

DENUDATONAL GEOMORPHOLOGY

Unit-3

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DENUDATONAL GEOMORPHOLOGY

Definition

Landforms and Land features caused by physical process and chemical process of disintegration.

NEED FOR STUDYING DENUDATIONAL - GEOMORPHOLOGY

- **Discrimination of Rock types**
- **Mapping and understanding of planation surfaces**
- **Detection of active tectonism by dating Planation surfaces occurring at different levels**
- **Mineral targetting in Talus cone, fan etc.,**

- **Depth and degree of weathering and there from erosion vulnerability**
- **Groundwater targetting**
- **Soil profile - Palaeo climatology and**
- **Landslide hazard zonation**

Denudational Processes

Weathering

weathering is the combined action of physical weathering, in which rocks are fractured and broken, and chemical weathering, in which rock minerals are transformed to softer or more soluble forms

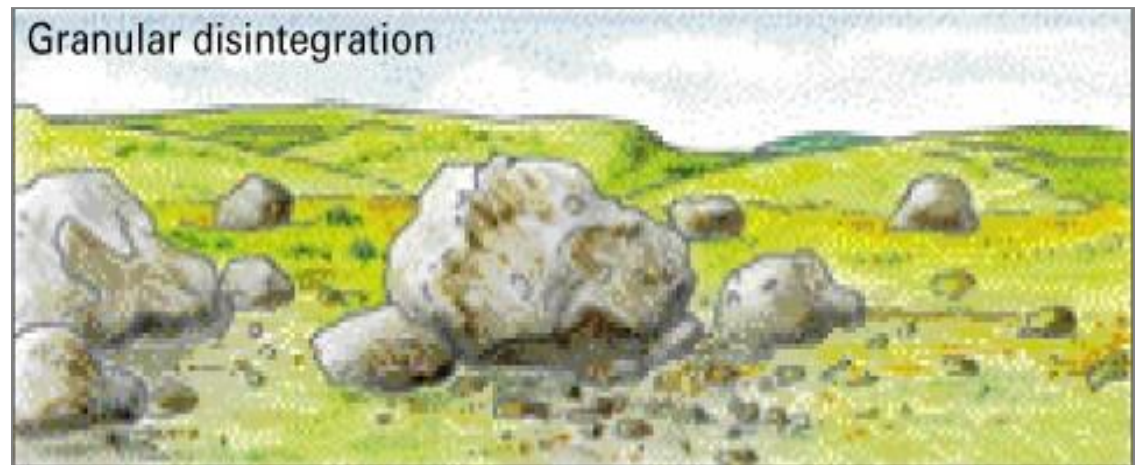
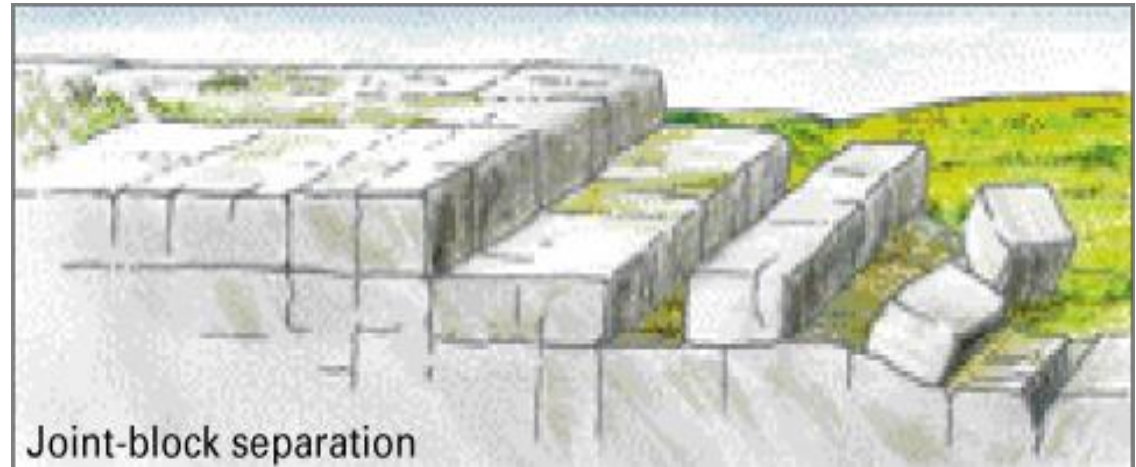


Figure 14.1, p. 483

Physical Weathering

Physical weathering produces regolith from massive rock by the action of forces strong enough to fracture the rock (frost action, salt-crystal growth, unloading, and wedging by plant roots)

in chemical weathering, the minerals that make up rocks are chemically altered or dissolved (the end products are often softer and bulkier forms that are more susceptible to erosion and mass movement)

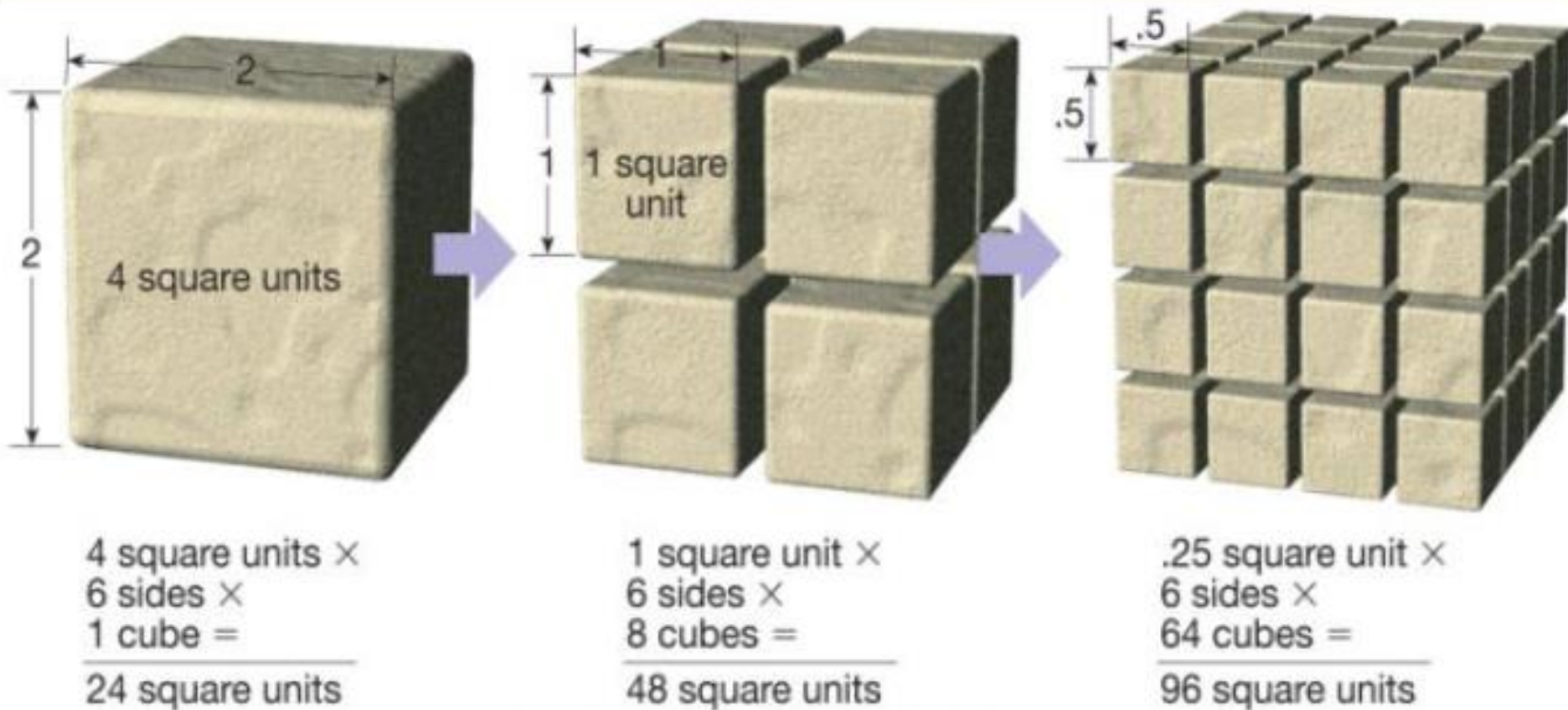
Physical weathering due to

- **pressure release**
- **water: freeze - thaw cycles**
- **crystallization of salt in cracks**
- **thermal expansion and contraction**

All this increases the total surface area exposed to weathering processes.

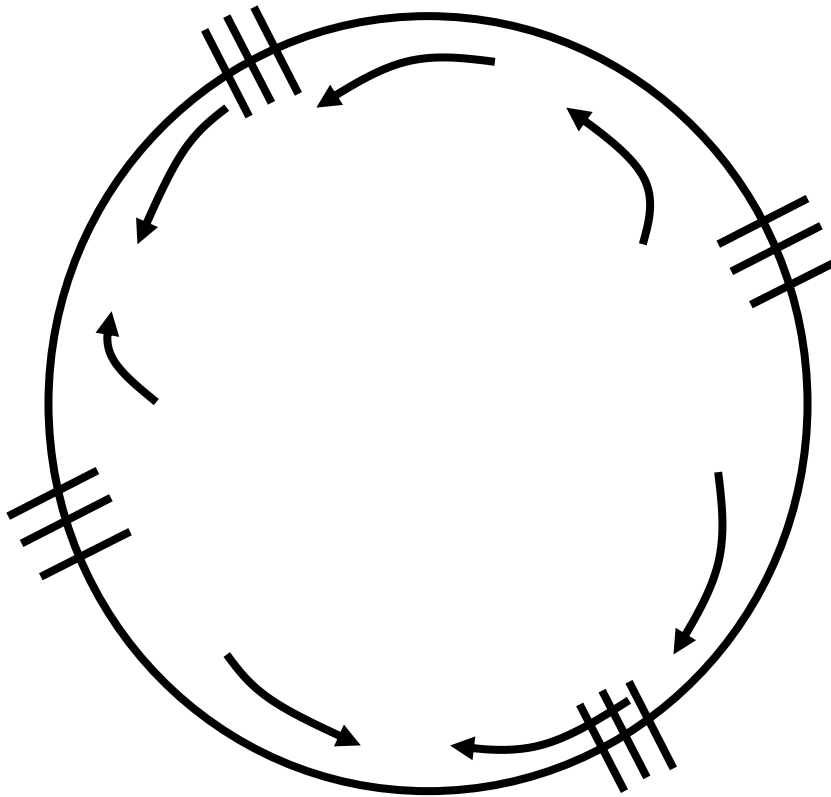
In mechanical or Physical weathering, a rock is broken down into smaller pieces without changing its mineral composition

Increase in surface area by mechanical weathering

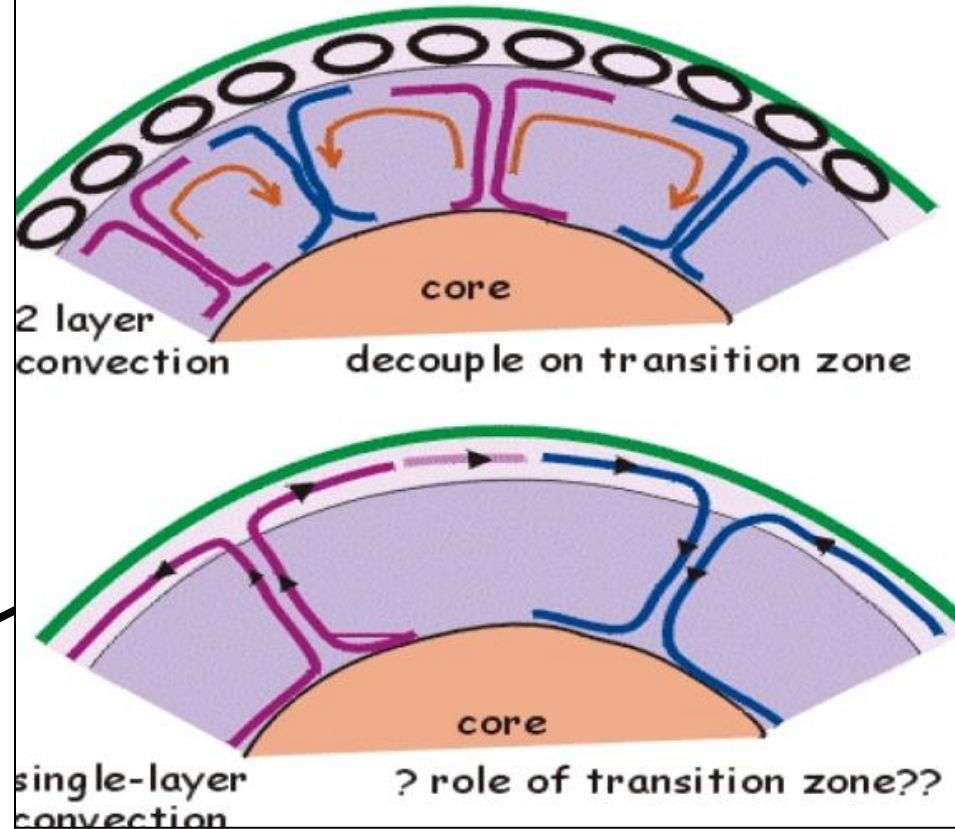


PHYSICAL WEATHERING

Due to compression and
ratification of the earth crust



Mantle convection models



mountain building /
Upwarping,
downwarping, grabening,
etc

Temperature Variations

Day time - 70° - 80°

Night time - -10°

Such repeated and alternate fluctuations cause physical disintegration. It is also called as thermal weathering.

(e.g) Exfoliation domes

Thermal expansion due to the extreme range of temperatures can shatter rocks in desert environments.

Repeated swelling and shrinking of minerals with different expansion rates will also shatter rocks.



Thermal Expansion and Contraction

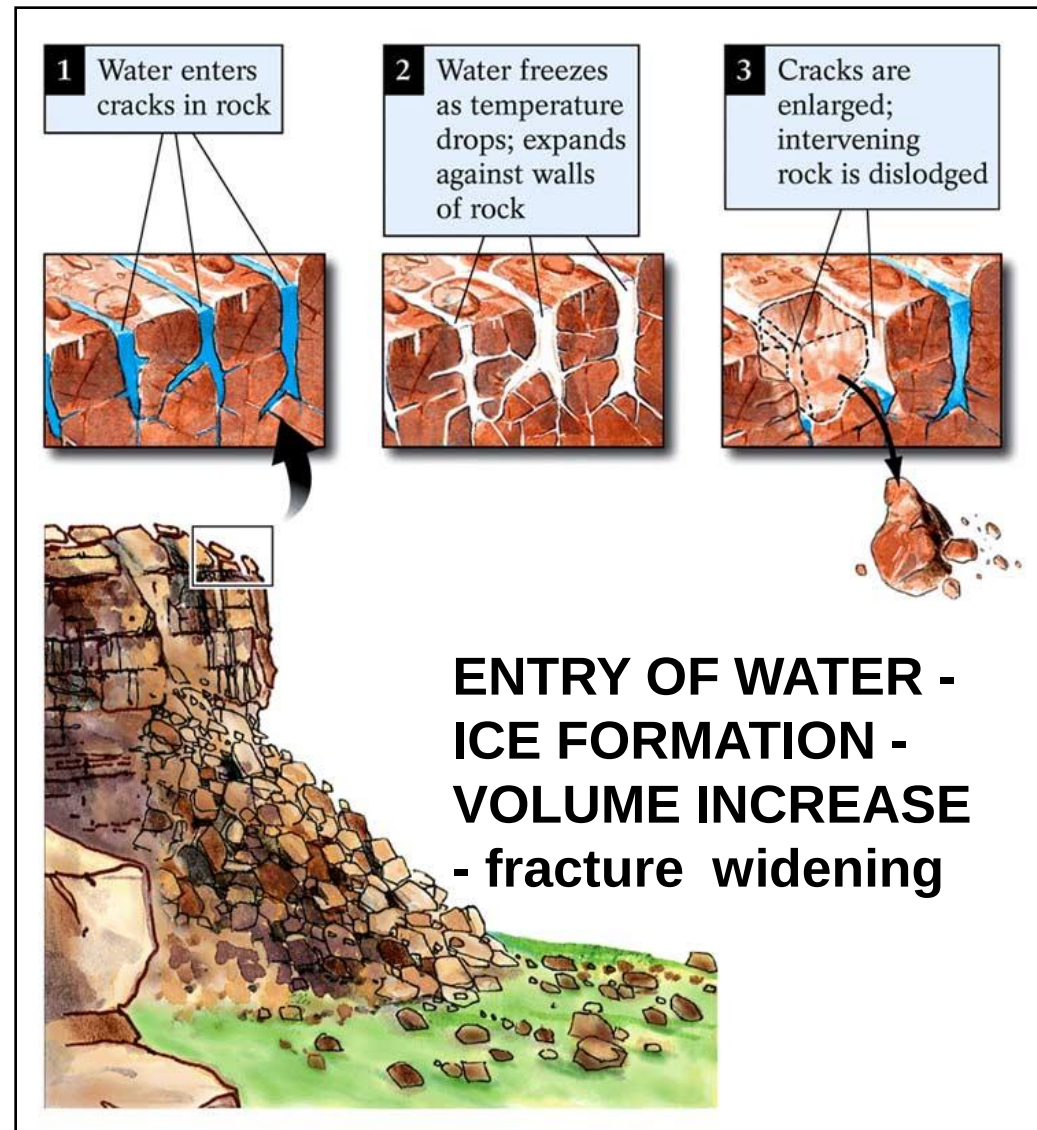


Source: Tom Bean

FREEZING / FROST ACTION

one of the most important physical weathering processes in cold climates is frost action, the repeated growth and melting of ice crystals in the pore spaces of soil and in rock fractures

when water freezes in bedrock joints and bedding planes, it expands and can split rocks apart



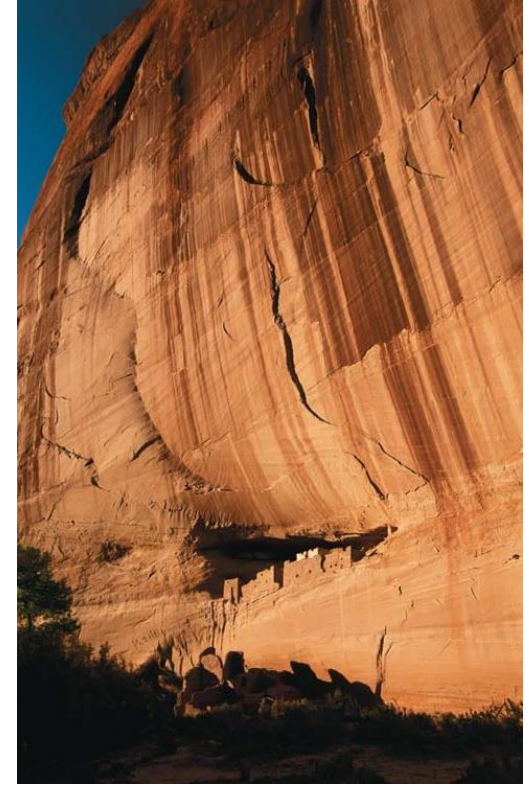
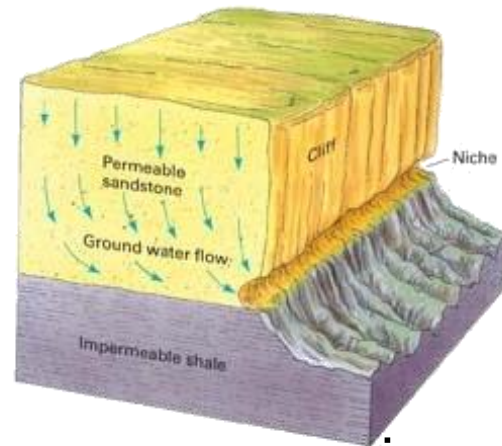
Evidence of Frost Wedging in Wheeler Park, Nevada



Wheeler Park Photo

Salt-crystal growth: Water evaporates from sandstone pores, leaving salt crystals behind. Crystals grow and disintegrate rock.

