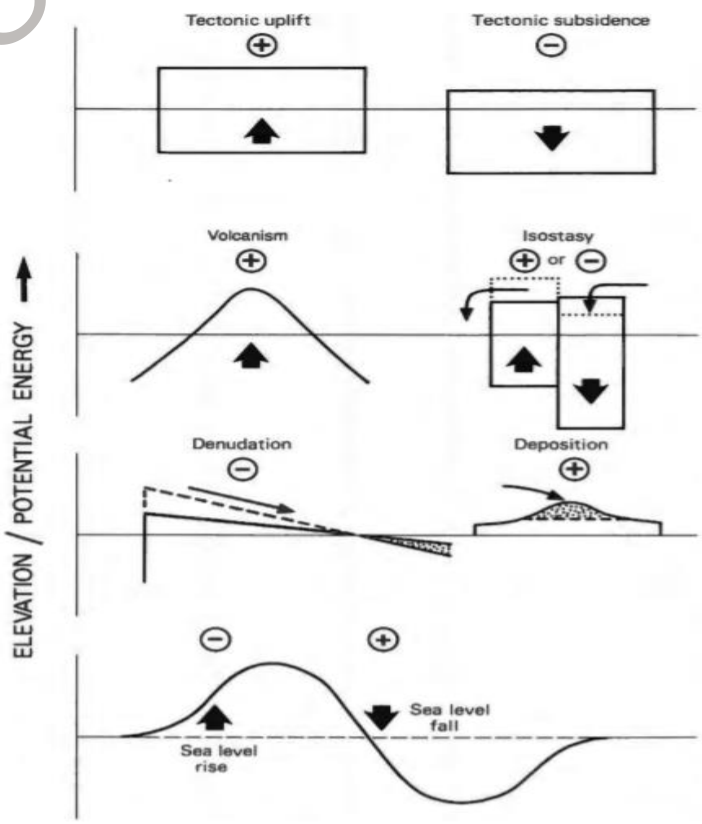
System- set of objects or characteristics which are related to one another and operate together as a complex entity.

Systems analysis focuses on the relationships between these objects or characteristics.

There are three kinds of system:

- **Morphological systems-** statistical relationships between the morphological properties of landform elements.
- **Cascading systems-** movements of mass and flows of energy through the landscape are described.
- **Process-response systems-** interactions between these two types of system resulting from adjustments between process.

Open system- movement of both energy and matter across the system boundary



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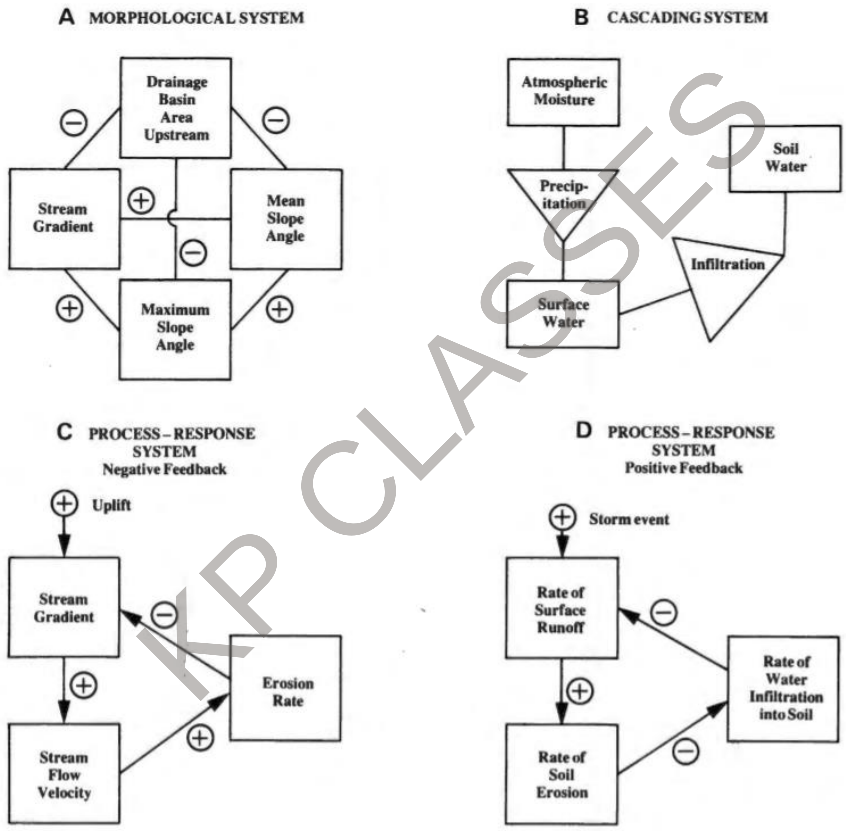
Closed system -only energy is transferred.
An input of mass or energy into a system is transmitted through it (throughout) and leaves as an output, but may also give rise to adjustments in the structure of a part of the system (subsystem). Variables within the system may be either **independent (causal) or dependent (responding to causal variables),** representing the form of the landscape, the rate of geomorphic processes acting upon it and the environmental factors controls the changes in the flow of energy and mass as well as adjustments to the structure of the system

