

GEOMORFOLOGÍA

Edier V. Aristizábal G.

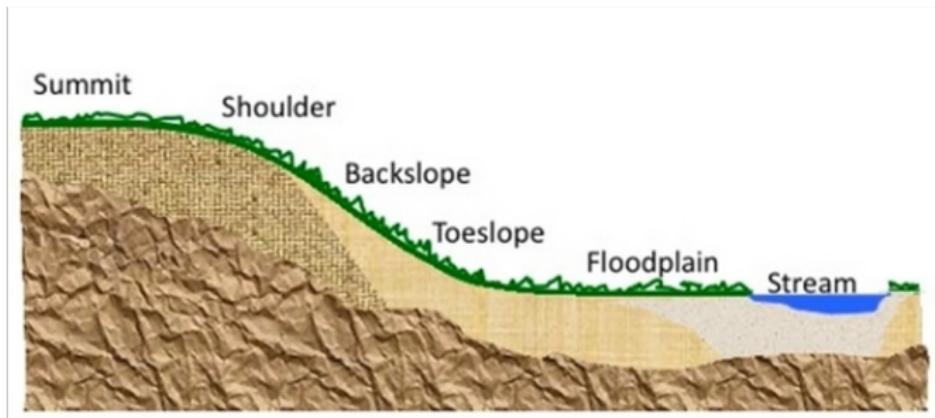
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Versión: June 28, 2020



Procesos de ladera

Meteorización + Erosión + Movimientos en masa + Sedimentación → Erosión fluvial + Transporte fluvial + Sedimentación



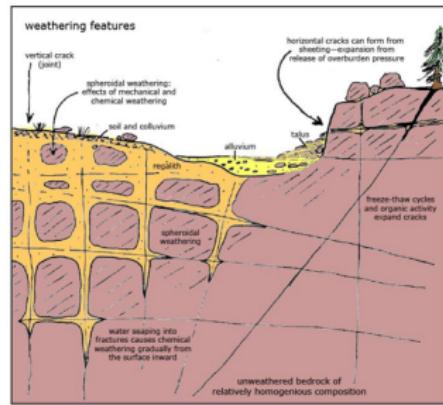
Coluvial

Torrencia

Aluvial

Meteorización

Proceso de alteración y separación de la roca y materiales del suelo sobre y cerca de la superficie terrestre por descomposición química, desintegración física y/o biológica (Anon, 1995).



Debido a la diferencia de energía de formación y la energía a la cual está expuesta la roca...

Factores que controlan la meteorización

Termodinámica

De los materiales parentales y las reacciones

Energía cinética

Tasas de reacción y procesos (tiempo)



Condiciones ambientales

Temperatura, humedad, Ph, plantas, etc,

Weathering:

Breakdown of pre-existing minerals
at or near Earth surface

Conditions at Earth surface:

- Low temperature
- Low pressure
- Commonly much water
- Dilute water
- Acidic water ($\text{pH} = 3 - 6$)
- Life present
- Abundant O_2



Conditions at depth in Earth (where most rocks form):