- Occurs in arid and semiarid regions



in arid climates, slow evaporation of ground water from outcropping sandstone surfaces causes the growth of salt crystals

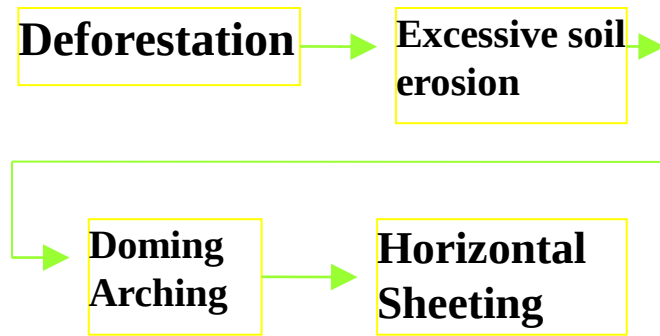


crystal growth breaks the rock apart grain by grain, producing niches, shallow caves, and rock arches

SOIL EROSION – Exfoliation Sheeting

Erosion

HORIZONTAL SHEETING



unloading occurs as rock is brought near the surface by erosion of overlying layers

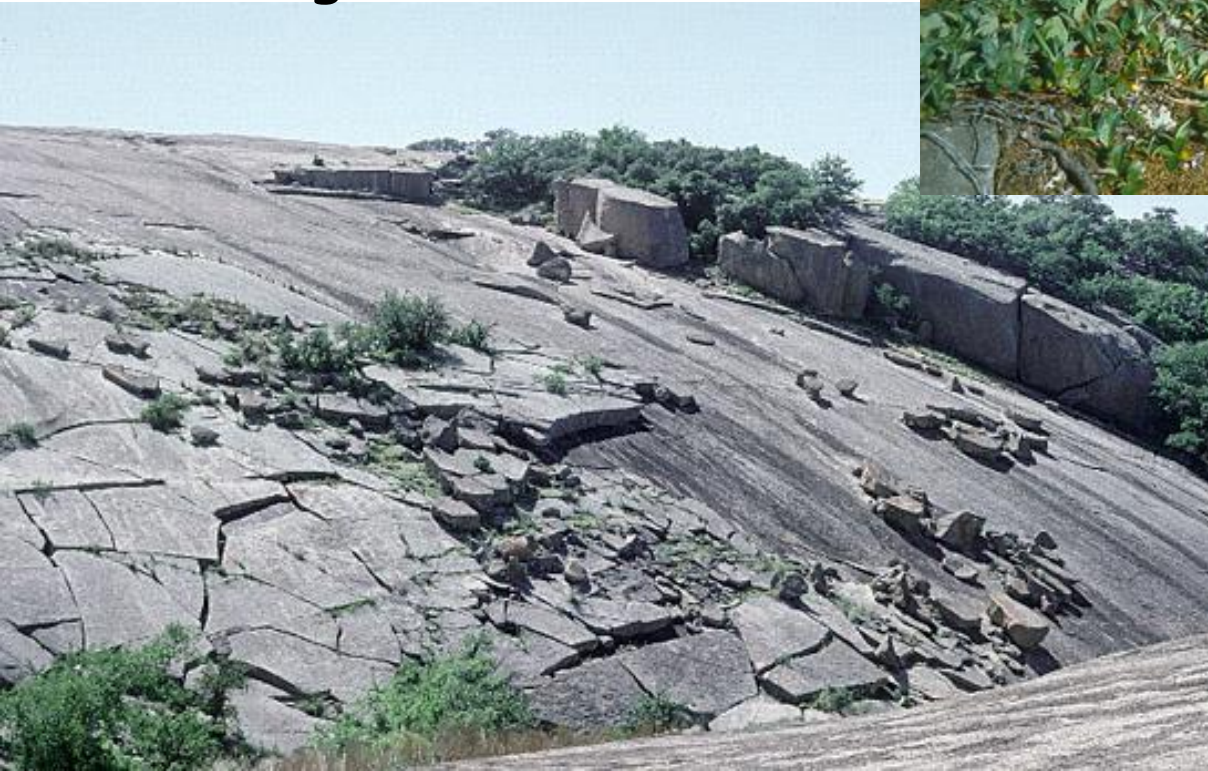
as the rock above is slowly worn away, the pressure is reduced, and the rock expands slightly in volume

this causes the rock to crack in layers that are more or less parallel to the surface, creating a type of jointing called sheeting structure

Exfoliation:

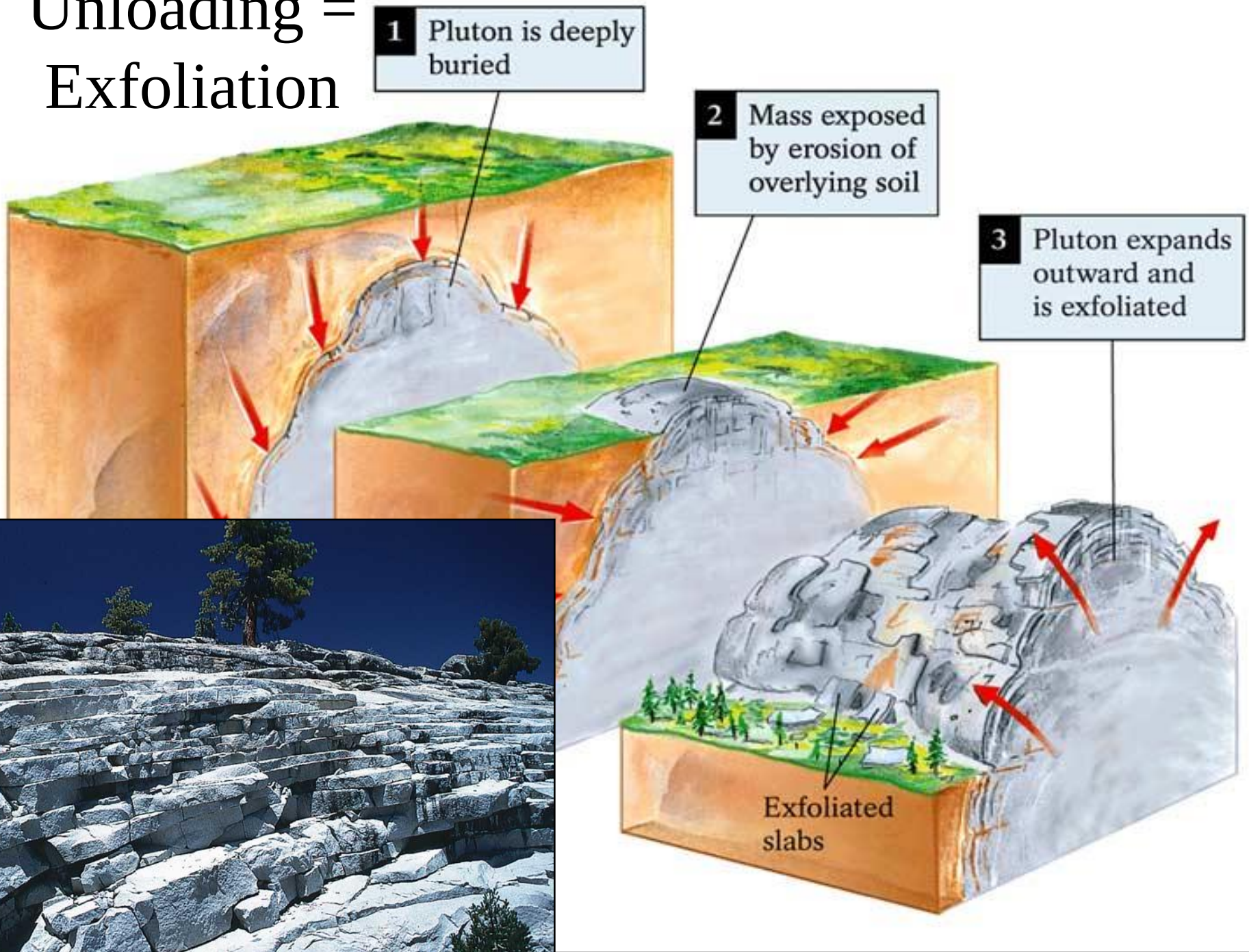
Rock breaks apart in layers that are parallel to the earth's surface; as rock is uncovered, it expands (due to the lower confining pressure) resulting in exfoliation.

Exfoliation of a small pluton

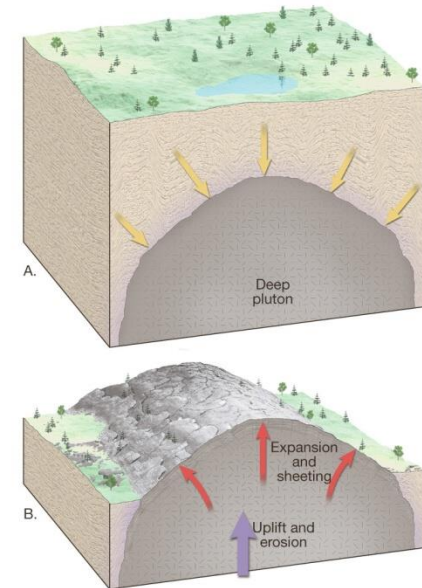


Exfoliation of Granite

Unloading = Exfoliation



Sheet Joints (Exfoliation)

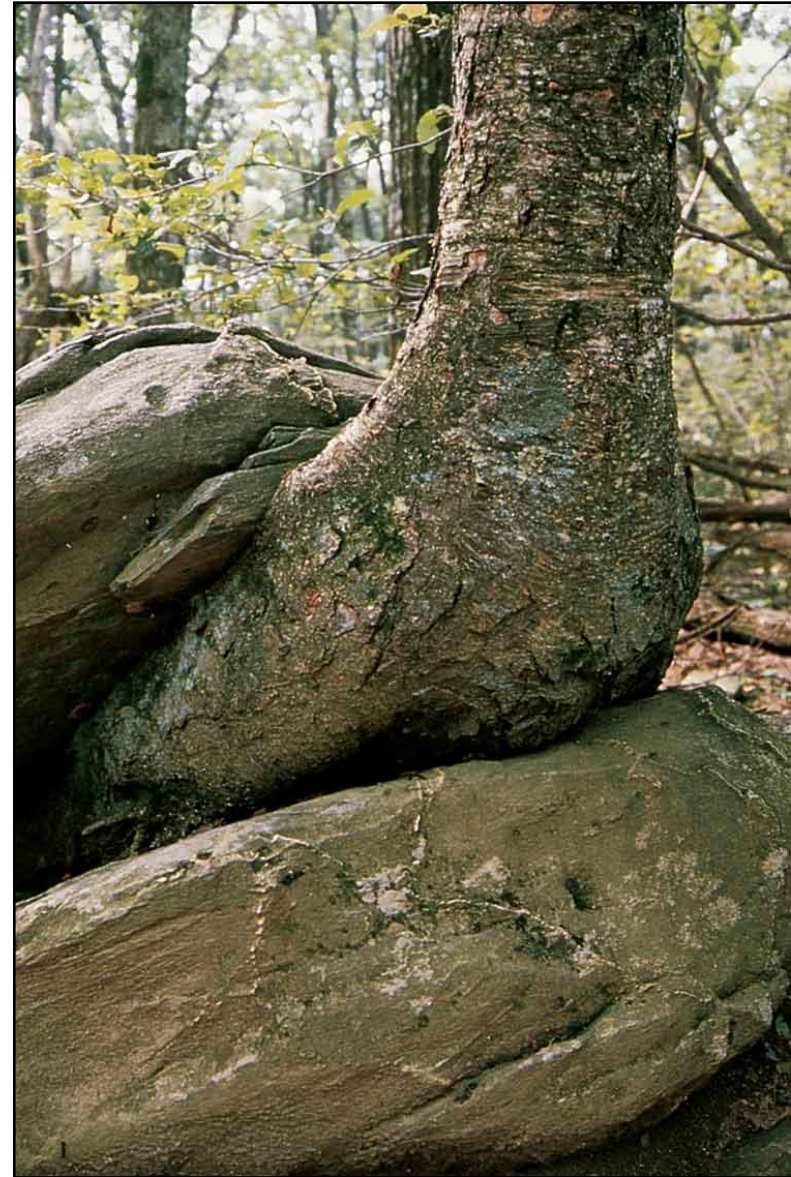


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PRYING ACTION OF PLANTS

ROOT WEDGING

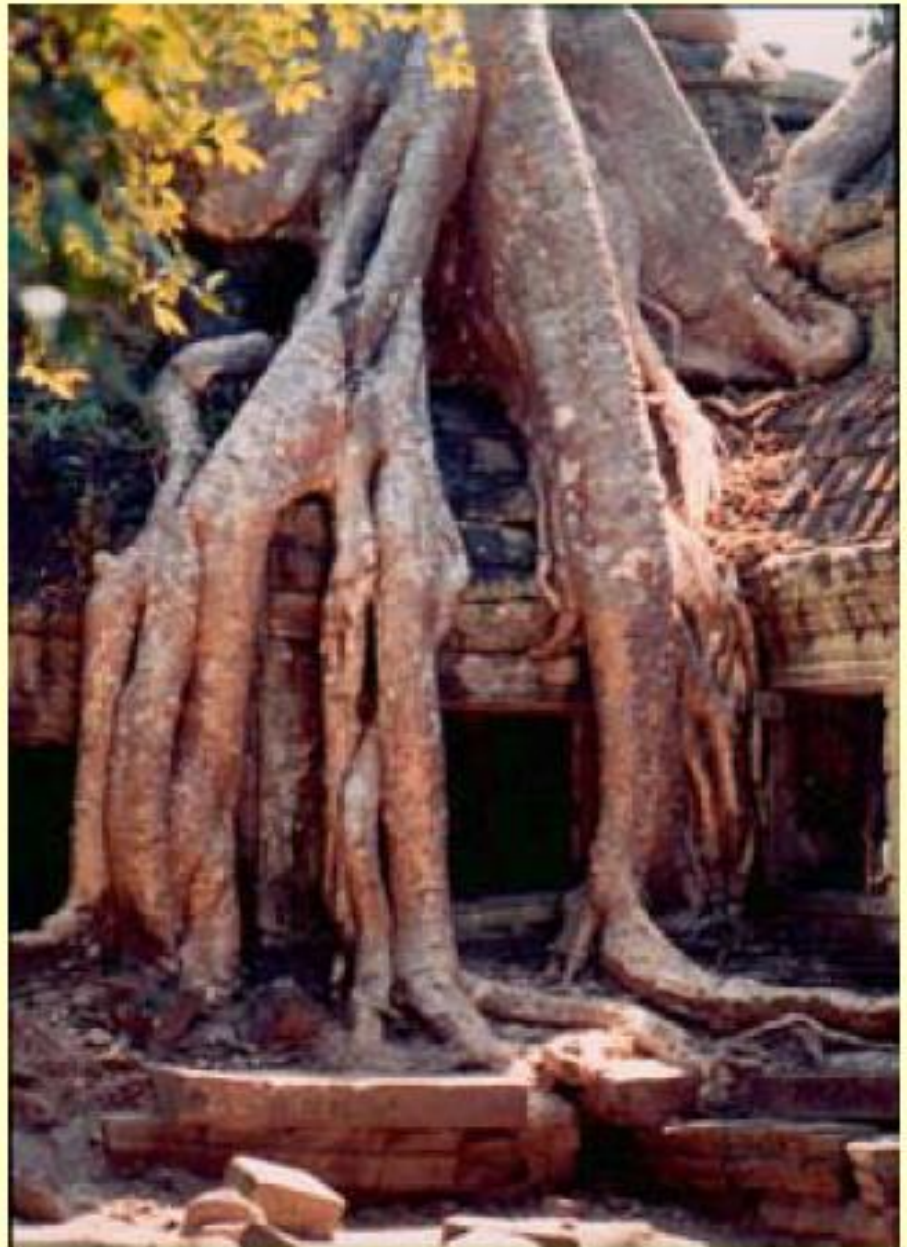
Tree Roots Growing
in Rock Fractures
Animal Burrows



Source: Runk/Schoenberger/Grant Heilman

Hydraulic
weathering
by tree
roots,
Angkor Wat
temple
complex,
Cambodia

Photo courtesy of Reece Rehm;
GEOG111 - Fall, 2000



PRYING ACTION OF ANIMALS

ANIMALS AND INSECTS LIKE ANTS MAKE DEEP HOLES IN THE CRUST AND INITIATE PROCESS OF DENUDATION INITIATE THE

➤ ***BURROWING***

burrowing





HUMAN ACTION

➔ *Quarrying and blasting*

Mass Wasting

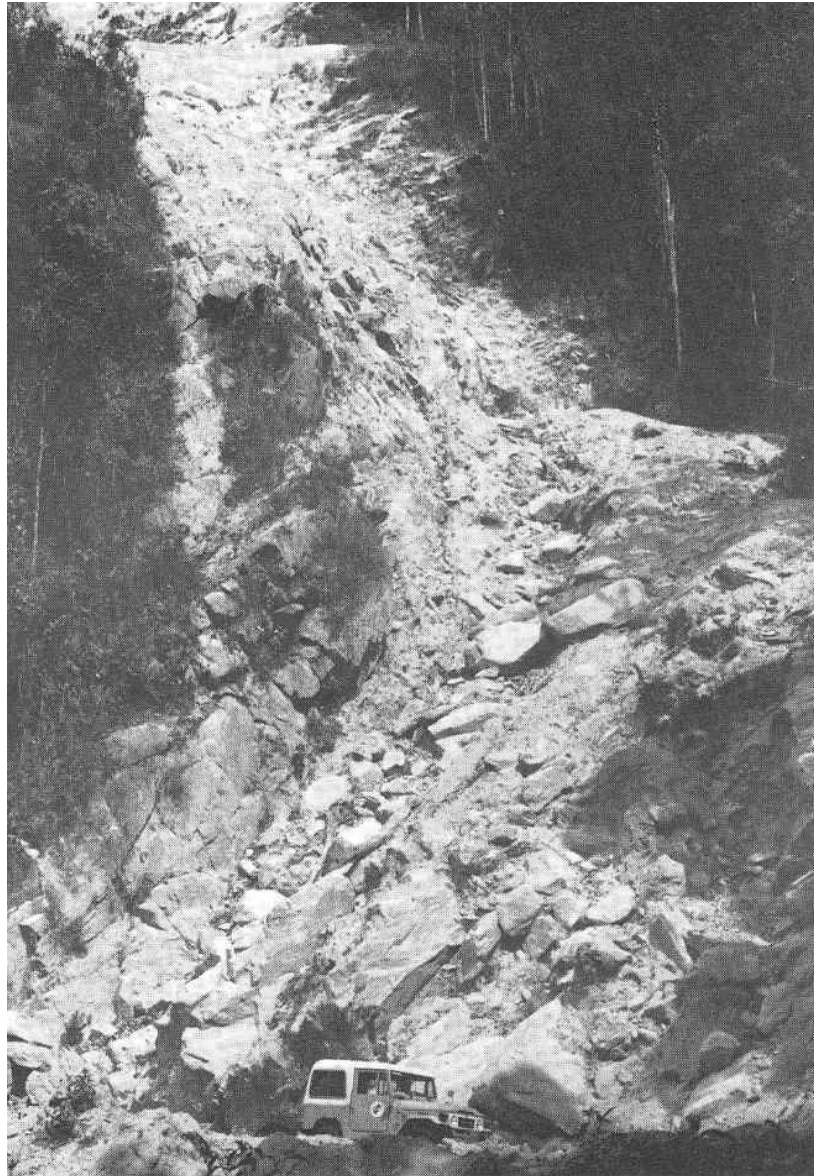
- Mass wasting is the downslope movement of regolith and masses of rock under the pull of gravity.
- Mass wasting is a basic part of the rock cycle.
 - Weathering, mass-wasting, and other aspects of erosion constitute a continuum of interacting processes.

Gravitational Gliding

**doming and
fracturing in upper
reaches**

**Rock flowage / soil
creep solifluction**

LANDSLIDE BLOCK - VENEZUELA

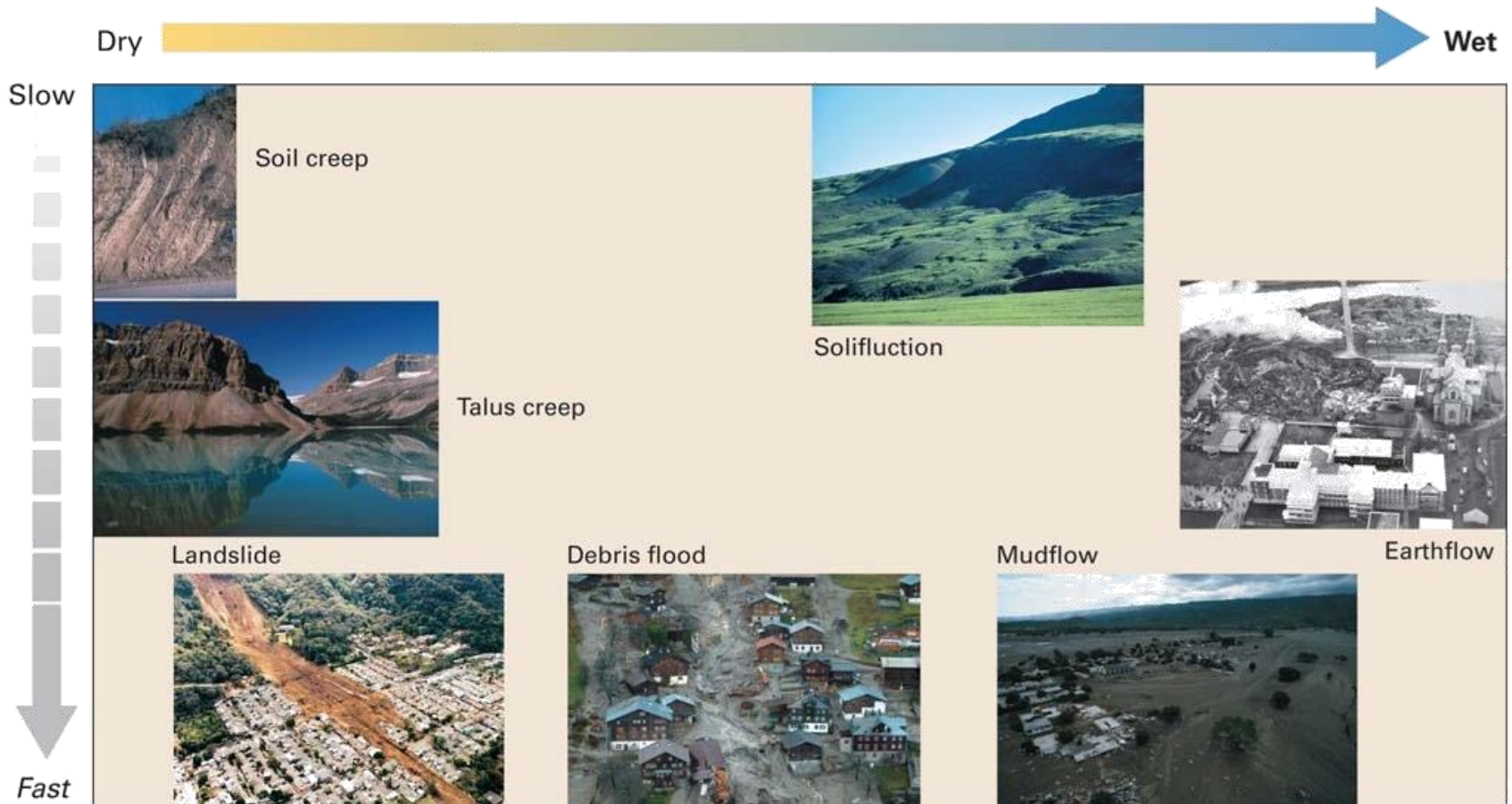


EXFOLIATION SHEETING DUE TO GRAVITATIONAL GLIDING

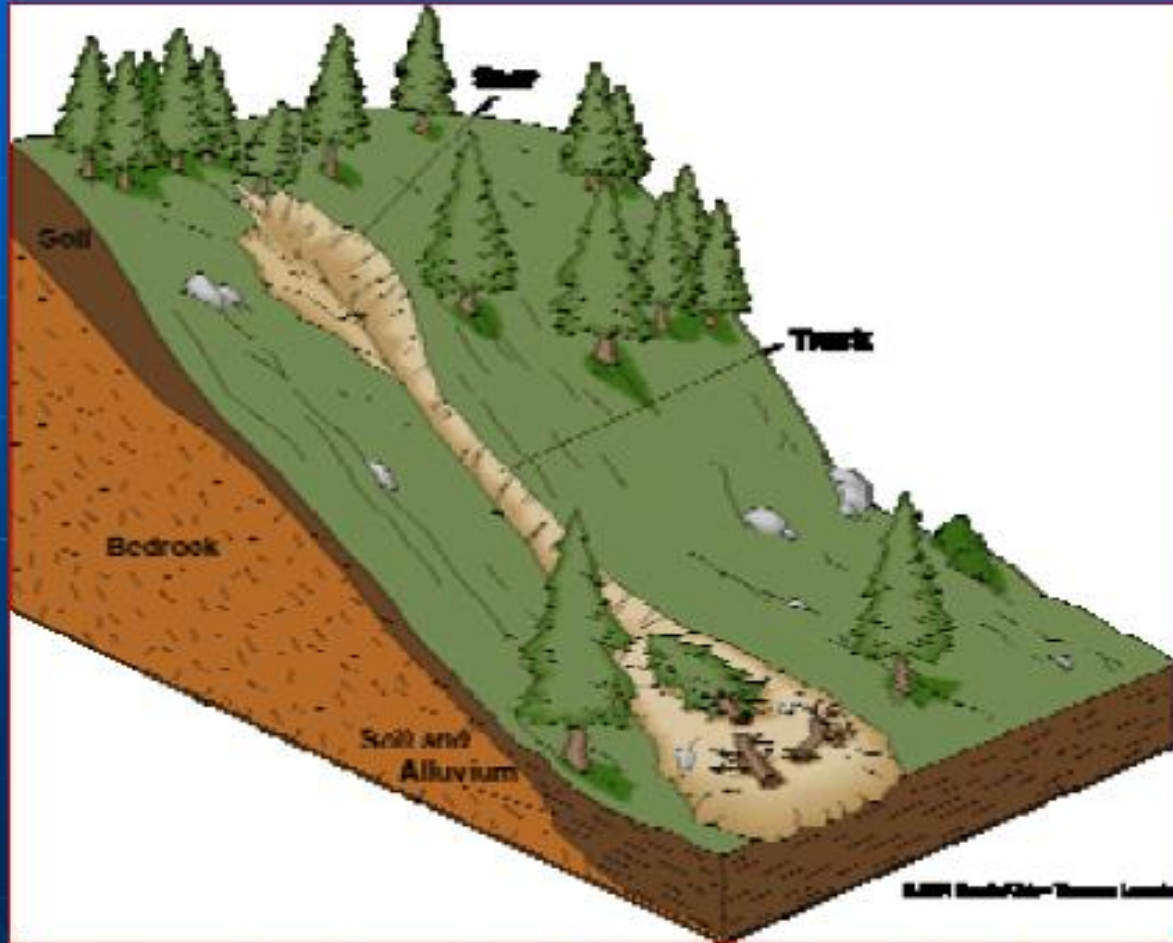


Mass Wasting

Mass Wasting: spontaneous downhill movement of soil, regolith, and bedrock under the influence of gravity