Negative feedback, a condition whereby the structure of the system is capable of adjusting in a way that minimizes the effect of externally generated changes.
Positive feedback- input change may engender a system response which produces an output which reinforces the original input and eventually causes a shift in the system to a new equilibrium state. This 'snowball effect' exhibiting positive feedback and is precipitated by the breaching of a threshold in the system.



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Magnitude and frequency

Understanding the frequency with which geomorphic events of different magnitudes occur is clearly a crucial component of any explanation of landform genesis.

- The highest frequency of events occurs in the lower to middle magnitude range, whereas there is only a small proportion of high magnitude events.

- Disturbances also affect the links between biotic and abiotic processes because plants often rapidly recolonize areas left bare by catastrophic events like landslides and floods.

Recurrence interval

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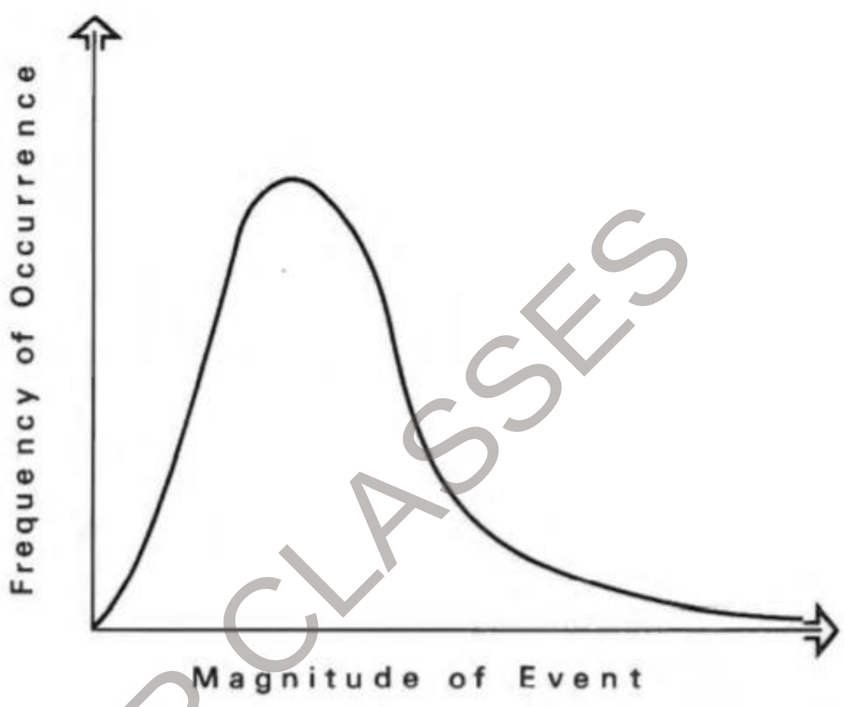
The frequency of an event of a specific magnitude is expressed as the average length of time between events of that magnitude.