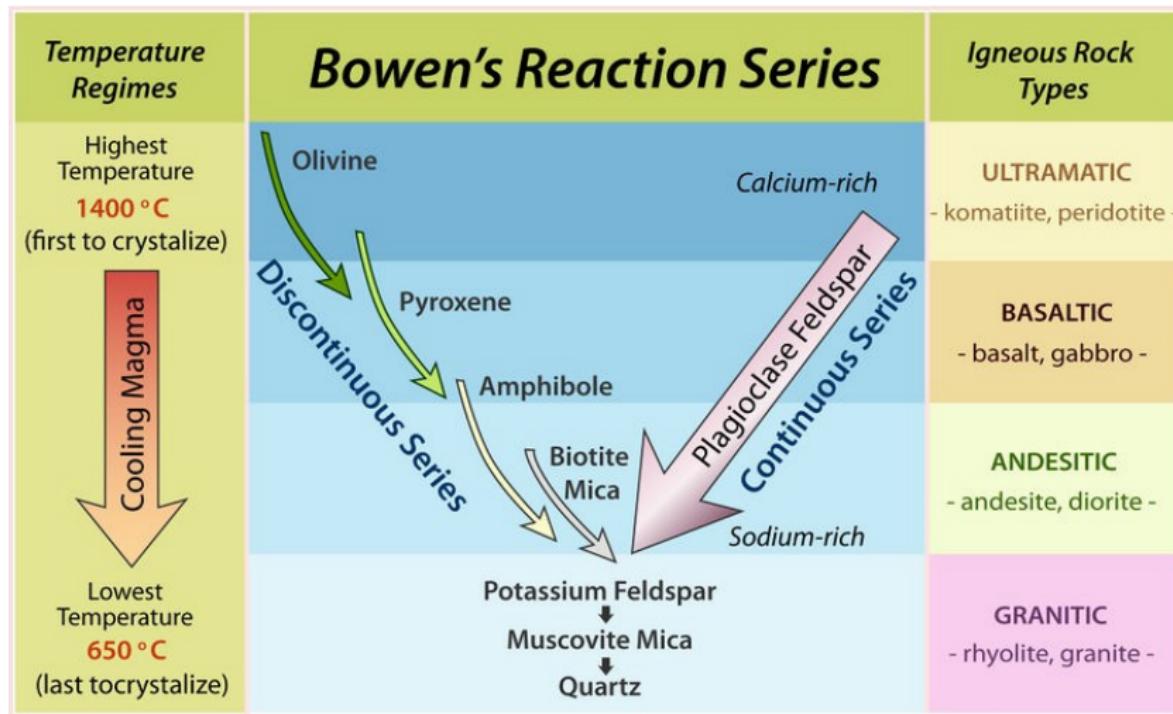
- High temperature
- High pressure
- Relatively little water
- Saline water (water with high concentrations of dissolved solids)
- Neutral to alkaline water ($\text{pH} = 6 - 10$)
- No known life
- Little O_2

Processes in weathering:

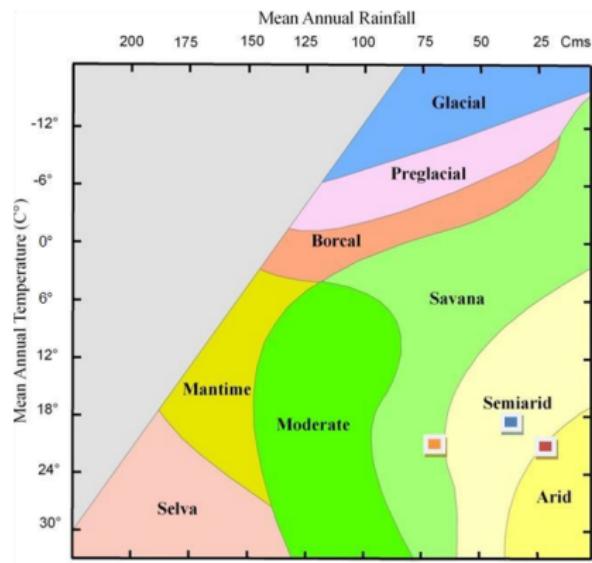
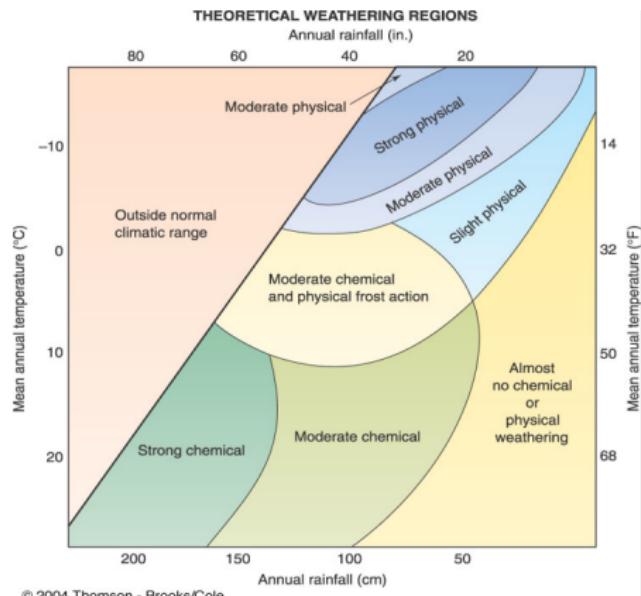
Mechanical weathering -
breakage of rock into smaller pieces

Chemical weathering -
Removal of chemical constituents from rock
Generation of new minerals