Mudflows



- Consist of at least 50% silt and clay sized particles, at least 30% water
- Usually follow pre-existing channels until the slope decreases, then fan out

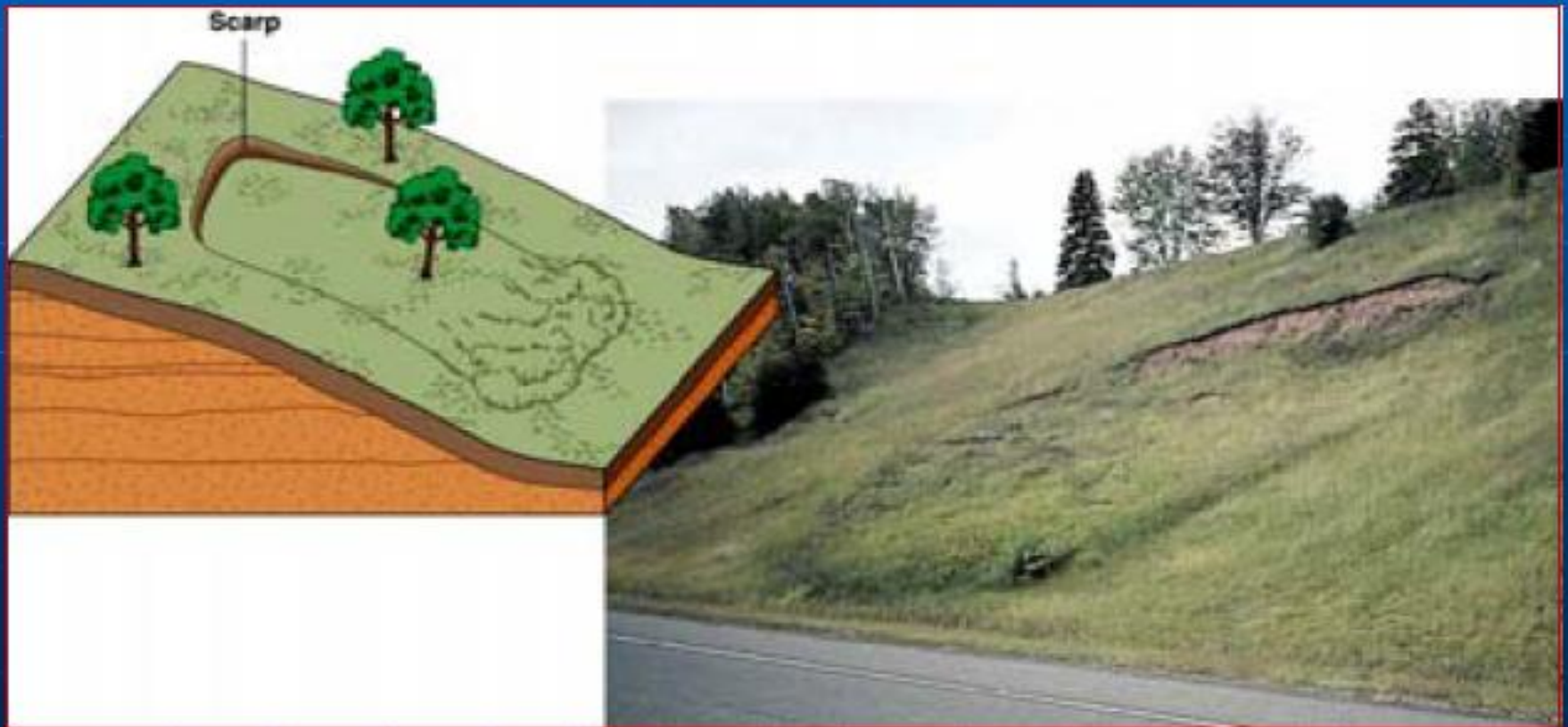
Debris flows

- Composed of larger sized particles than mudflows
- Don't contain as much water as mudflows
- Rarely confined to pre-existing channels



Earthflows

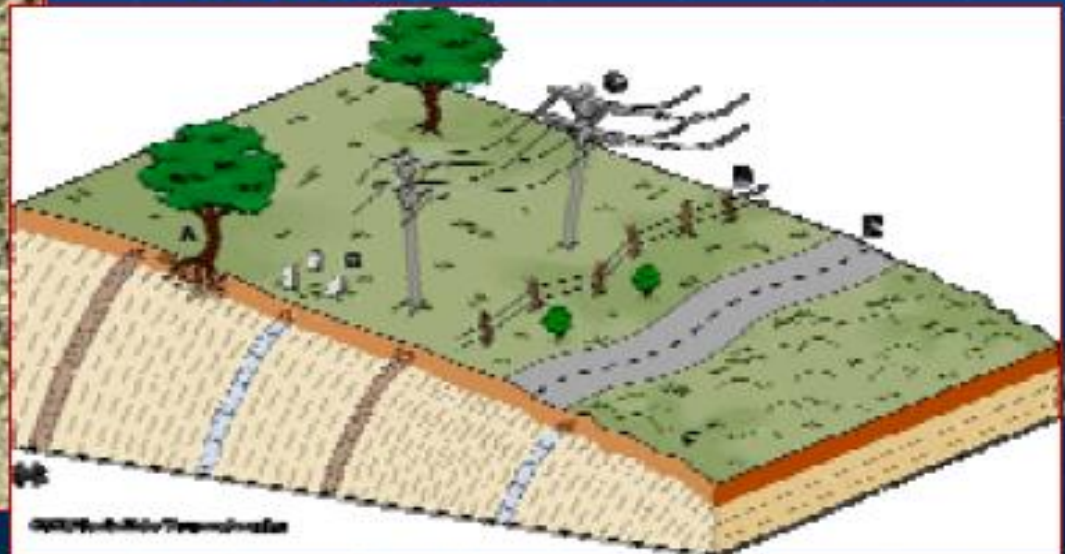
- Slumps from the upper part of a hillside
- Occur most commonly in humid climates



Creep

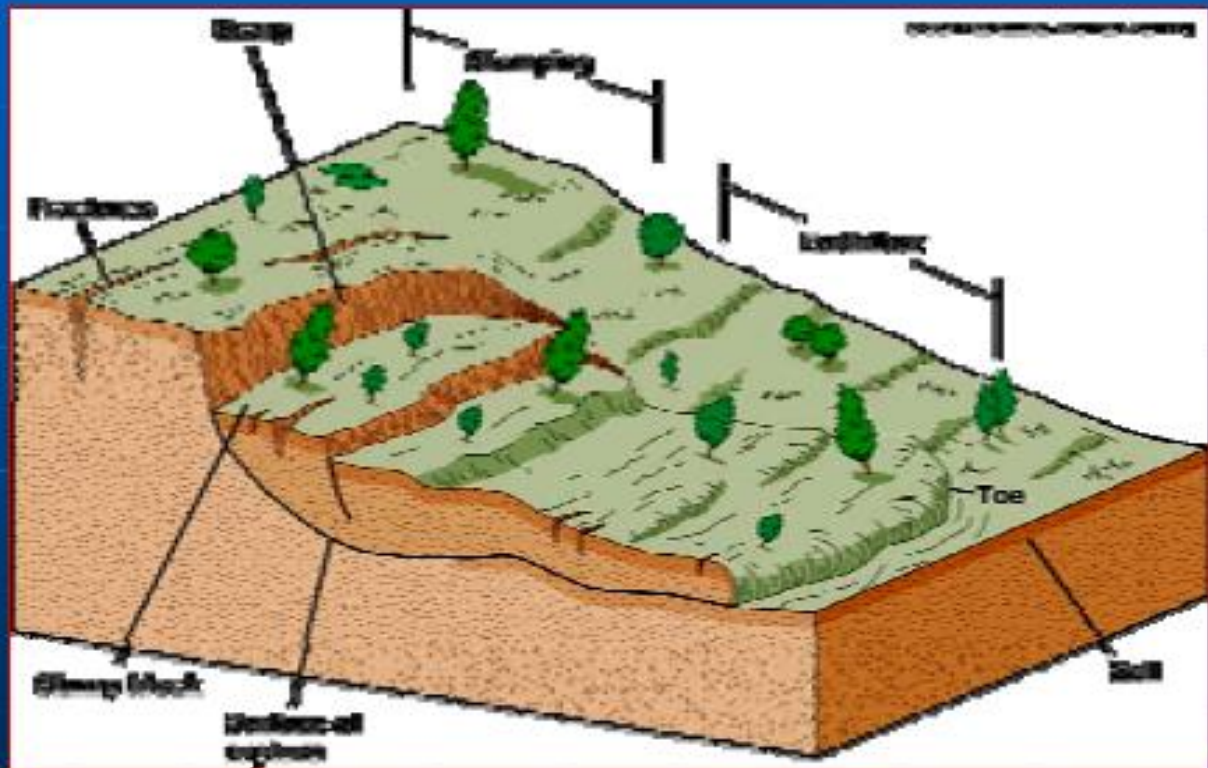


- Slowest type of flow, most common in humid climates such as the southeastern US
- Extremely destructive over time; difficult to recognize or control



Complex Movements

- Occurs when several of the recognized types are involved in a mass movement
 - slide-flow
 - debris avalanche



TYPES OF MASS WASTINGF (Modified after Varnes 1978)

Type of movement			Type of material		
			Rocks	Predominantly coarse - debris	Predominantly fine - soil
Falls			Rock fall	Debris fall	Earth fall
Topples			Rock topple	Debris topple	Earth topple
Slides	Rotational		Rock slump	Debris slump	Earth slump
	Translational	Few units	Rock block slide	Debris block slide	Earth block slide
		Many units	Rock slide	Debris slide	Earth slide
Lateral spreads			Rock spread	Debris spread	Earth spread
Flows			Rock flow	Debris flow	Earth flow
			Rock avalanche	Debris avalanche	
			Deep creep	Soil creep	
Complex and compound			Combination in time and/or space of two or more principal types of movement		

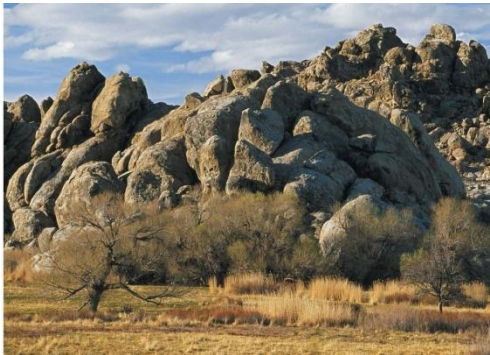
In **chemical weathering**, a rock is broken down by chemical reactions that change its mineral composition and physical and chemical properties

Weathering

Chemical Weathering

Chemical Weathering: chemical change in rock minerals through exposure to the atmosphere and water

- Most effective in warm, moist climates
- Hydrolysis
- Oxidation
- Carbonic acid action
 - Dissolves limestone, creating caverns
 - Weathers buildings, tombstones
- Soil acids weather basalt

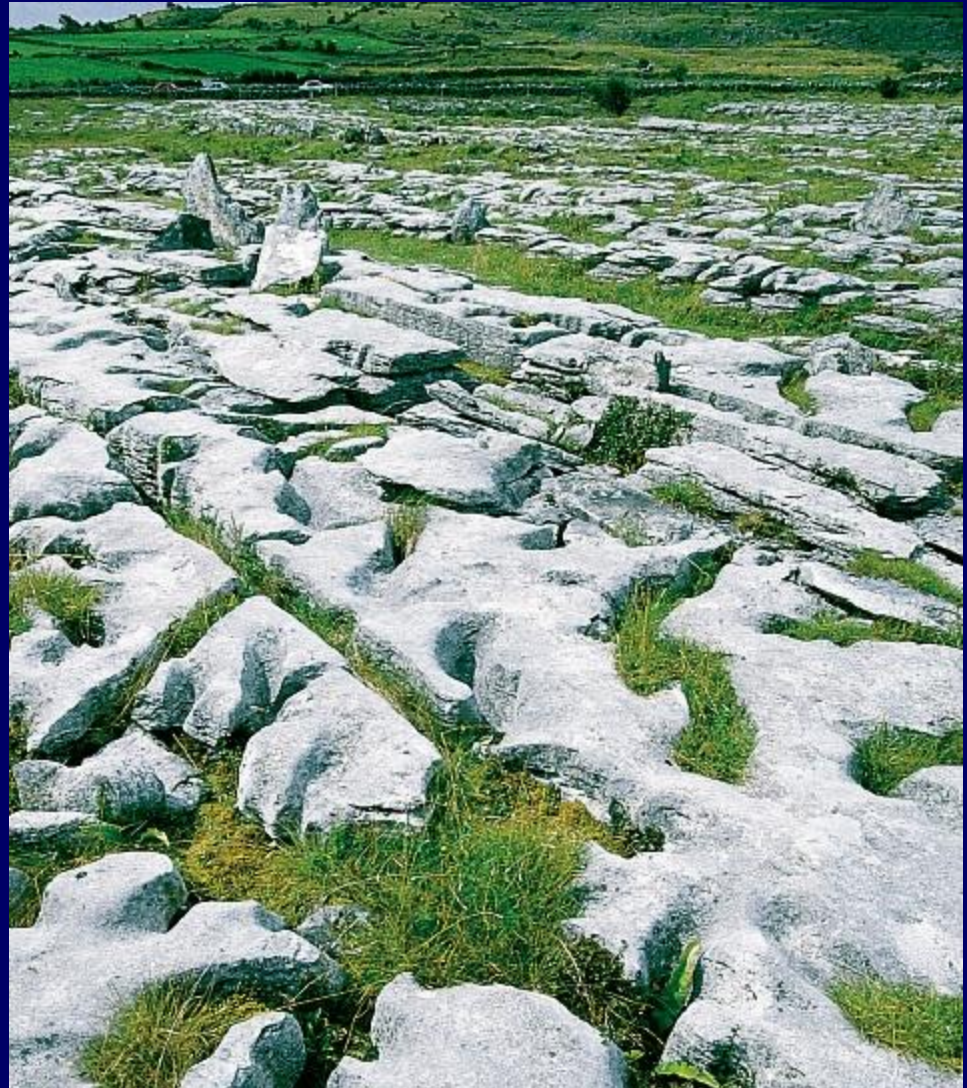


Chemical Weathering and its Landforms

the dominant processes of chemical change affecting silicate minerals are **oxidation, hydrolysis, and carbonic acid action**

oxidation and hydrolysis change the chemical structure of minerals, turning them into new minerals that are typically softer and bulkier and therefore more susceptible to erosion and mass movement

carbonic acid action dissolves minerals, washing them away in runoff



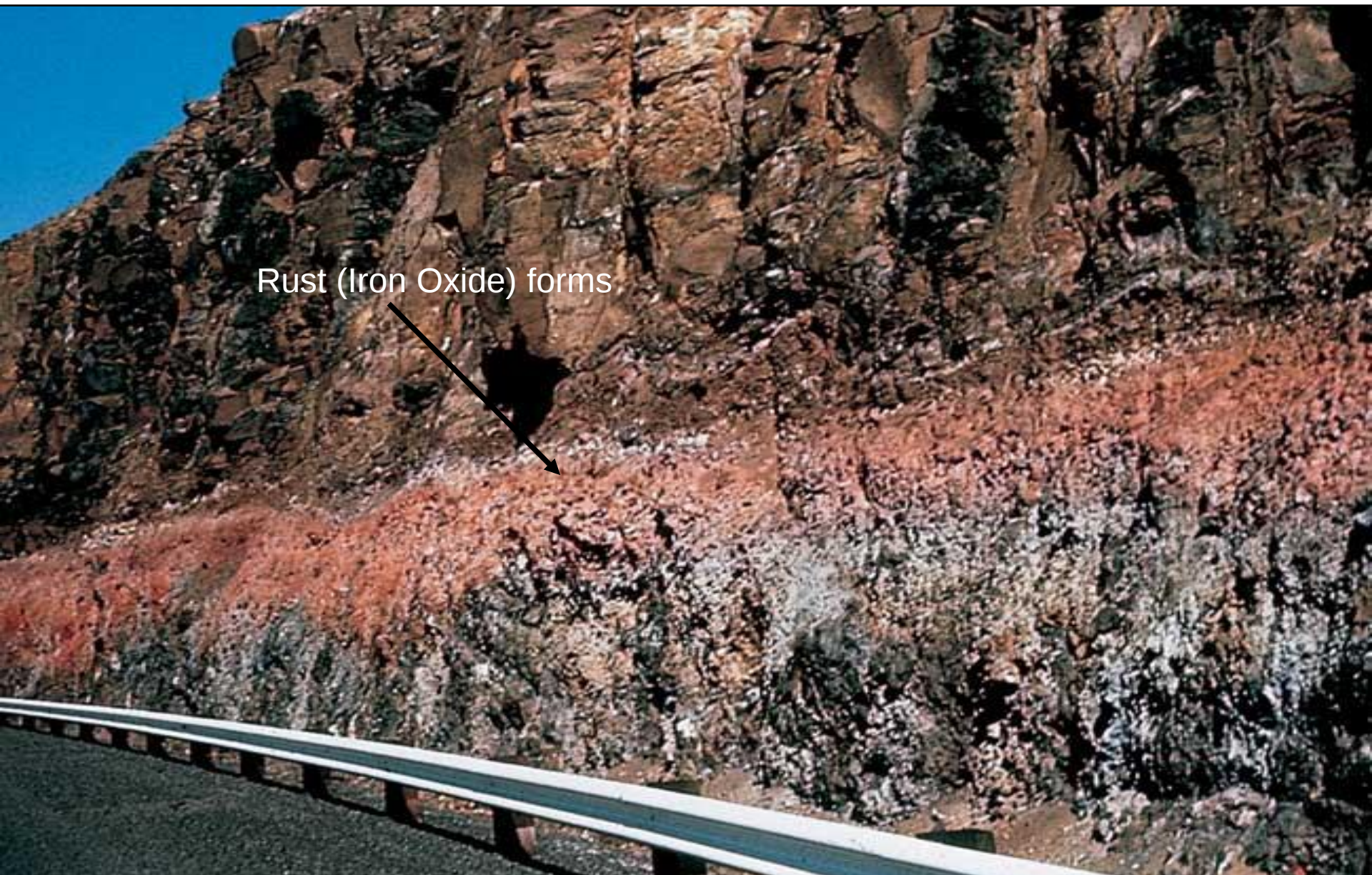
Oxidation

Oxygen dissolved in water promotes oxidation of sulfides, ferrous oxides, native metals