- Relationships that quantify the relationship between the size of an event and the chance that it will occur in a given time period. It is important to note that different environments can have different recurrence intervals for the same process, a result of differing climate and tectonic setting.
- Measurements of the operation of various geomorphic processes over a range of time scales show that extreme, high intensity events are rare and that low to medium-intensity events prevail for the great majority of the time.



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Response time of a landscape or landform to changes in driving or resisting forces varies greatly depending on the type of change, the rates of landscape forming processes, and the resistance of the landscape to a particular change.

Relaxation time an increase in rate of uplift or decrease in river discharge, is fully reflected in a change in form. This can range from a few minutes for changes in a small section of an alluvial channel to tens of millions of years for the uplift of a major mountain range.

Scale in morphology

Spatial scale

Landforms at each scale are indicated together with the main endogenic and exogenic factors influencing landform genesis at the different scales

Global scales: at these scales, broad patterns in global climate and plate tectonics influence patterns of erosion and deposition that, in turn, influence the size and extent of mountains, plateaus, lowlands, coastal plains, and river basins. Such patterns also affect the distribution of soil types and the relative importance of glacial, fluvial, eolian (wind-driven), and coastal processes in shaping topography.

Regional scale: physiographic provinces are areas in which similar suites of geomorphological processes govern landscape formation and dynamics, and thus where one finds similar suites of landforms.

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Small scale: valley segments where different types of processes and/or histories have led to development of distinct landforms and dynamics. The difference between u-shaped valleys carved by glaciers valleys and v- shaped valleys cut by streams is a classic example.

Finer spatial scales: landscapes can be divided into distinct hillslopes, hollows, channels, floodplains, and estuaries.

SPATIAL SCALE	DIMENSIONS		EXAMPLES OF LANDFORMS				MAJOR CONTROLLING FACTORS		TEMPORAL DURATION SCALE	
	Linear (km)	Areal (km^2)	Endogenic	Fluvial	Exogenic Glacial	Aeolian	Endogenic	Exogenic		
Micro	<0.5	<0.25	Minor fault scarps	Pools and riffles in a small river channel	Small moraine ridges	Sand ripples	Individual earthquakes and volcanic eruptions	Microclimates; meteorological events	Steady time	10^1a
Meso	0.5–10	0.25–10^2	Small volcanoes	Meanders	Small glacial valleys	Dunes	Local and regional isostatic uplift; localized volcanism and seismicity	Local climates; short-term climatic change	Dynamic time	10^3a
Macro	10–10^3	10^2–10^6	Block–faulted terrain	Floodplains of major rivers	Highland ice caps	Sand seas	Regional uplift and subsidence	Regional climates; long-term climatic change (glacial-inter-glacial cycles)		
Mega	>10^3	>10^6	Major mountain ranges	Major drainage basins	Continental ice sheets	Large sand seas	Long-term patterns of uplift, subsidence and continental motion	Major climatic zones; very long-term climatic change (ice ages)	Cyclic time	10^7a

Multiple Choice Questions:

Q.1 ‘The present is the key to the past' is belongs to:

1. Uniformity of law
2. Uniformity of state
3. Principal of Uniformitarianism
4. Principal of conservation

Q.2 Principal of Uniformitarianism is given by:

1. Herry Hass
2. James Hutton
3. Alfred Wegner
4. Wadatti Benioff

Q.3 Opposite to ‘uniformitarianism’ is:

1. Law of Gradualism
2. Law of Conservation
3. Law of Catastrophism
4. Orogenesis

Q.4 The interaction between tectonics and landform genesis is:

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1. Morphotectonics
2. Neotectonics
3. Epeirogenesis
4. None of above

Q.5 Which of the following is exogenic processes is:

1. Denudation
2. Volcanic activity
3. Isostatic uplift
4. Faulting in terrain

Section: 2(difficult level)

Q.1 Match the following:

1. Morphological systems-	a) the system is capable of adjusting in a way that minimizes the effect of externally generated changes.
2. Cascading systems	b) causes a shift in the system to a new equilibrium state.
3. Negative feedback	c) movements of mass and flows of energy through the landscape are described.
4. Positive feedback	d) statistical relationships between the morphological properties of landform elements.

1. 1-d, 2-c, 3-a, 4-b 2. 1-b, 2-d, 3-a, 4-c 3. 1-c, 2-b, 3-a, 4-d 4.1-c, 2-d, 3-a, 4-b

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Q.2 Morphoclimatic zones are:

1. the movement and exchange of water between the oceans, land, and atmosphere
2. Landforms associated with a particular climatic environment.
3. Waterbodies are associated with exogenic processes.
4. Landforms associated with a particular endogenetic environment.

Q.3 Choose the correct pair:

1. Endogenic: Lowering of relief
2. Exogenic: Highland Icecaps
3. Endogenic: Erosion
4. Exogenic: Denudation

Q.4 Which of the following is not a driving forces of endogenic processes is:

1. Rotation of Earth
2. Meteorological events
3. Radioactive decay
4. Gravitational force

Q.5 Relation between magnitude and frequency of an events:

1. Magnitude of event increases – frequency decreases
2. Magnitude of event increases - frequency increases

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3. Magnitude of event is equal to frequency of events
4. There is no relation between magnitude and frequency

Q.6 Slow and small but measurable change in the form of the channel, over the succeeding years is a property of:

1. Static equilibrium
2. Steady state equilibrium
3. Dynamic equilibrium
4. Decay equilibrium

Q.7 Match with correct pair:

a. Progressive lowering of the channel floor and possibly a gradual decrease in channel gradient.

b. channel bed approaches base level and the channel gradient become so low that rates of erosion reach a minimum.

1. a-Decay equilibrium, b- Dynamic equilibrium
2. a-Dynamic equilibrium, b- Static equilibrium
3. a-Static equilibrium, b- Steady state equilibrium
4. a-Dynamic equilibrium, b- Decay equilibrium

Question no.	Answer	Q. no (sec-2)	Answer	Q.no (sec2)	
1.	**3**	1	**1**	5	**1**
2.	**2**	2.	**2**	6	**2**
3.	**3**	3.	**4**	7	**4**
4.	**1**	4.	**2**		
5	**1**				

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2. Weathering and associated landforms

It is the breakdown of rocks by mechanical disintegration and chemical decomposition.

Many rocks form under high temperatures and pressures deep in the Earth's crust. When exposed to the lower temperatures and pressures at the Earth's surface and brought into contact with air, water, and organisms, they start to decay.

The process tends to be self-reinforcing: weathering weakens the rocks and makes them more permeable, so rendering them more vulnerable to removal by agents of erosion, and the removal of weathered products exposes more rock to weathering

Complex interactions between the lithosphere, the atmosphere, the hydrosphere and the biosphere, and gives rise to three major types of products.

1. Chemical processes lead to the release of compounds in solution and the creation of new mineral products.
2. Physical processes cause the breakdown of the original rock into smaller particles.
3. Dissolved material may subsequently be reprecipitated or be reincorporated into other minerals, but the great proportion is carried by rivers to the ocean.

Role of Water in Weathering

Water plays a vital role in mechanism of weathering. It is a polar solvent, the covalently bonded H_20 molecule has a positive charge at each end balanced by a negative charge in the middle. The positive and negative parts of water molecules become· attached, respectively, to the anions and cations of solids and free them by neutralizing their charge; water is thus a highly effective solvent.