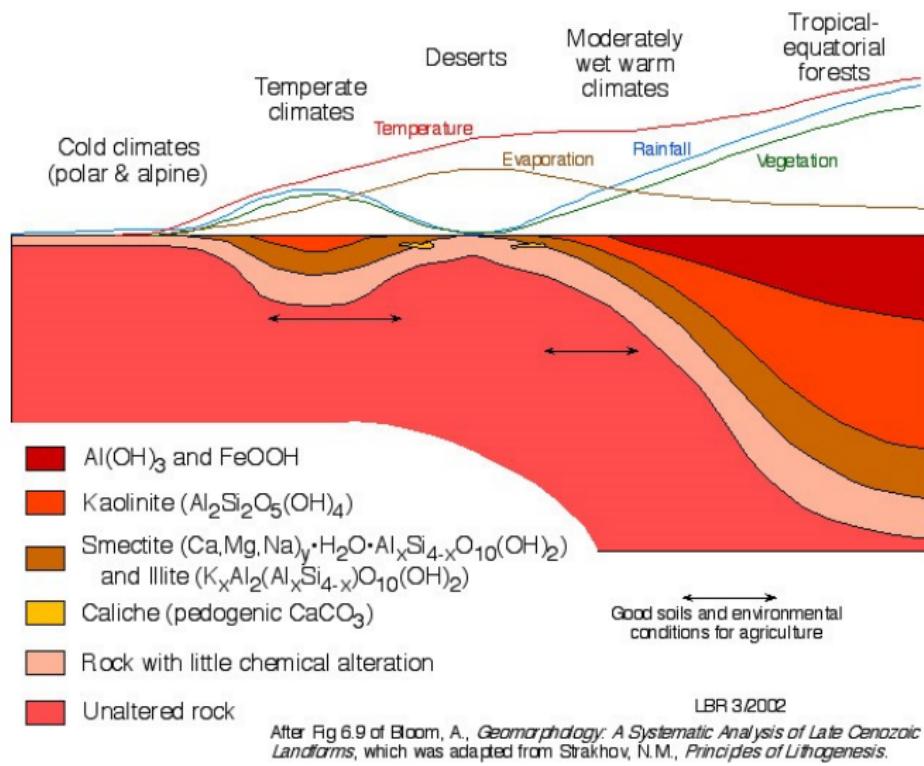
Desequilibrio Termodinámico



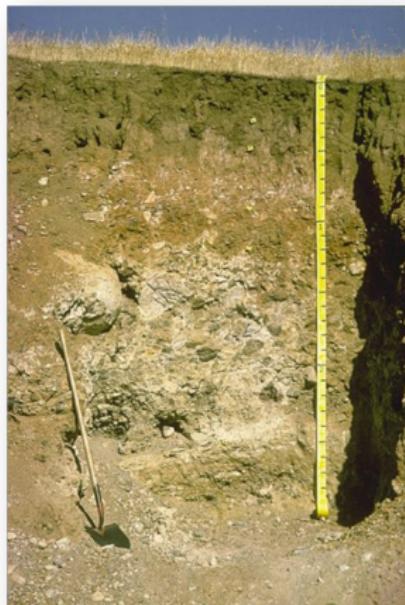
Regiones Morfogenéticas



Distribución de suelos



Definición: Suelo



- **Edafólogos:**
 - Material terrestre que ha sido alterado por procesos físicos, químicos y biológicos que permite que halla vida vegetal.
- **Ingenieros :**
 - Material sólido terrestre que se puede remover con pala.
- **Geólogos**
 - Combina ambas definiciones

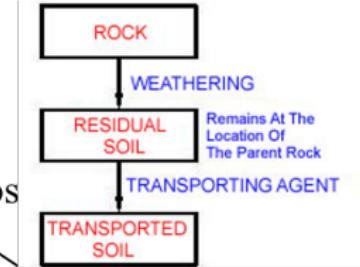
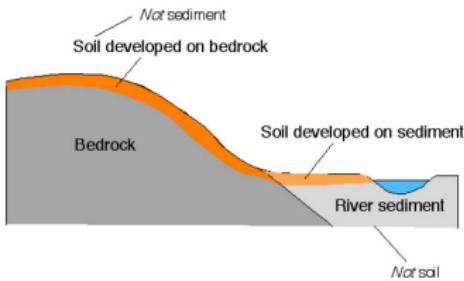
Definición: Suelo

Se entiende por perfil de un suelo a la sección vertical de un terreno, constituido por una secuencia de horizontes o capas, separables por sus características morfológicas, físicas, químicas y mineralógicas.