***ADDITION OF OXYGEN → CONVERSION
OF SILICATES INTO OXIDES CAUSE
PHYSICAL DISTINTEGRATION***



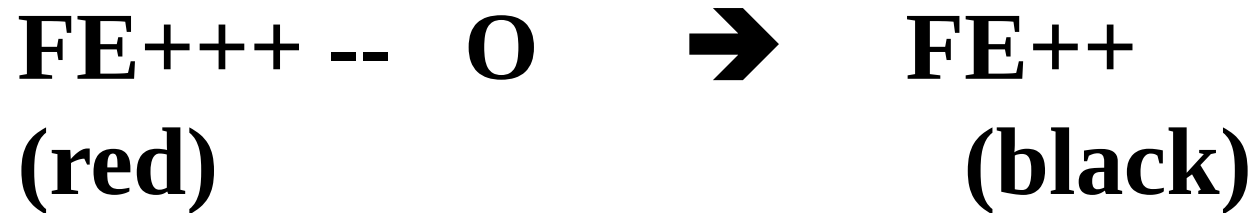
Oxidation of Basalt



Rust (Iron Oxide) forms

REDUCTION

*REMOVAL OF OXYGEN OR ADDITION OF
HYDROGEN DESTRUCT ROCKS*



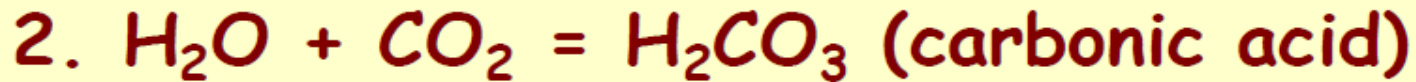
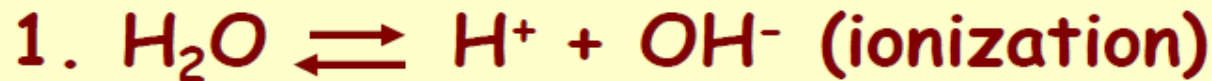
Ferric to Ferrous

Hydration: attachment of water molecules to crystalline structure of a rock, causing expansion and weakness

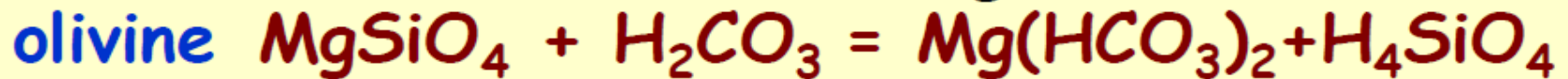
ADDITION OF WATER MOLECULES IN IT MINERAL LATTICE CAUSE WEATHERING



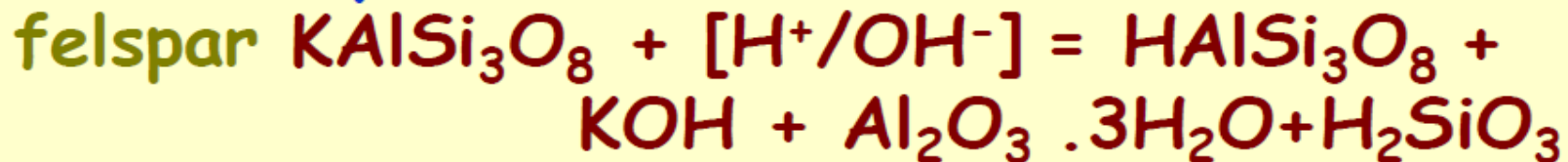
1. Hydrolysis and 2. Carbonation



Interactions with minerals, e.g.:



- entirely dissolves



- produces "clay" minerals

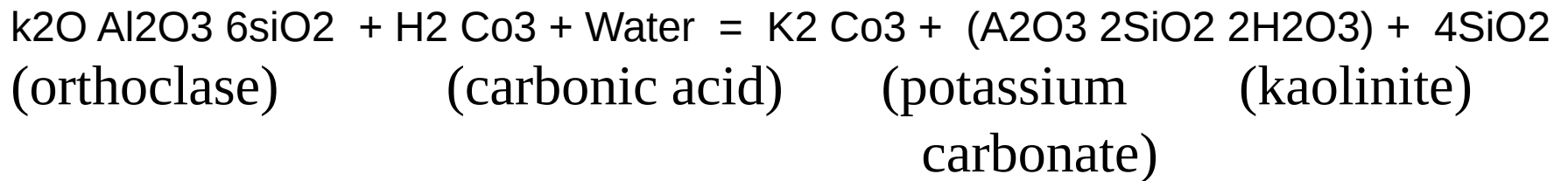


- partially dissolves (leaving 'quartz sand')

CARBONATION

Addition Of CO_2 Into Rock Elements And the resultant Decay of Rocks Called **Carbonation**.

CO_2 is Added into the Elements Like Calcium, Magnesium , Sodium or Potassium Form Carbonates,



- Similarly ($\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$) changes to clay
(Albite)
- gabbro and pyroxene also changes to clay.

Olivine/pyroxene to clay



+ H_2CO_3 (acid)



Feldspars to clay



+ H_2CO_3 (acid)

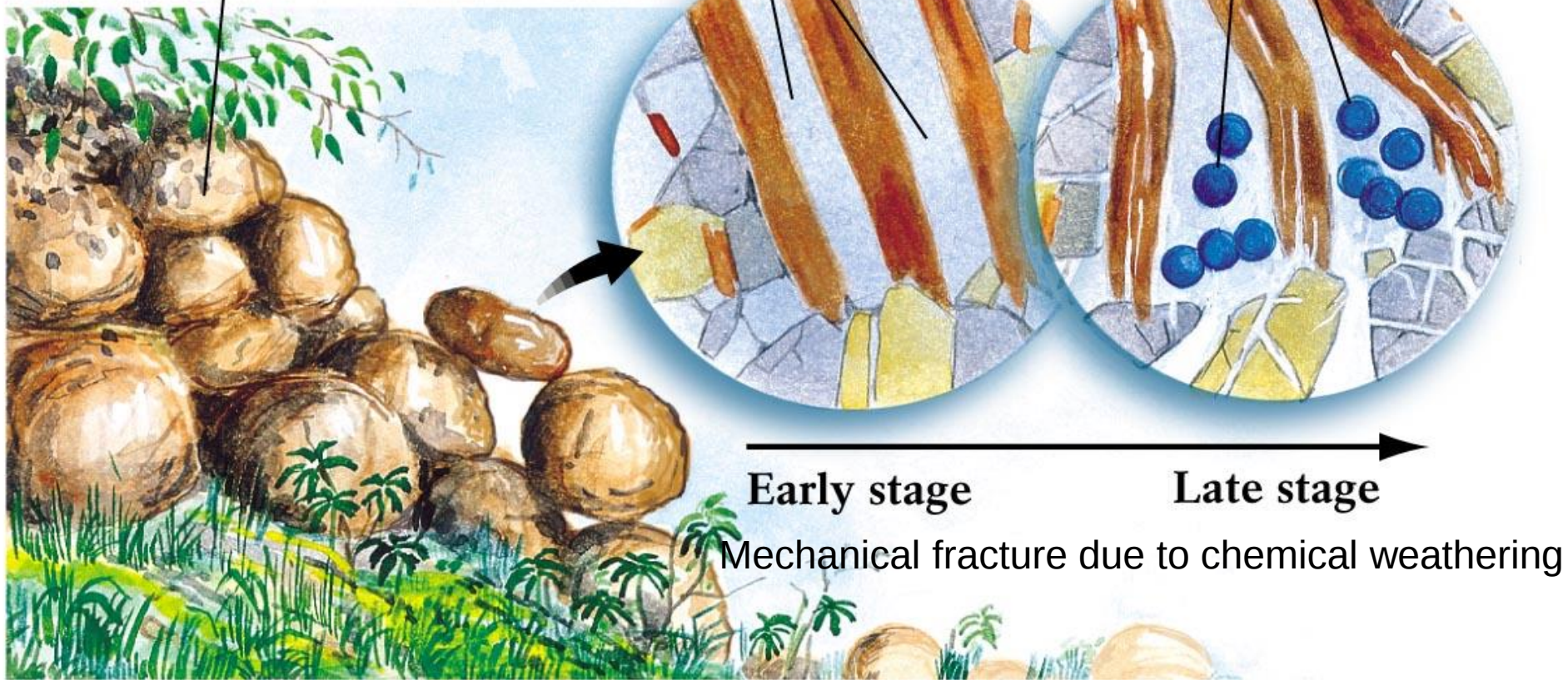


Hydrolysis – Feldspar to Clay

Concentric layers of weathered rock at surface of each boulder

Feldspars become
Clay mineral
layers

Absorbed water molecules
cause clay layers to expand,
pushing other layers apart



Water is the main operator:

Dissolution: Many ionic and organic compounds dissolve in water Silica, K, Na, Mg, Ca, Cl, CO₃, SO₄

Acid Reactions

Water + carbon dioxide <---> carbonic acid

Water + sulfur <---> sulfuric acid

H⁺ effective at breaking down minerals

Precipitation and resolidification:

During the Course of transport such solution get resolidified as secondary crystals.

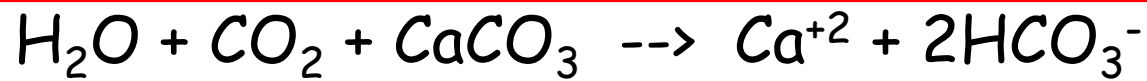
(E.g)

Silicious solutions	—————→	Secondary silica like Amythist, Amorphous Qtz, Geoid, plasma etc.,
---------------------	--------	---

Solution: process by which rock is dissolved in water

- Is strongly influenced by pH and temperature
- When water becomes saturated, chemicals may precipitate out forming *evaporite* deposits.
- Calcium carbonate (calcite, limestone), sodium chloride (salt), and calcium sulfate (gypsum) are particularly vulnerable to solution weathering.

Dissolution



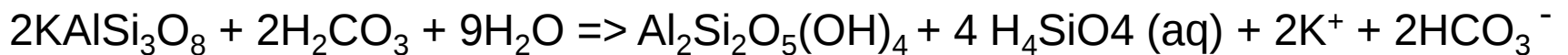
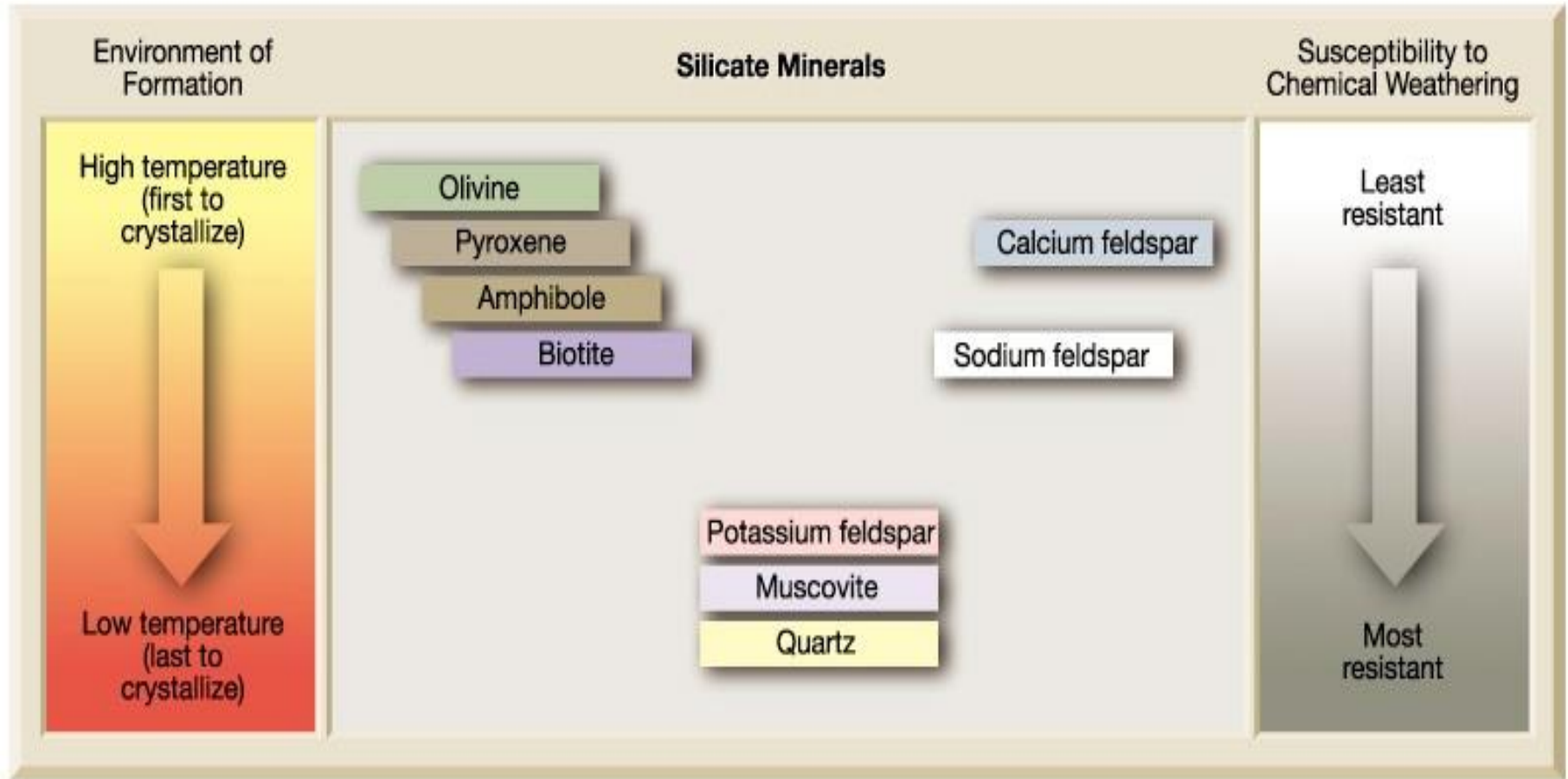
water + carbon dioxide + calcite
dissolve into calcium ion
and bicarbonate ion

Biological activity in soils
generates substantial CO_2

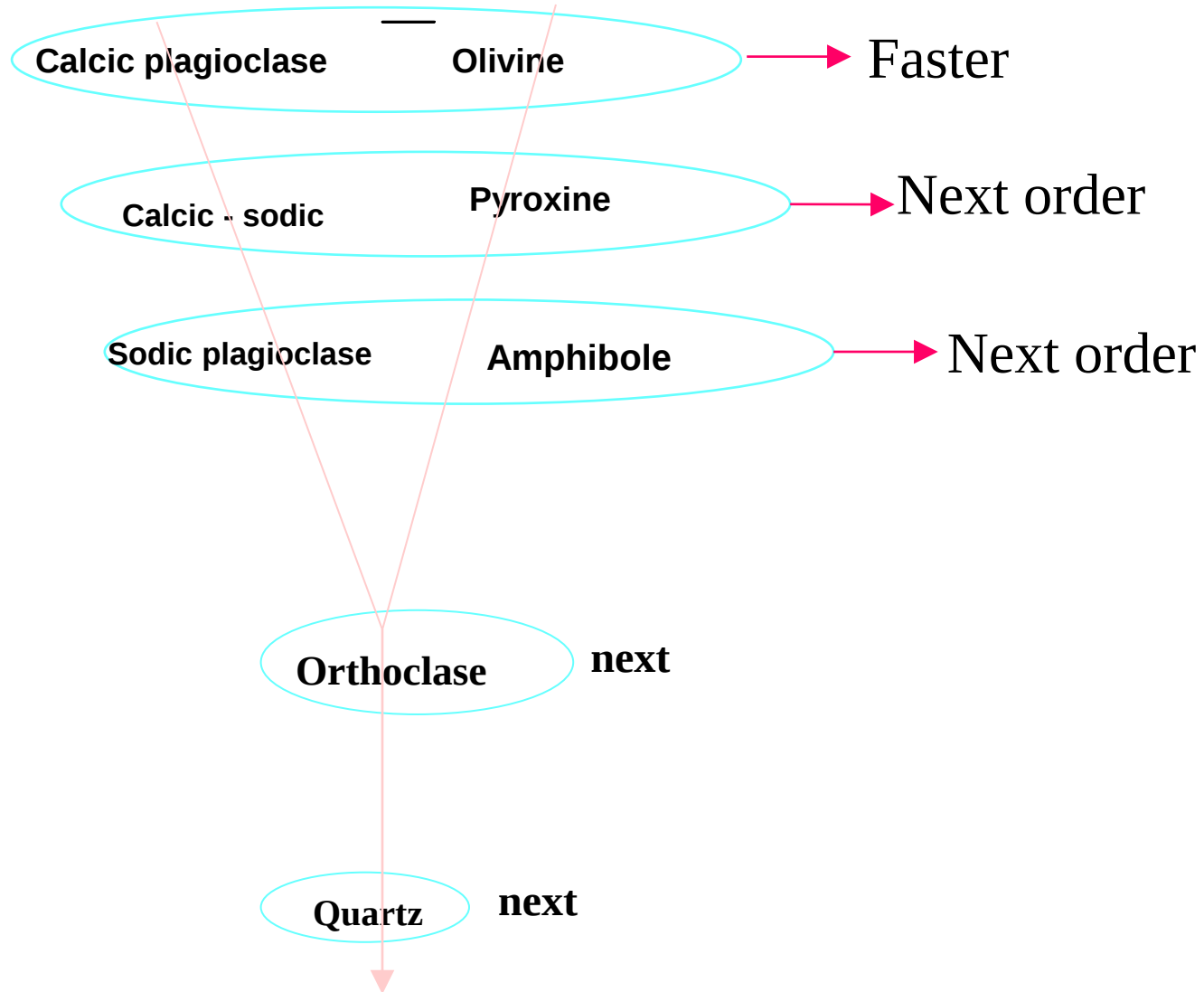
Bicarbonate is the dominant
ion in surface runoff.



Bowens Reaction Series and Weathering



Solution acitivity



DENUDATONAL LAND FORMS

Summit Zone Features

Summit Zone Features

Denudational Hills

Highly Dissected

Moderately Dissected

Poorly Dissected

Erosional Plateau

Highly Dissected

Moderately Dissected

Poorly Dissected

Erosional Mesa / Butte

Highly Dissected

Moderately Dissected

Poorly Dissected

Tors

Exfoliation Domes / Born Horte

Residual Hills

Arched hills

Inselberg

Intermontanane Valley

Slope Zone Features

Debris Slope / Scree Slope

Barren Slope

Midslope Mounds

Rock Slump

Debris Avalanche

Rock Creep / Rock Slide

Foot Hill Zone

Talus Cone / Fan

Debris Wash Plain

Plain Zone

Pediment

Rocky Pediment

Weathered Pediment Shallow

Weathered Pediment Moderate

Weathered Pediment Deep

Pediplain

Deeply Weathered

Moderately Weathered

Poorly Weathered

Lateritic upland

Dissected

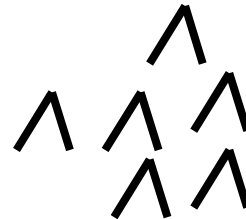
Undissected

DENUDATIONAL LANDFORMS

SUMMIT ZONE

Dendudational hill or Hill complexes

hills of irregular X, Y, Z

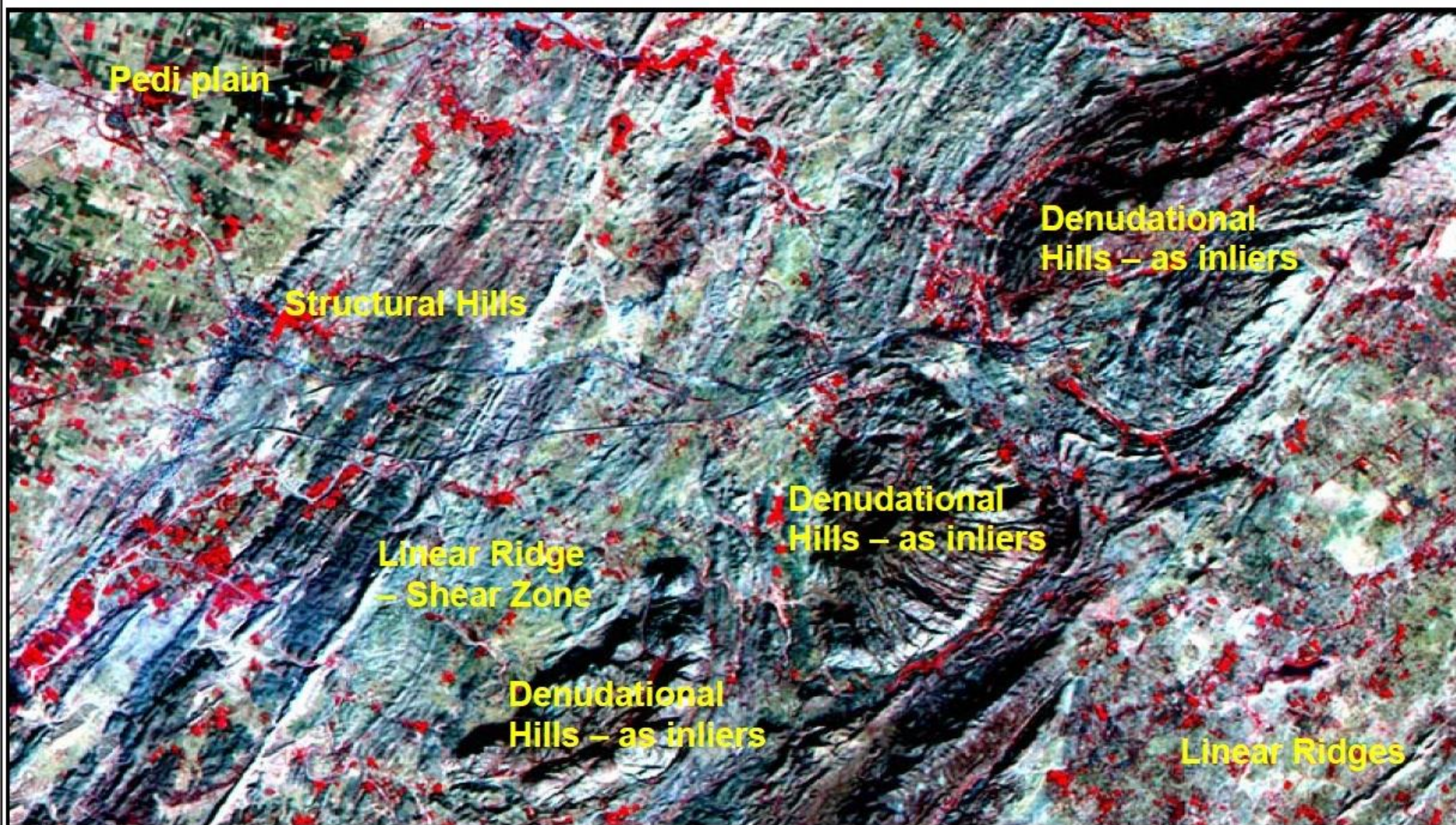




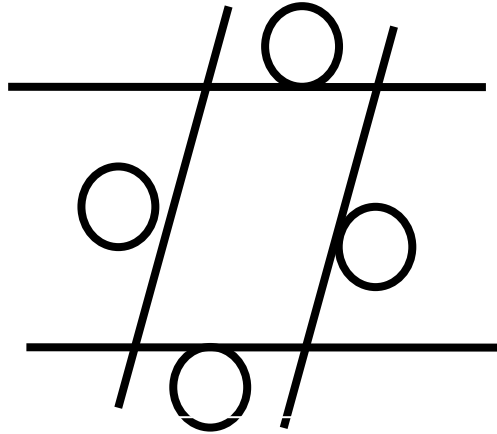
Hill
complexes

**Size less,
shapeless,
pattern less &
relief less hills**

Fig. 4.20: Satellite image of Aravali region showing the Structural landforms



Dissected Hills



Expression

- ⇒ Hills dissected by criss crossing fractures
- ⇒ With cliffs, peaks and serrations

Environment

- ⇒ better Groundwater possibility
- ⇒ prone for land slides / subsidences
- ⇒ streams down below expected to carry more silt.