A proportion of H_20 molecules are always decomposed into hydrogen ions (H+) and hydroxyl ions (OH-) (a state known as dissociation), the concentration of H+ ions being expressed as pH.

Gravity and capillary suction are the two different driving force of water movement in rock and soil.

Force of gravity: Water may enter the soil or bedrock simply through percolation through interconnected voids between particles by which water can move only downwards.

Capillary suction: Important mechanism whereby horizontal and upward movements of moisture can occur, which affects the water films attached to soil and rock particles, by which water can move lateral and upwards. Capillary suction, together with the force of gravity, therefore influence both the movement and distribution of water in soil and rock

The downward movement of water through the weathering zone which leads to the removal of soluble products. Kaolinite, which have been stripped of metal cations together with iron and aluminium oxides and hydroxide.

i. **Extreme leaching** removal of iron and silicon to leave an aluminium-rich residue in the form of the mineral gibbsite.
ii. **Moderate leaching** cations released in the solutions moving through the weathering mantle and the formation of illite and smectite is favoured.

The intensity of leaching is never uniform throughout an entire weathering profile. The resulting reduction in the intensity of leaching is due to compaction and the downward translocation of fine particles which reduces the size of voids usually reflected in mineralogical changes with depth.

Clay minerals such as illite and smectite, altered in the zone of active leaching towards the top of a profile, may be relatively stable at lower levels where leaching is less intense.

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Vertical differentiation in mineralogy in weathering profiles may also reflect the stage-by-stage alteration of primary rock minerals. Smectite and illite may form near the weathering front only to be eventually altered to kaolinite, and perhaps gibbsite.

Mineral stability

Types and proportions of the various minerals in a weathering profile are usually quite different from the original bedrock. Some minerals seem to survive more of less unaltered even after being subject to prolonged weathering, whereas others decompose very rapidly.

- Part of the reason for this relationship between susceptibility to weathering and temperature of crystallization appears to lie in the relative strength of the bonds between oxygen and the cations in each mineral.
- Olivine, for instance, is the most unstable mineral in the weathering series and crystallizes at the highest temperature in the reaction series. Quartz, on the other hand, is the most stable and crystallizes at the lowest temperature.
- With the sequence from most to least mobile proceeding as Ca^{2+}, Na^{+}, Mg^{2+} > K^{+} > Fe^{2+} > Si^{3+} > Fe^{3+} > Al^{3+}.
- The most mobile cations (Ca^{2+}, Na^{+}, Mg^{2+}) are readily stripped from mineral surfaces, tend to remain in solution, and are the first to be lost from rocks as they weather. The least mobile cations (Si^{3+}, Fe^{3+}, and Al^{3+}) are relatively insoluble and become concentrated in residual soils over time as weathering strips away more mobile elements.

Thermodynamically, there being a larger change in free energy accompanying the decomposition of an unstable mineral like olivine than a comparatively stable mineral like muscovite

Types of Weathering

Chemical weathering

Weathering involves a huge number of chemical reactions acting together upon many different types of rock under the full gamut of climatic conditions. Chemical weathering along microfractures in a rock will weaken it and help physical processes break it down more rapidly.

Weathering involves a huge number of chemical reactions acting together upon many different types of rock under the full gamut of climatic conditions.

Chemical weathering is the breaking of chemical bonds — metallic, ionic, and covalent. The corresponding principal weathering processes are electron exchange (oxidation/reduction), ionization (solution), and ion exchange (as in acid attack).

- The end results of chemical weathering depend on a variety of interacting factors including the composition and texture of the parent material and the chemical, physical, and biochemical processes acting in a particular environment.
- The mobility and stability of the secondary minerals and solutions produced depend on environmental conditions like Ph, Eh, and temperature.
- As many rocks are dominated by a mix of ionic and covalent bonds, solution and acid attack are major weathering processes.

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