Tipos de Suelo

Soil:
Unconsolidated mass of
Newly-formed minerals,
Relict minerals,
Organic matter,
Organisms, &
Water
that has formed in place.
(not sediment)



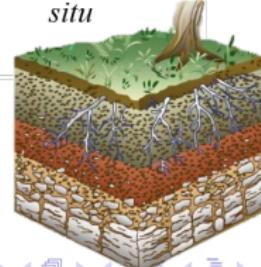
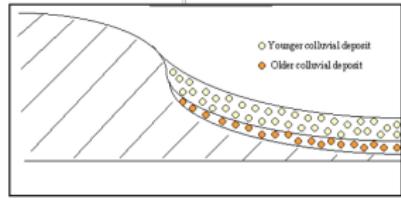
Suelos

Suelos
Transportados

↓
Meteorización y
transporte

Suelos
Residuales

↓
Meteorización *in*
situ



Suelos *insitu* & Suelos transportados



Suelos Transportados

Los suelos transportados son clasificados como:

- ✓ Glaciales
- ✓ Aluviales
- ✓ Coluviales
- ✓ Eólicos
- ✓ Lacustres
- ✓ Marinos

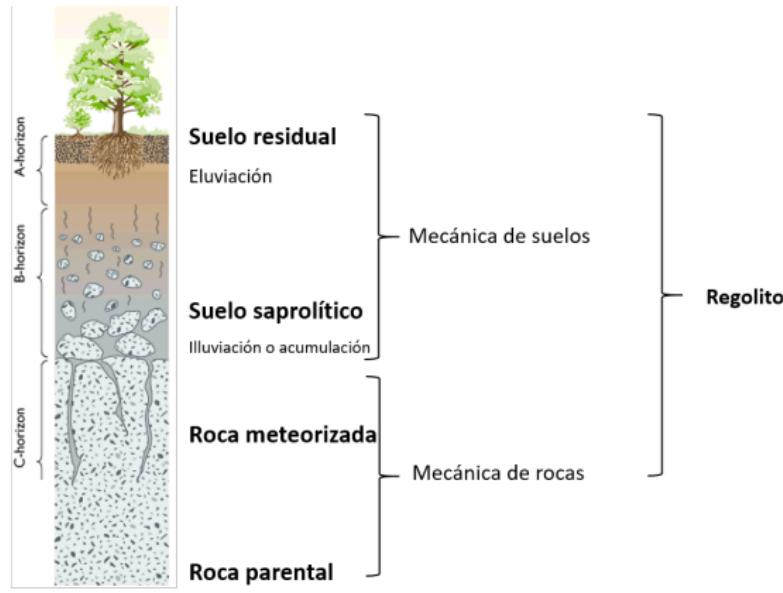


Suelos *insitu*

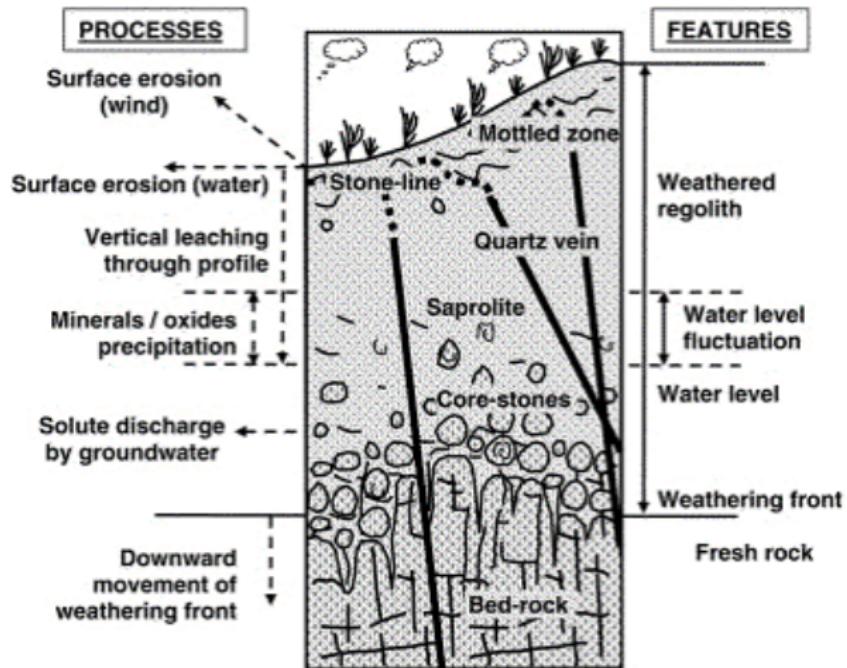
Los suelos y las alteración de rocas pueden ser considerados dos sistemas abiertos independientes. Los suelos implica actividad de plantas y animales, mientras que la alteración de rocas implica interacción entre el agua y los materiales ricos en silicato.