DISSECTED HILLS

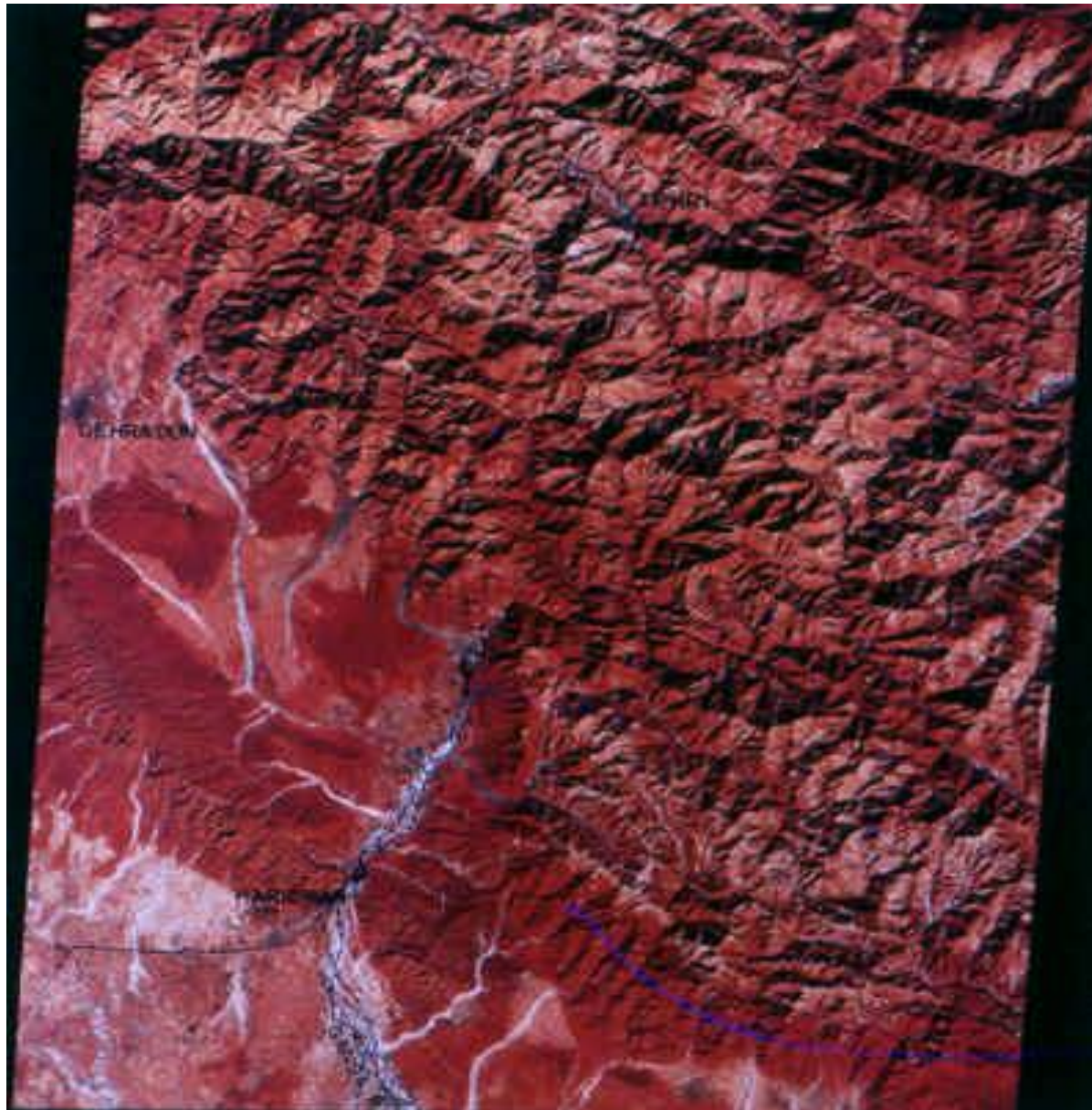
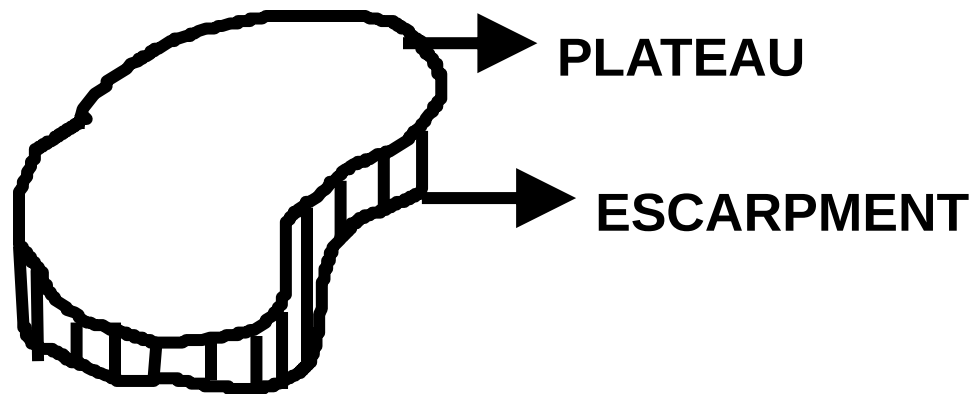




Fig. 2.17 Highly dissected denudational hills (HDDH) and Moderately dissected denudational hills (MDDH) within the Plateau-Ridge-Valley Complex of Hoshangabad district, Madhya Pradesh state. The density of drainage lines is relatively moderate and therefore moderate dissection in case of MDDH, whereas, the density of drainage lines is relatively high and therefore high dissection in case of HDDH.

Plateau: Vast horizontal plate like landforms covering several hundred sq km Surrounded by vertical wall like escarpments are developed due to tectonic processes

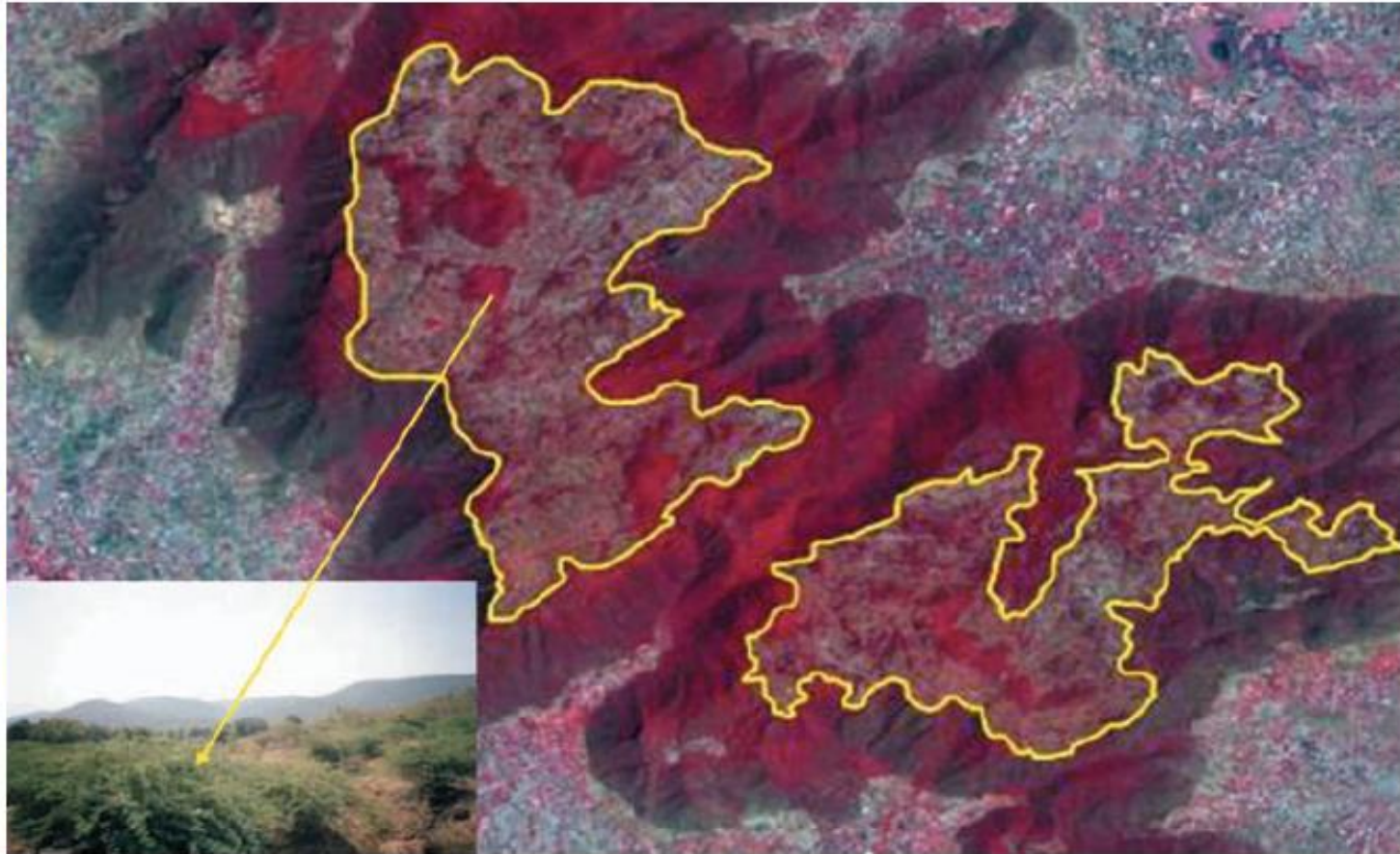
- E-g***
- i) Plateau in Sst - Vindhya***
 - ii) Plateau in Cuddapah***
 - iii) All Deccan trap plateau***
 - iv) Plateau in metamorphites (charnockite)***



b) Signatures

- normally boat like
- rims / slopes prolific with vegetation

Fig. 2.23 Plateau Top in the low dissected upper plateau in Pachamalai hills consisting of charnockites in Tiruchirappalli district, Tamil Nadu. There is an elevation difference of 1000m (approx.) between the plateau top and foot hills. The top is undulated.



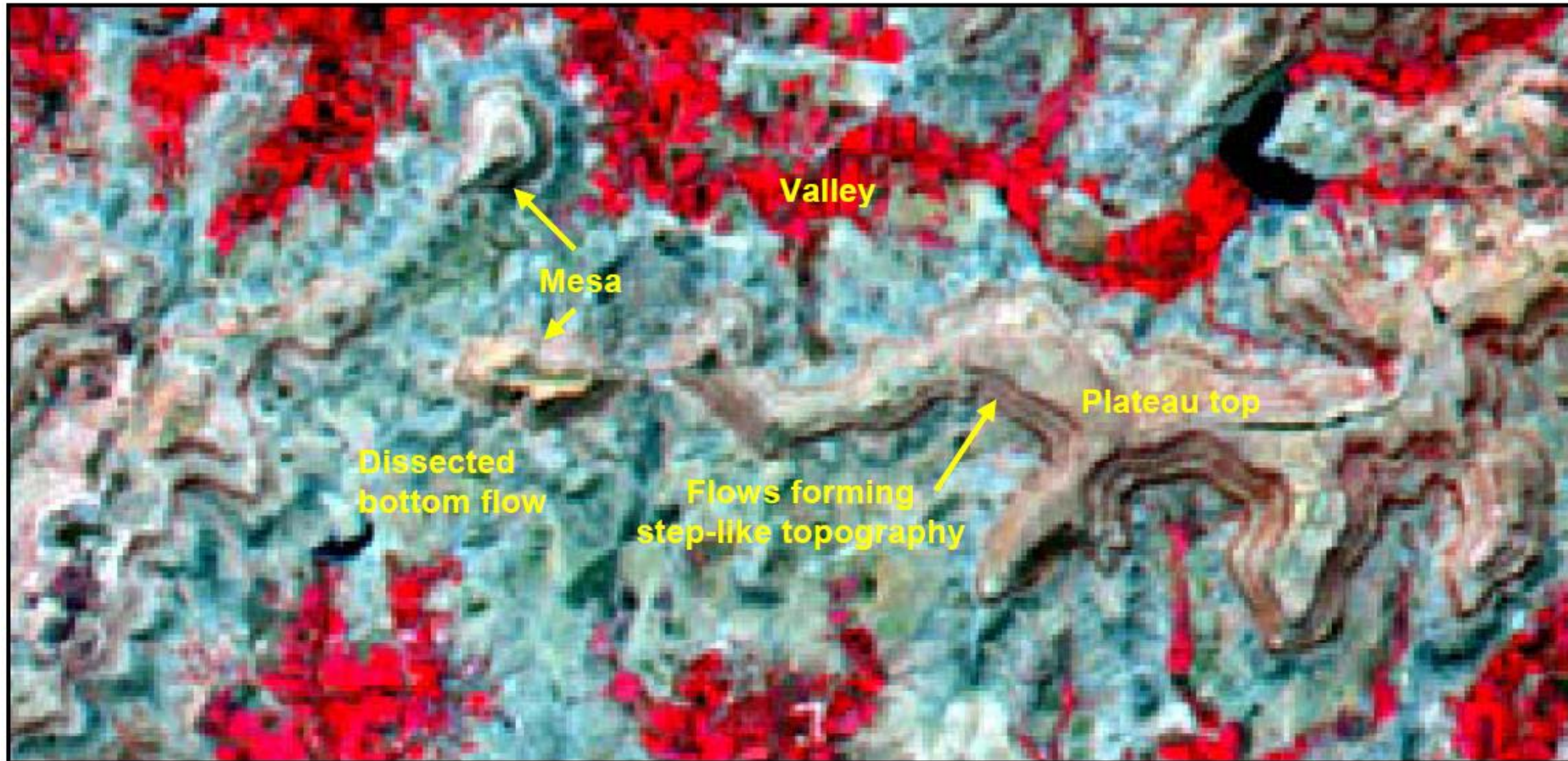


Fig. 4.7: Satellite image of Deccan trap area showing a pile of basalt flows forming step like topography

Fig. 4.18: Satellite image of Peninsular India showing the Denudational landforms.

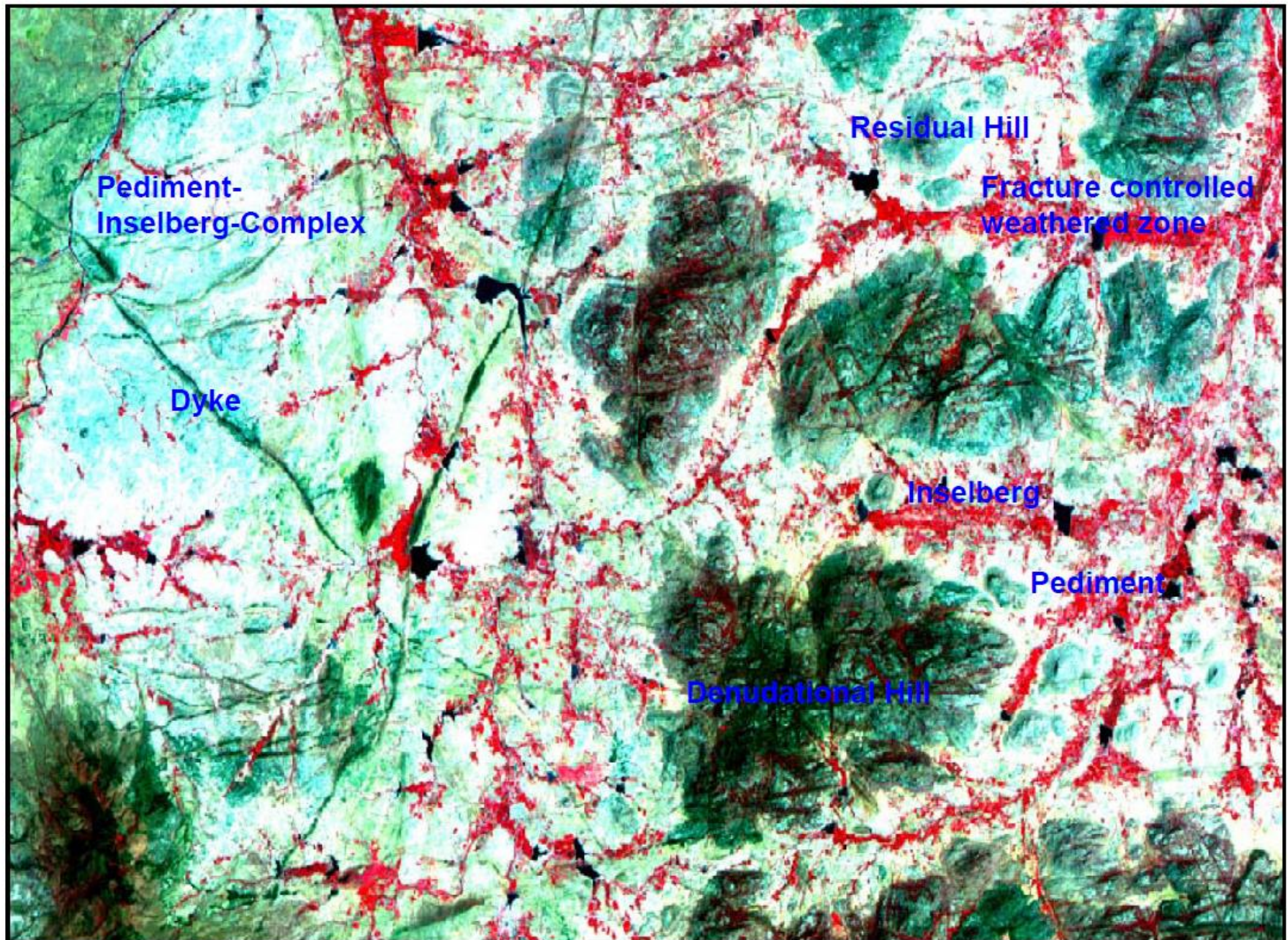
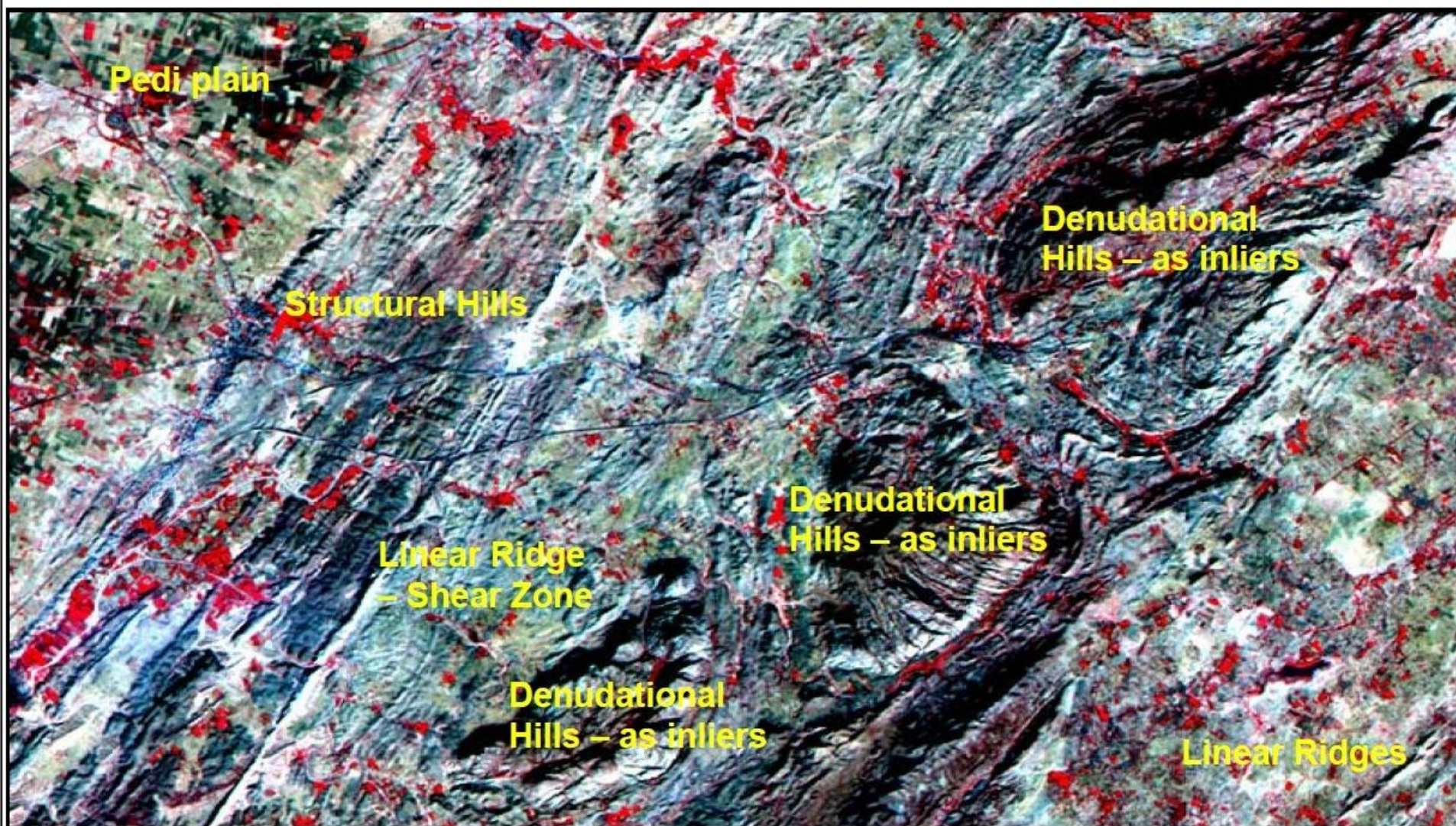


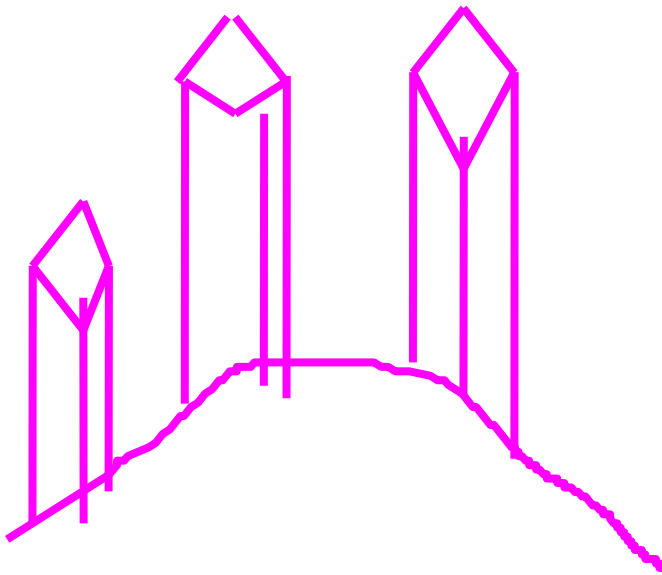
Fig. 4.20: Satellite image of Aravali region showing the Structural landforms



TORS

Tor is a complexly jointed blocked hills

(a) Tor complex



Tor: A high, isolated, craggy hill, pinnacle, or rocky peak; or a pile of rocks, much-jointed and usually granitic, exposed to considerable weathering, and often assuming peculiar or fantastic shapes.