Suelo: Horizontes superficiales que limitan con la atmósfera, con la presencia de organismo vivos (plantas, bacterias, animales).

Roca meteorizada: alteraciones a lo largo de conductos con fluidos (fracturas, diaclasas, fallas, etc). No necesariamente están cubiertas por suelos, no contienen grandes cantidades de materia organizada u organismos vivos. Los procesos de alteración ocurren entre agua precipitada y la roca.

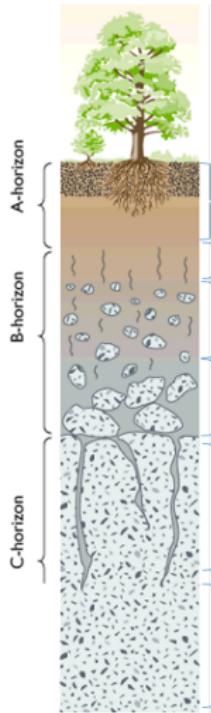


Perfil de Meteorización



Fuente: Taylor & Eggerton (2001)

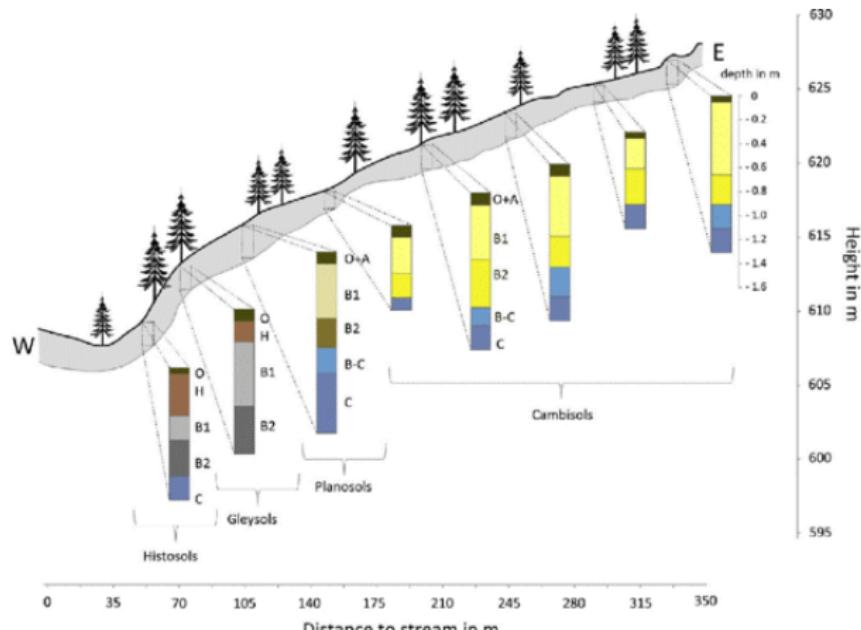
Clasificaciones del Perfil de Meteorización



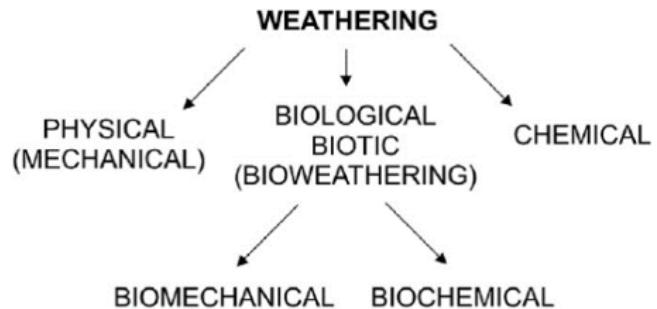
DEARMAN		DEERE & PATTON	
A-horizon	VI – Suelo residual Sin estructura y fábrica de roca parental	IA – Suelo residual Materia orgánica	S. residual
B-horizon	V – CM Conserva estructura y fábrica de roca parental	IB – Suelo residual Sin estructura y fábrica de roca parental	S. saprolítico
	IV – Muy M < 50% bloques	IC – Suelo residual Conserva estructura y fábrica de roca parental	
C-horizon	III – Mod M > 50% bloques	IIA – Roca meteorizada Transición entre saprolito y roca meteorizada	R. meteorizada
	II – Lig M Decoloración	IIB – Roca meteorizada Roca parcialmente meteorizada	
	I – Roca fresca	III – Roca sin meteorización	R. parental