- **No heavy metal seggregate in the foot.**
- **Less reservoir siltation in the foot hill reservoirs**

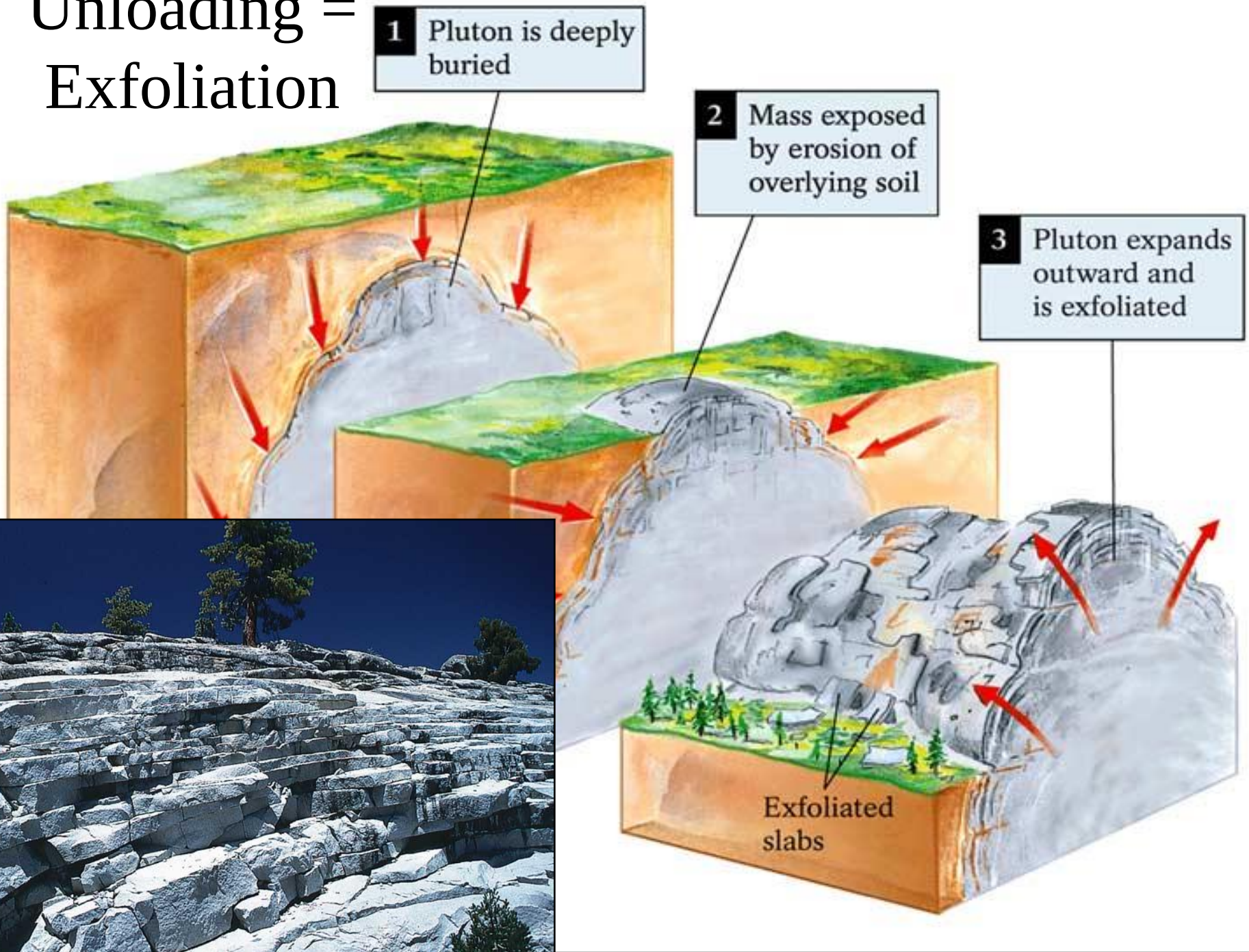


Eastern Head, Fort Lee, N. J., 1940
 (Courtesy of William Allen, Boston, Mass.)
 This is the traditional account of the building of the rock, except for the building

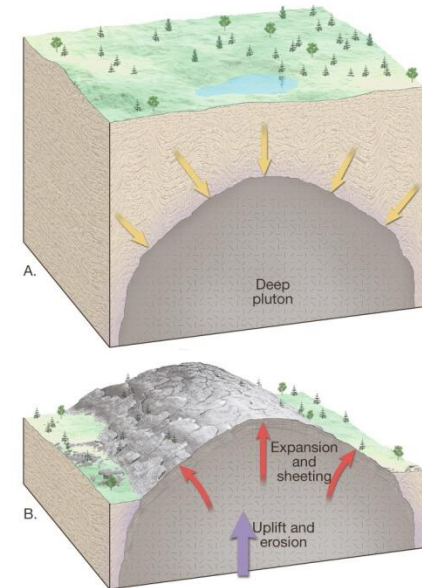
Exfoliation domes

- ◎ **solid rocks occur at the core with shells of different layers outside.**
- ◎ **mostly occur in semi arid and arid tracts.**

Unloading = Exfoliation

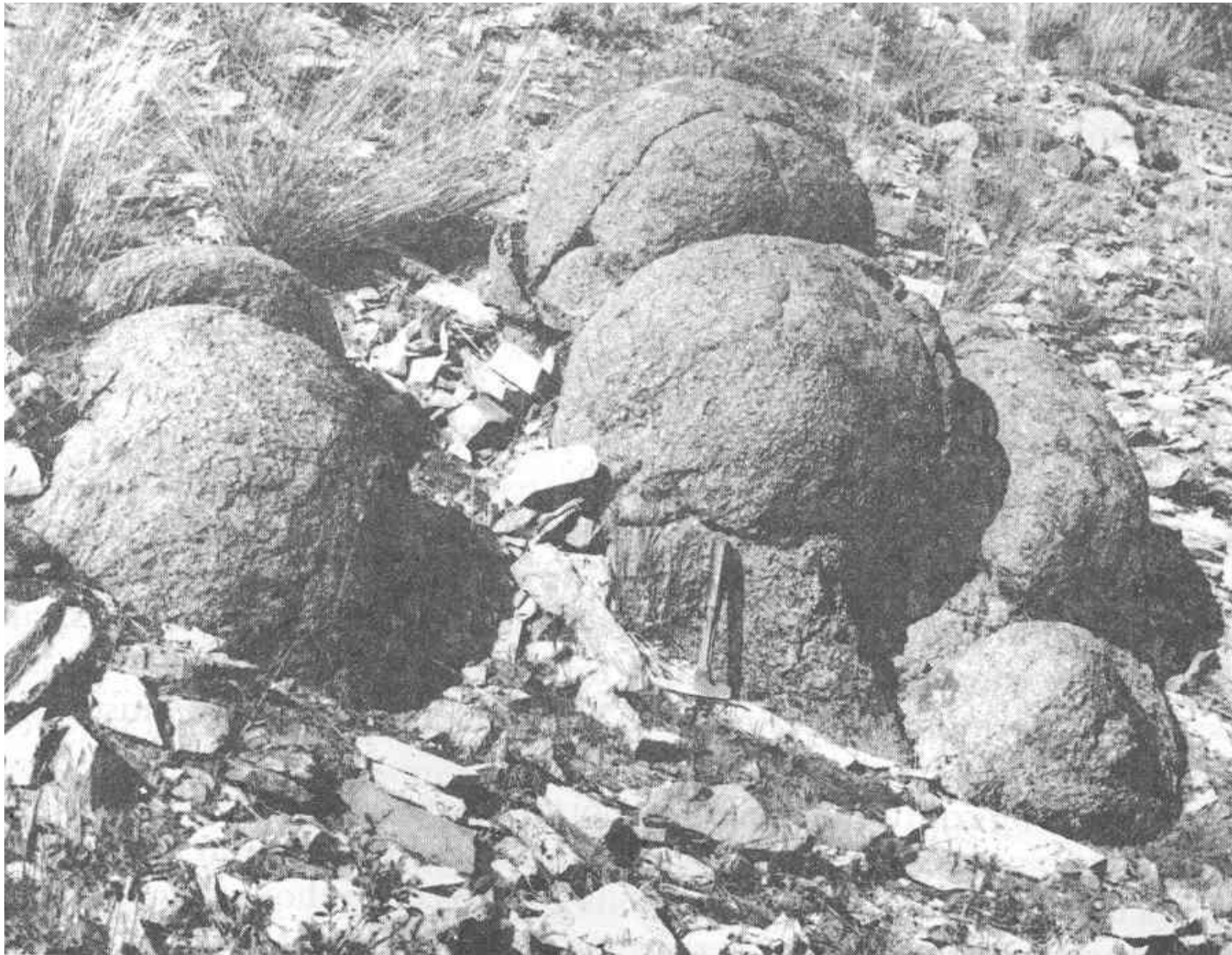


Sheet Joints (Exfoliation)



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SPHEROIDAL WEATHERING





ESCARPMENTS

A steep slope or long cliff that results from erosion or faulting and separates two relatively level areas of differing elevations

A steep slope or long cliff formed by erosion or by vertical movement of the Earth's crust along a fault. Escarpments separate two relatively level areas of land.

Residual hills

Suggest maturity of weathering process
debris slope with scattered material

(e.g) hills in Bangalore area

RESOURCE:

Foot hills will have metal, mineral and concentrates

ENVIRONMENT:

- Erosion prone
- Downward reservoirs siltation prone.

Residual hills: A small remnant hill, which has witnessed all forms of denudation.



Fig. 4.18: Satellite image of Peninsular India showing the Denudational landforms.

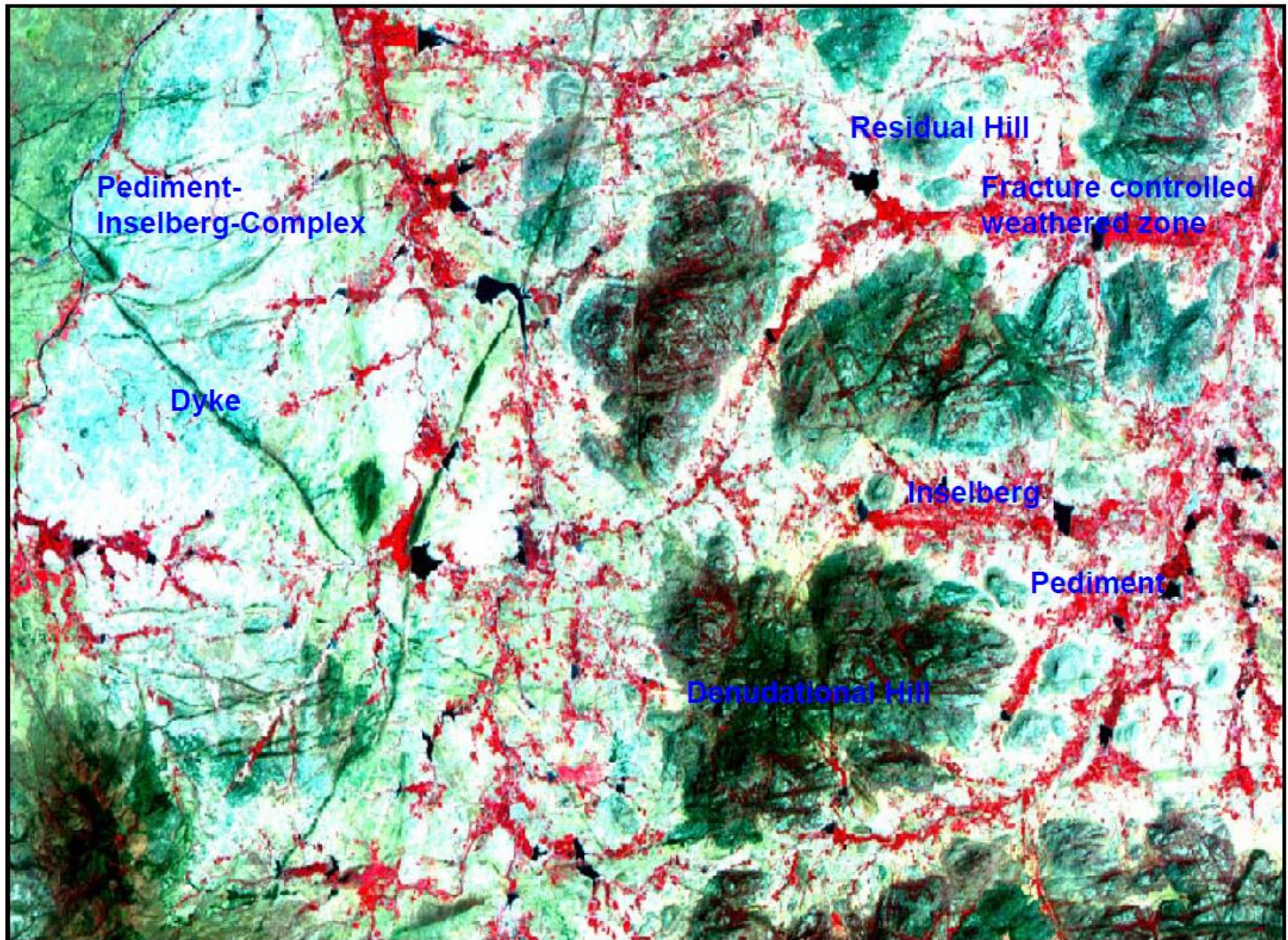
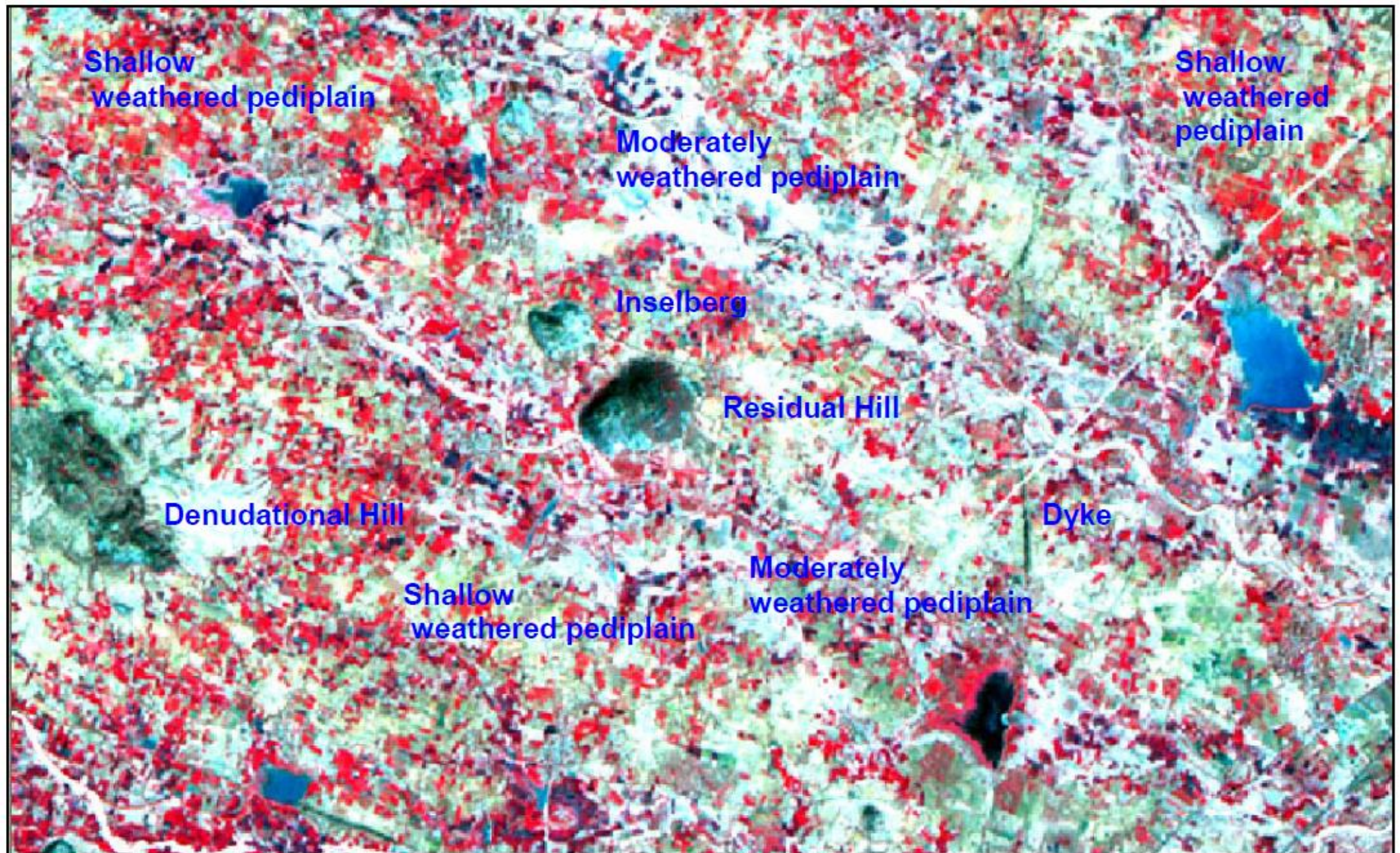
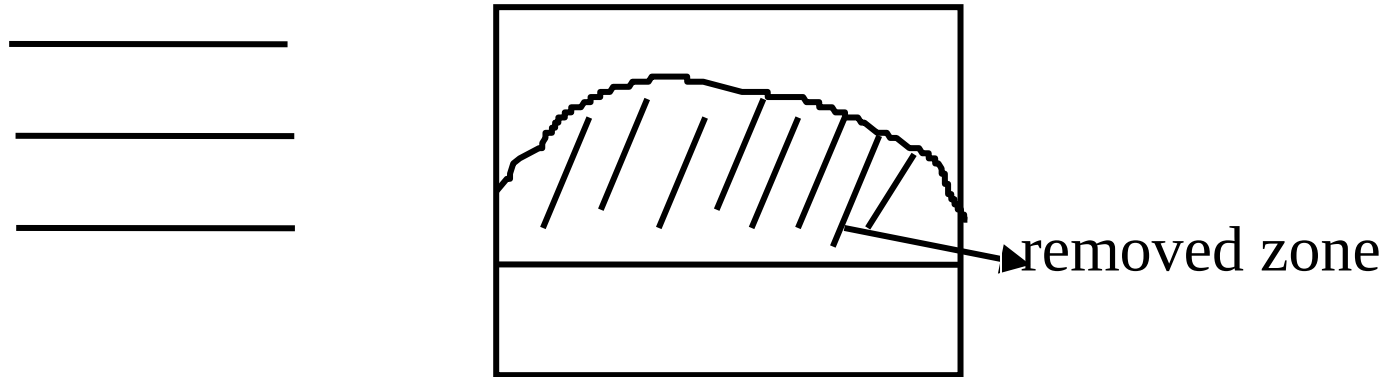


Fig. 4.19: Satellite image of Peninsular Gneissic Complex showing weathered zones



Arched hills

Due to differential resistance, bottom portion scooped out leaving the top layer.



unstable area for heavy structures.

E.g:

- **Granitic areas**
- **S.st areas**
- **Cuddapah**

Landscape Arch, Arches, N.P. Utah



ARCHID HILL

(DELICATE ARCH, ARCHES NATIONAL PARK, UTAH)



Inselberg

➤ *isolated conical hills*

- No mineral resources in foot hills.
- No siltation in downward reservoirs.

Inselberg A prominent, isolated, steep-sided, usually smoothed and rounded, residual knob, hill or small mountain of circumdenudation rising abruptly from and surrounded by an extensive and nearly level

INSELBERG



Fig. 2.22 Inselberg along Manapparai – Turaiyur main road in Tiruchirappalli district, Tamil Nadu. The rock here is used for floors in the houses after it is polished.

Balanced rocks

Balanced Rock is one of the most popular features of [Arches National Park](#), situated in [Grand County, Utah, United States](#).

Balanced Rock is located next to the park's main road, at about 9 miles (14.5 km) from the park entrance.





Intermontane Valley: The valley between the mountains.