Catena

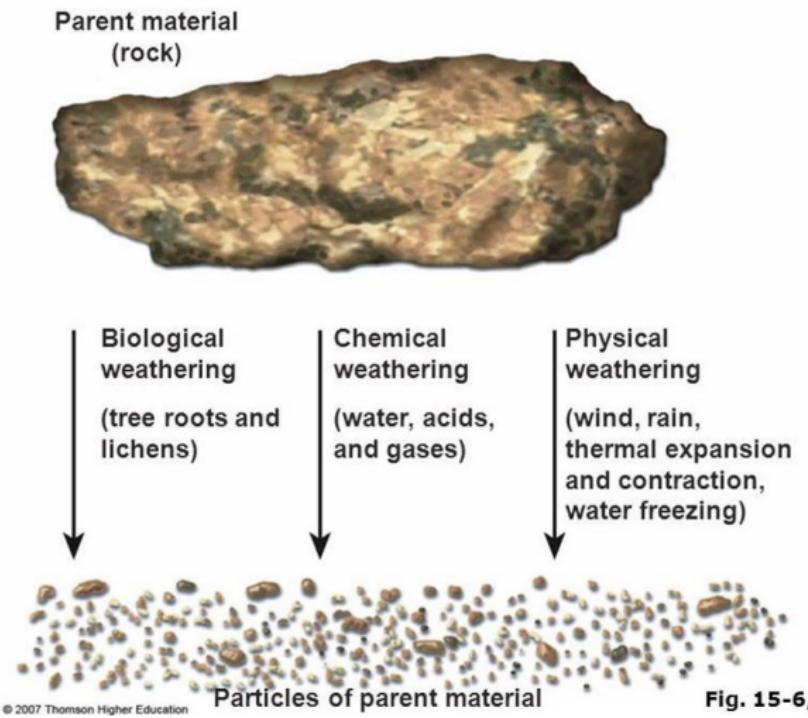
Secuencia de perfiles de suelo los cuales sus características han sido determinadas principalmente por la variación topográfica y las condiciones de drenaje bajo las cuales fueron formados.



Tipos Meteorización



Tipos Meteorización

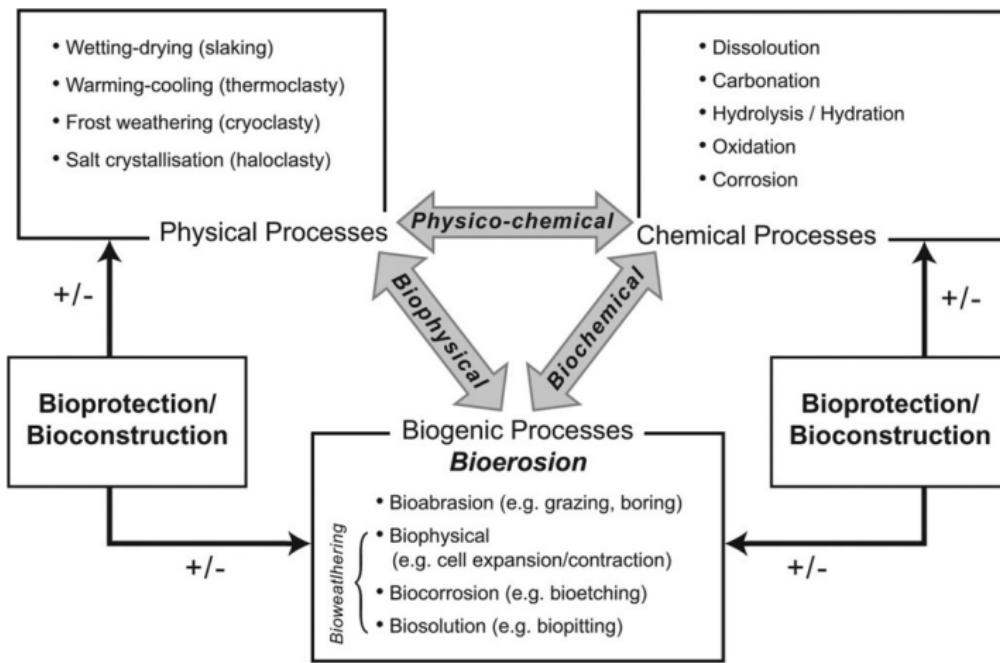


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Particles of parent material