**Intermontane
Valley**

SLOPE RELATED LAND FORMS

Slope Zone Features

Debris Slope / Scree Slope

Steep

Moderate

Shallow

Barren Slope

Midslope Mounds

Rock Slump

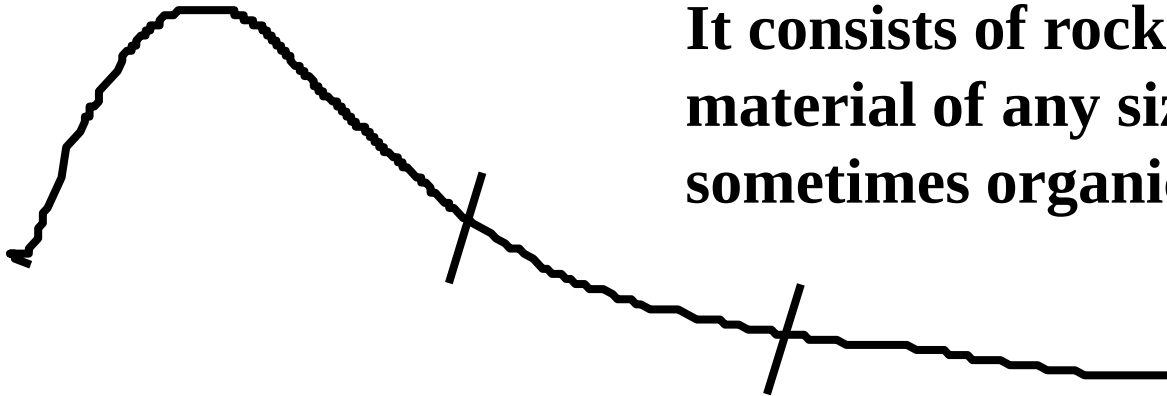
Debris Avalanche

Rock Creep

SLOPE ZONE

Debris slope:

debris - Any surficial accumulation of loose material detached from rock masses by chemical and mechanical means, as by decay and disintegration. It consists of rock clastic material of any size and sometimes organic matter



Zone between summit zone and pediment

DEBRIS SLOPE



TEAR SCAR - AUSTRIA



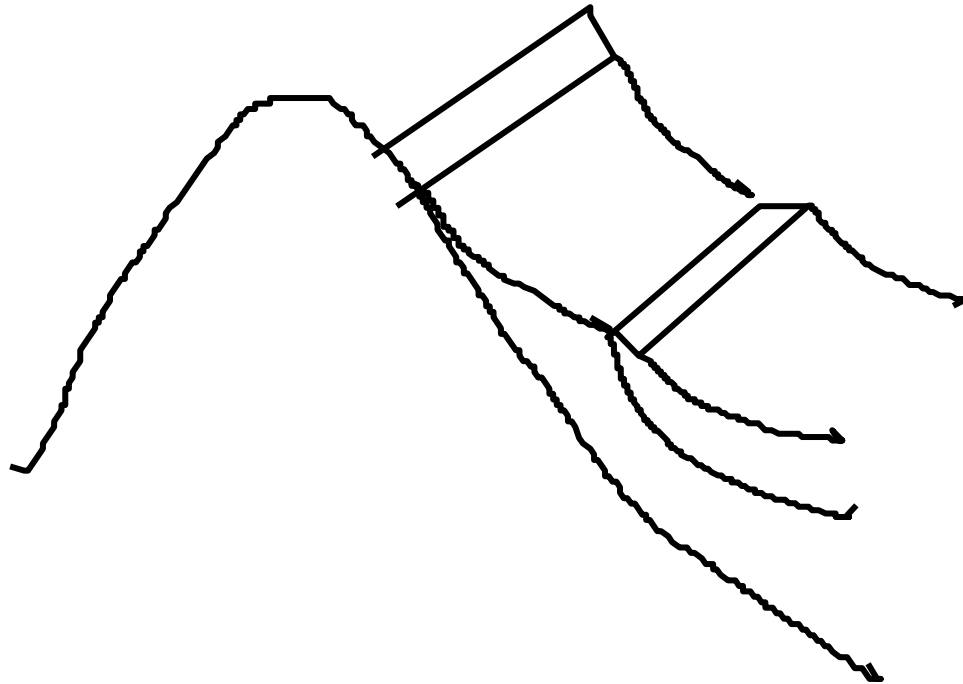
SCREE SLOPE - LADAKH



Rock slumb

→ Slope 60° to 30°

→ Along debris slope there will be a series of parallel to sub parallel slips will be there.



ROCK SLUMP



SLUMP



DEBRIS SPLAY (VALLEY OF FIRE, NEVEDA)



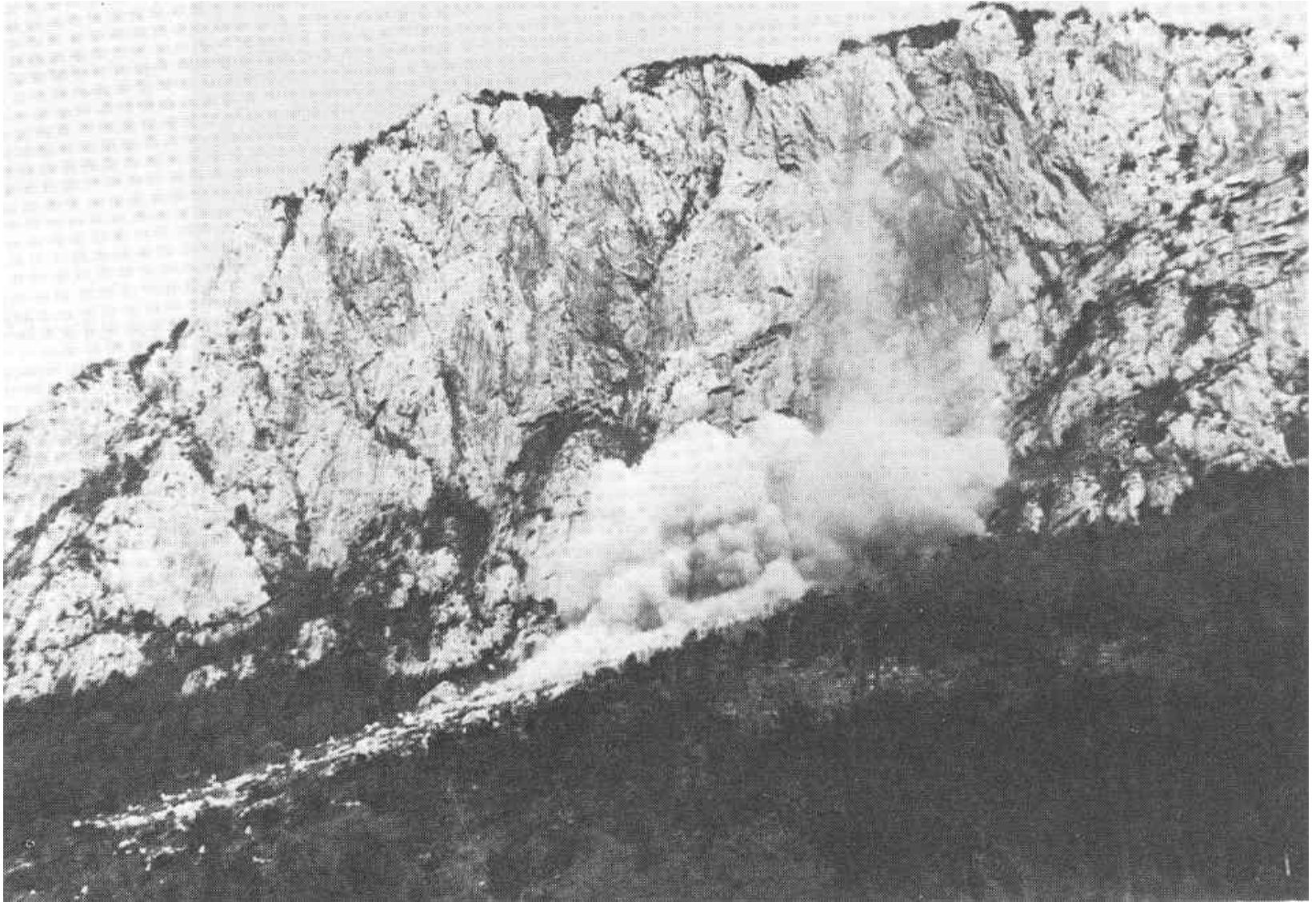
MID SLOPE MOUNT



CREEP, SLOPE BENT - AUSTRIA



ROCK FALL - ITALY



FOOT HILL FEATURES

Foot Hill Zone

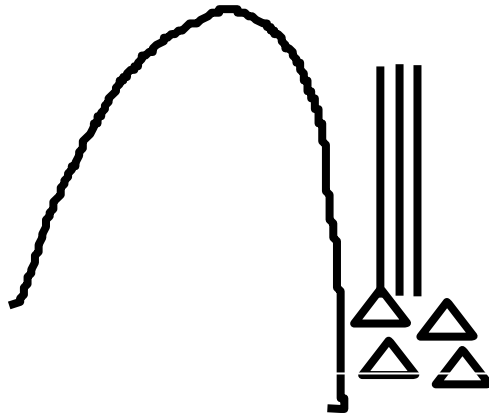
Rockfall zone

Talus Cone / Fan

Debris Wash Plain

Composite slope

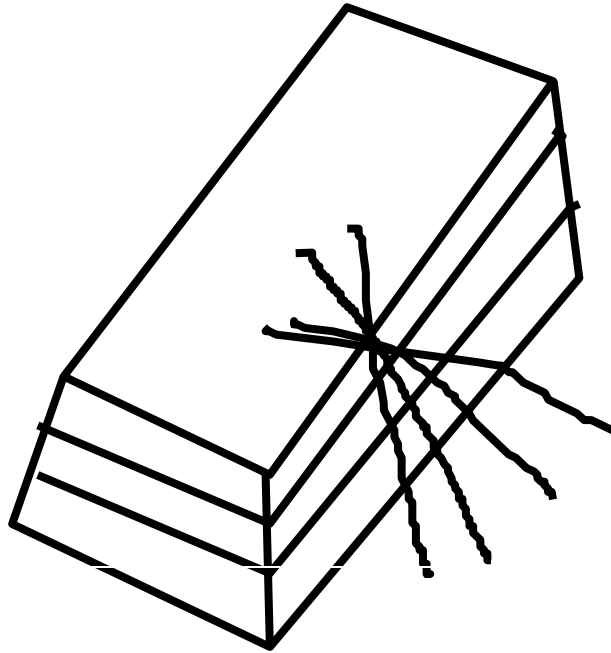
(III) FOOT HILL ZONE:



2.5.16 Rock fall

- if the slope is steeper then rocks will fall like a water fall
- as result the foot hills have heaps of angular and assorted materials

Talus cone/ Fan

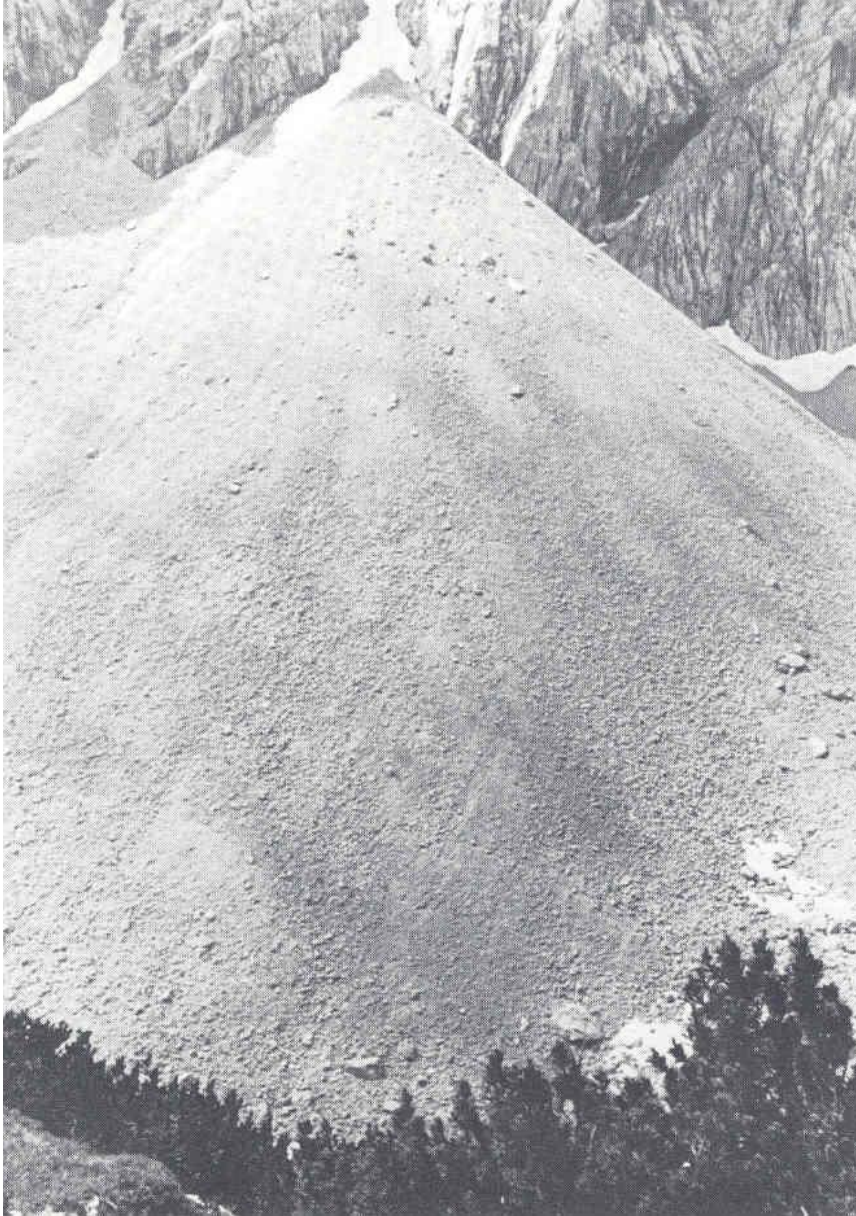


➔ eroded materials from the hills getting dumped at the foot hills with coning effect

$> 15^{\circ}$ - *cone*

$< 15^{\circ}$ - *fan*

SCREE CONE - AUSTRIA



scree - A collective term for an accumulation of coarse rock debris or a sheet of coarse debris mantling a slope.

Scree is not a synonym of talus, as scree includes loose, coarse fragment material on slopes without cliffs. Compare - talus, colluvium, mass movement.

PLAIN RELATED FEATURES

Plain Zone

Pediment

Rocky Pediment

Weathered Pediment Shallow

Weathered Pediment Moderate

Weathered Pediment Deep

Pediplain

Deeply Weathered

Moderately Weathered

Poorly Weathered

Lateritic upland

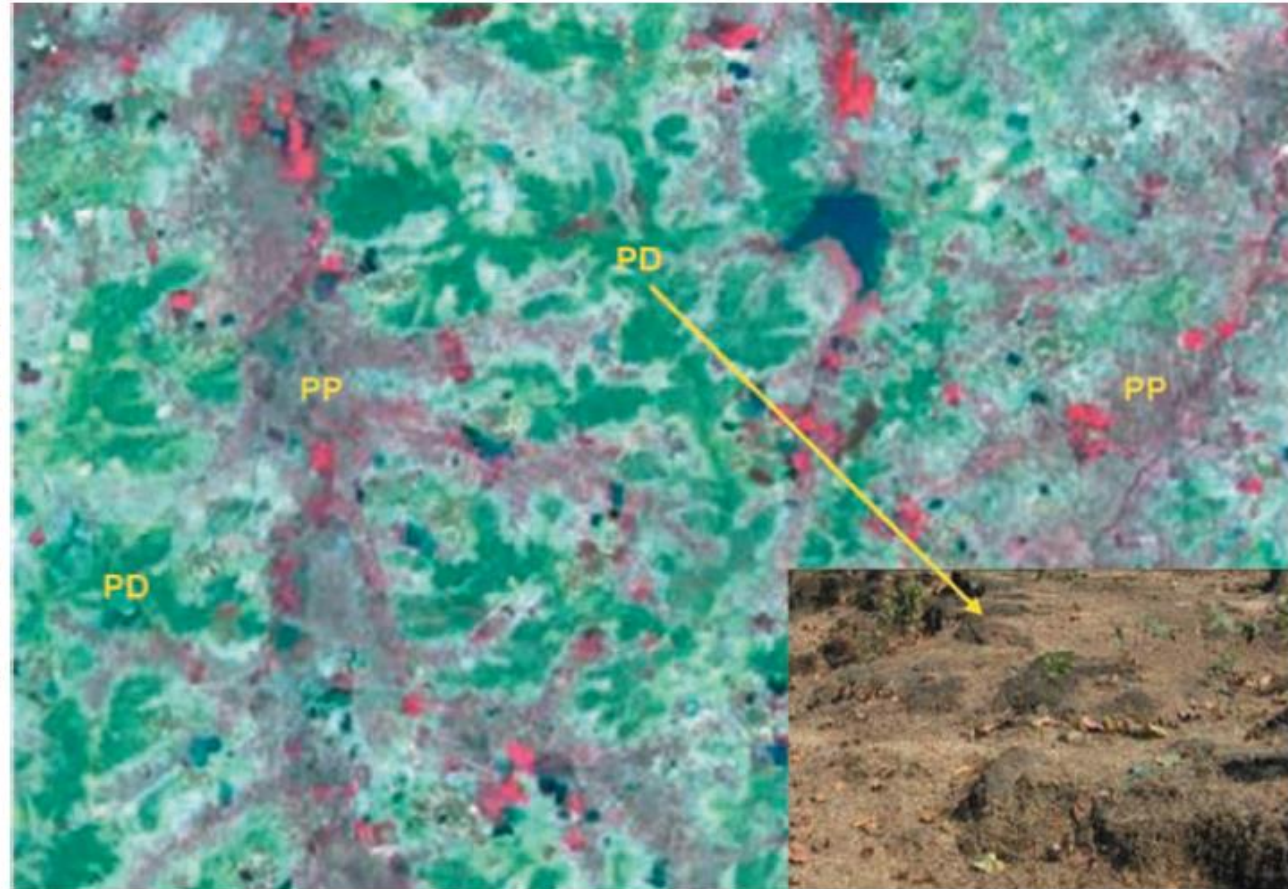
Dissected

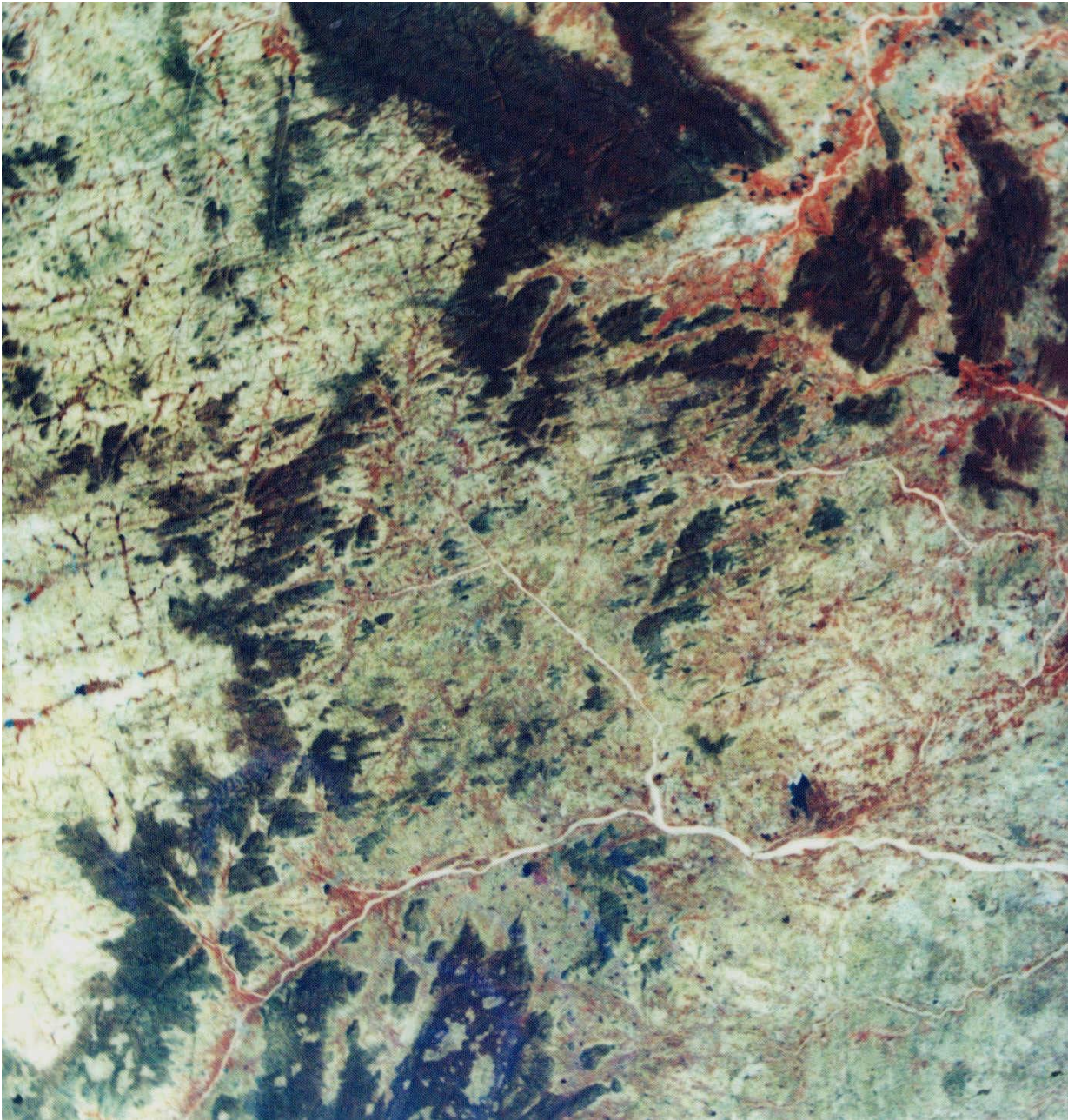
Undissected

Pediment:

A broad, flat or gently sloping, rock floored erosion surface or plain of low relief, typically developed by sub aerial agents (including running water) in an arid or semiarid region at the base of an abrupt and receding mountain front or plateau escarpment, and underlain by bedrock (occasionally by older alluvial deposits) that may be bare but more often partly mantled with a and discontinuous veneer of alluvium derived form the upland masses and in transit across the surface.

Figure 2.31 Pediments (PD) and pediplains (PP) occurring in Raipur district, Chhattisgarh state as seen from the IRS LISS-III rabi season satellite image. The green tone of the pediment areas is because of the laterite lithounit, which brings a good contrast between the pediplains and pediment areas.



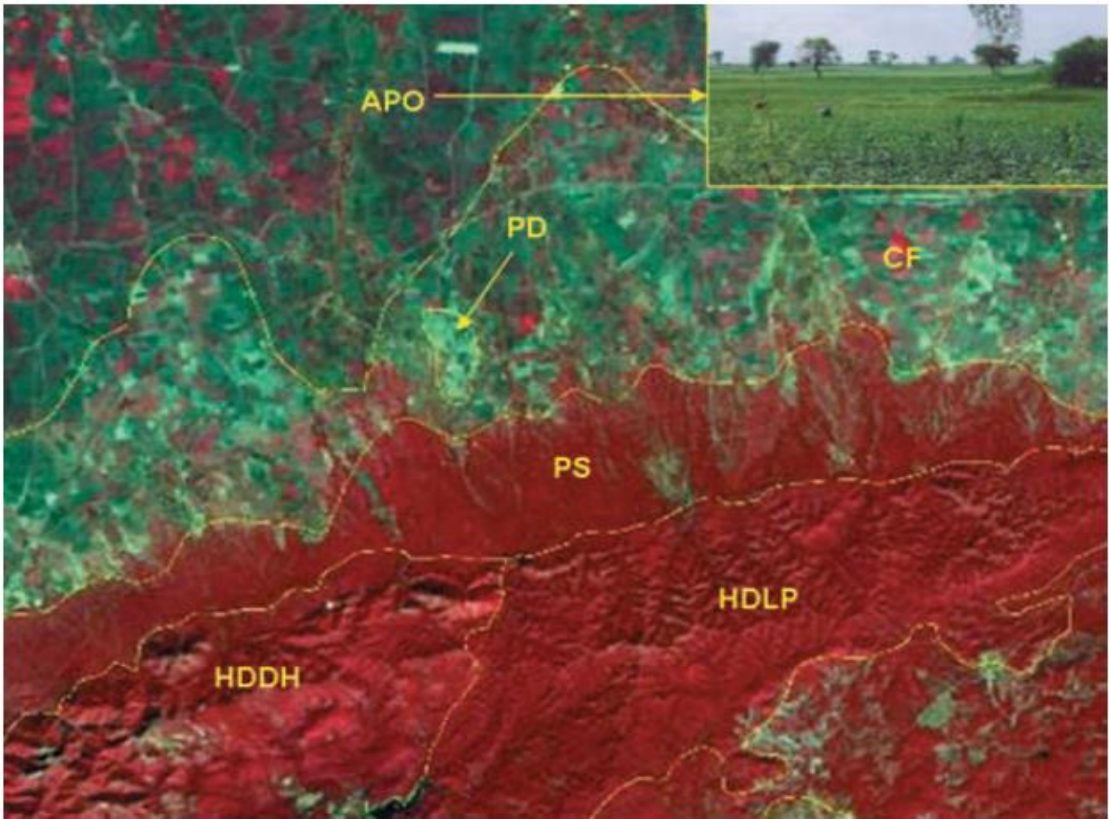


**Dissected
Pediment**

Dissected Pediment



Fig. 2.18 Highly dissected denudational hills (HDDH), highly dissected lower plateaus (HDLP), Piedmont slope (PS), colluvial fans (CF), pediment (PD) and older alluvial plains (APO) in Hoshangabad district.

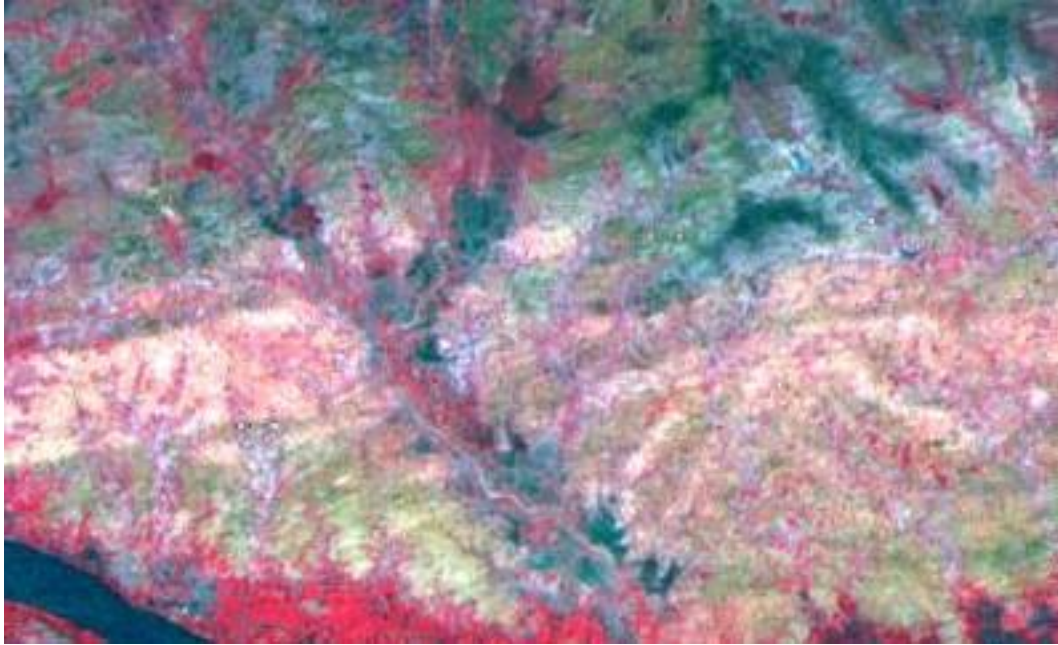


Pediment-Inselberg Complex:

The pediments dotted by numerous inselberg of small sizes, which makes it difficult to distinguish from the pediments. Hence it is called as a complex of pediment and inselberg.

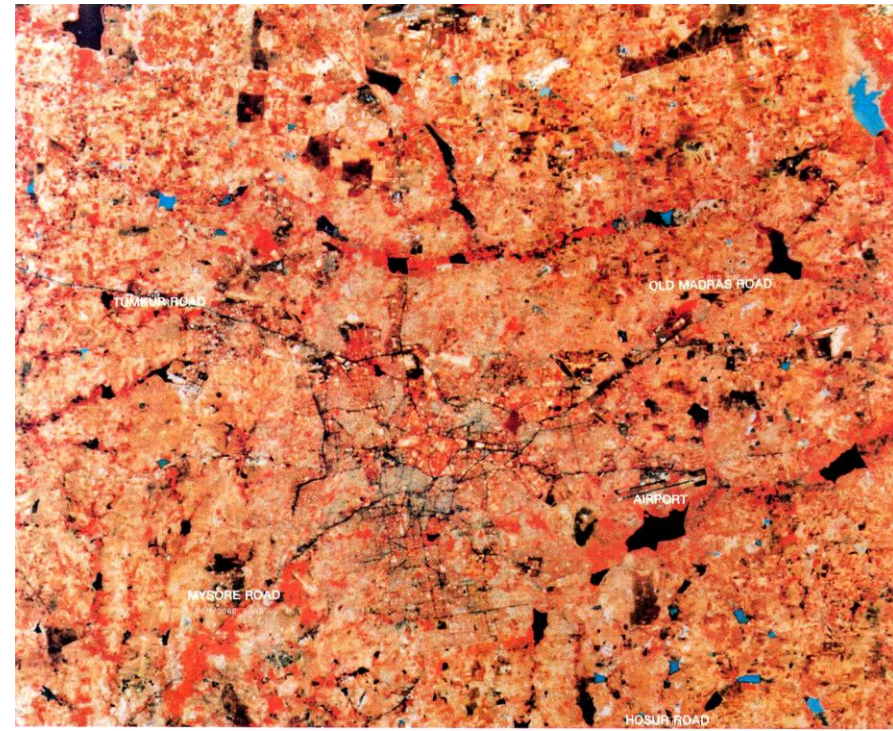


Fig. 2.28 Pediment Inselberg Complex southeast of Tataayyagarpettai in Tiruchirappalli district, Tamil Nadu. It is difficult to separate inselberg and pediment here. Pediment dotted with inselbergs (appearing as dark spots in the image) is seen here.



ROCKY PEDIMENT

WEATHERED
PEDIMENT MODERATE

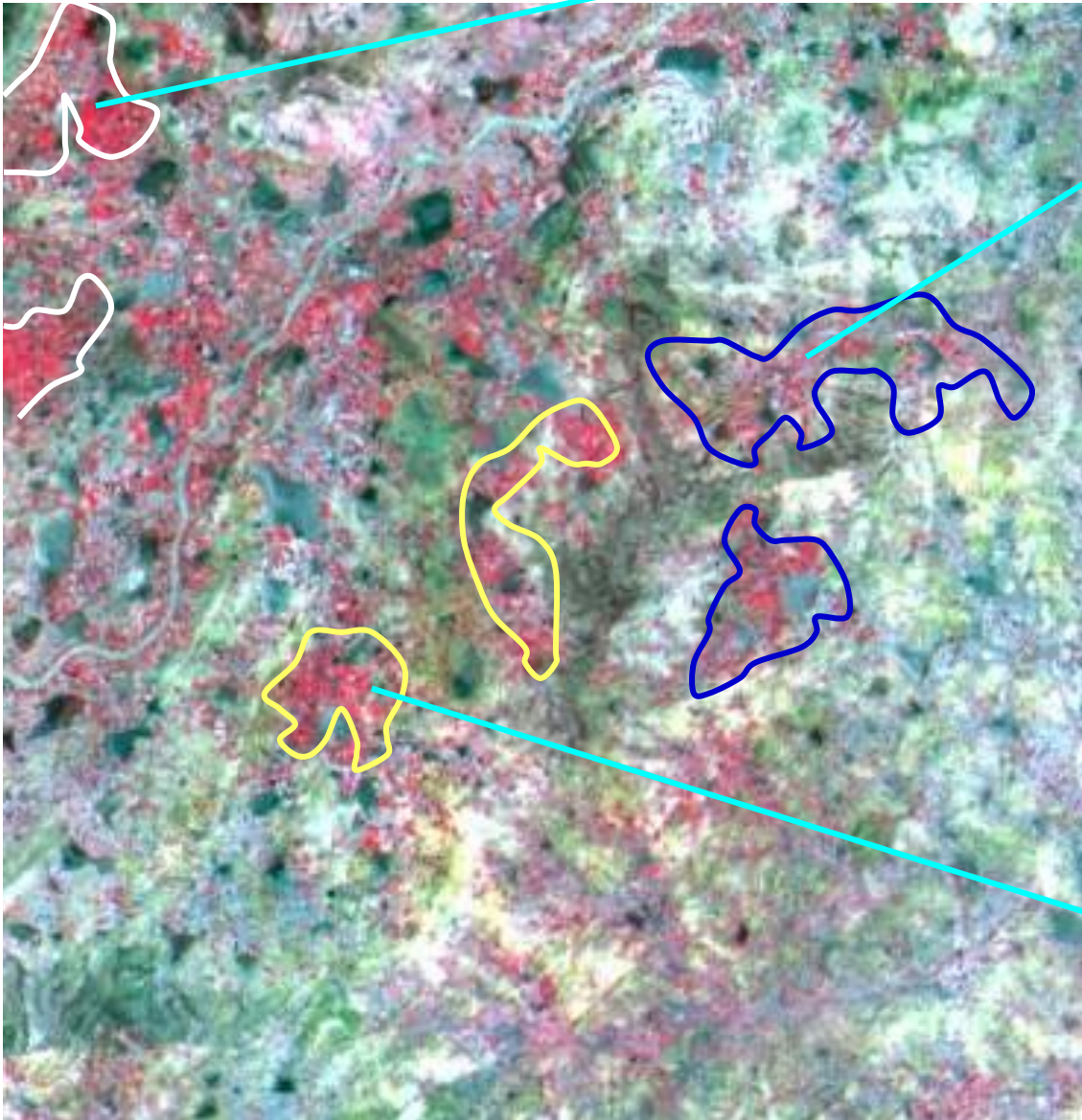


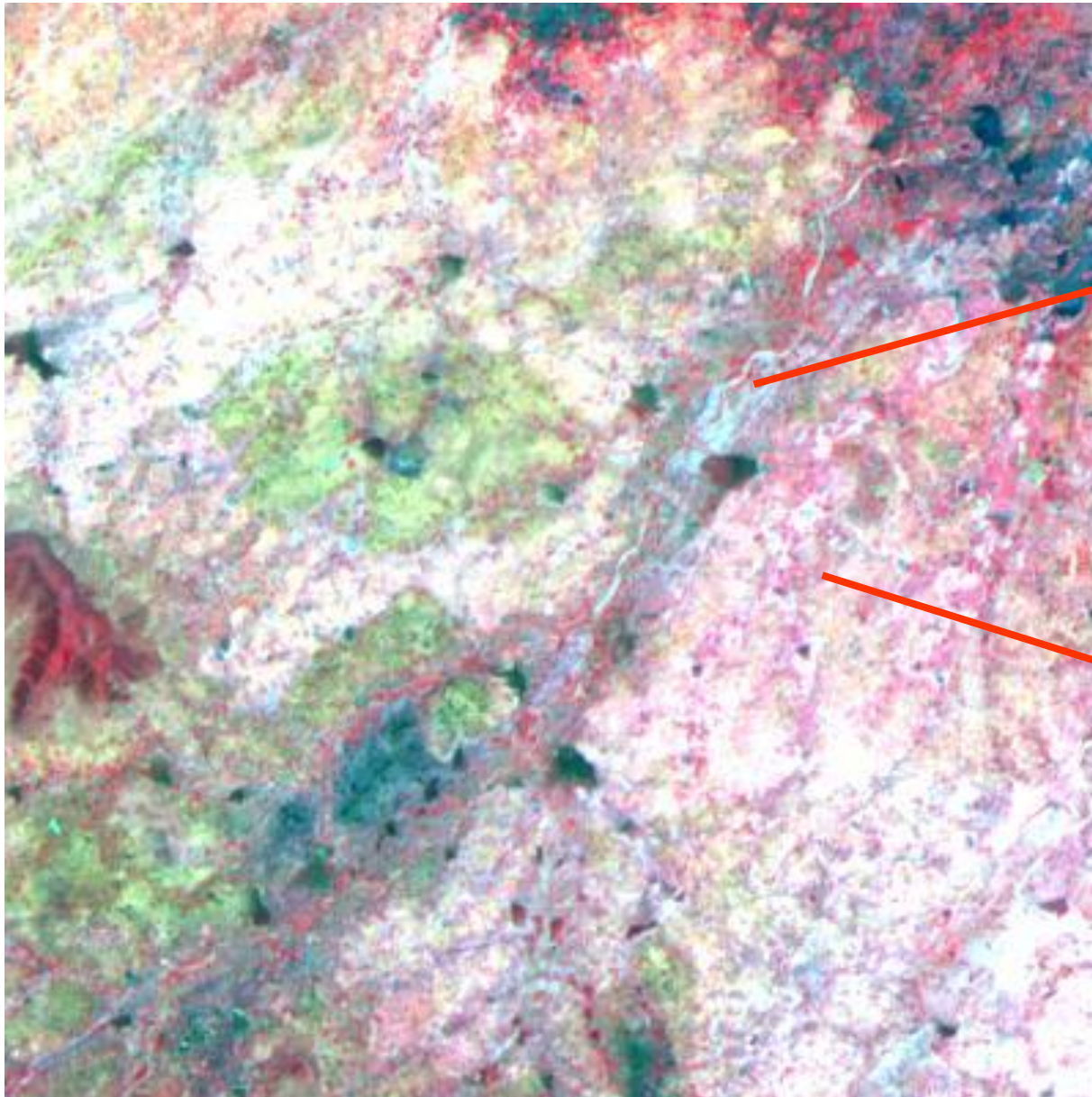
PEDIMENTS

**WEATHERED
PEDIMENT DEEP**

**WEATHERED
PEDIMENT
SHALLOW**

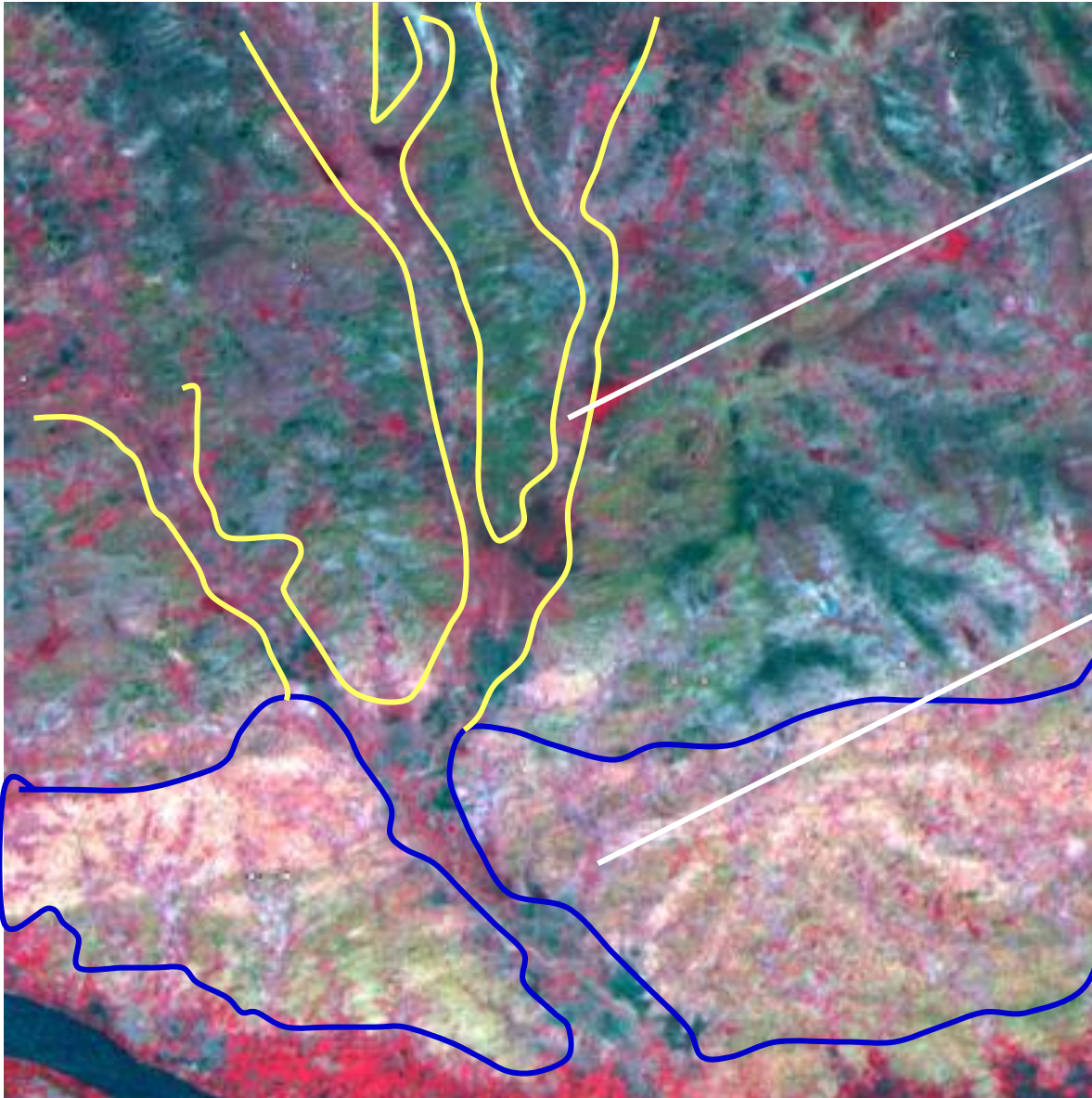
**WEATHERED
PEDIMENT
MODERATE**





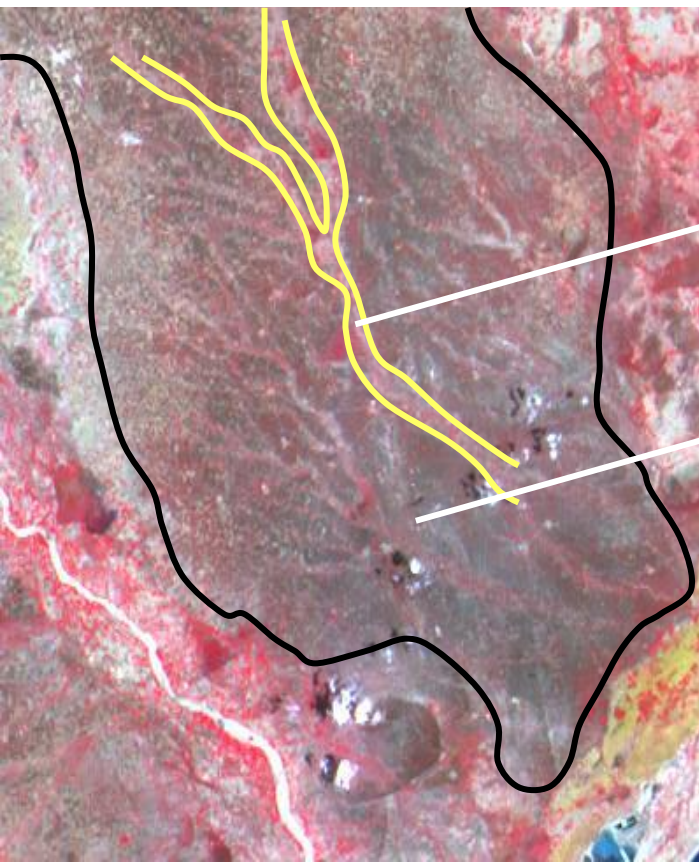
**COLLUVIAL
FILL**

PEDIPLAIN



**COLLUVIAL FILL
MODERATE**

**ROCKY
PEDIMENTS**



Pediplain:

An extensive, multi-concave, thinly alluviate rockcut erosion surface formed by the coalescence of two or more adjacent pediments and occasional desert domes, and representing the end result (the “peneplain”) of the mature stage of the erosion cycle.



Fig. 4.19: Satellite image of Peninsular Gneissic Complex showing weathered zones