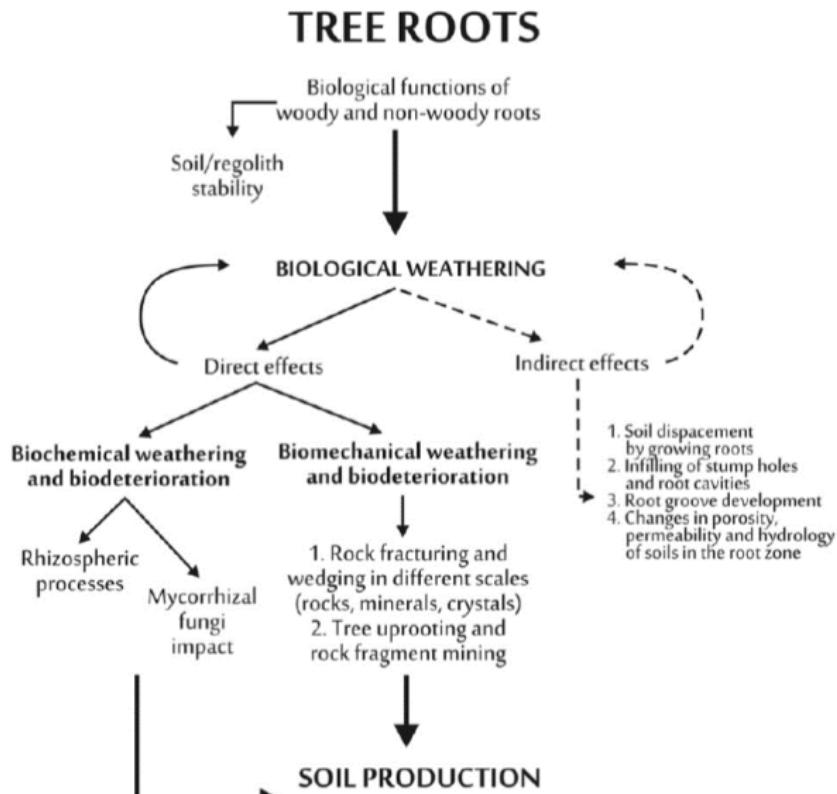
Fig. 15-6, p. 340

Meteorización Biológica



Fuente: Chapter 5 The rock coast of the British Isles: weathering and biogenic processes, Martin A. Coombes (2014)

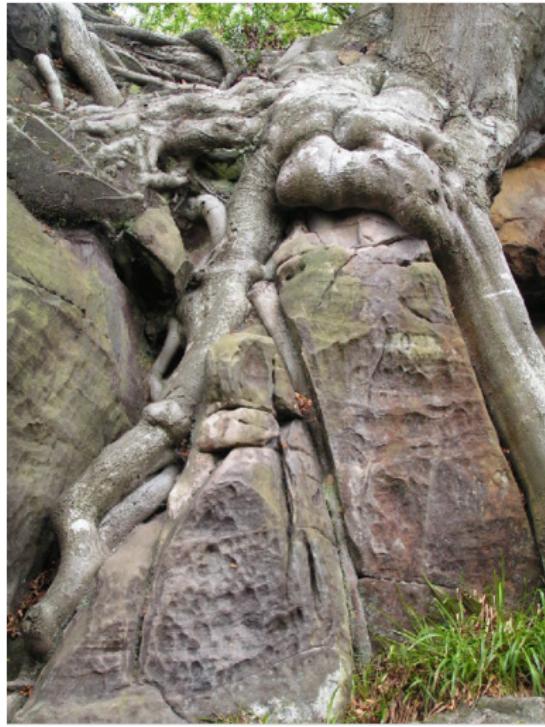
Meteorización Biológica



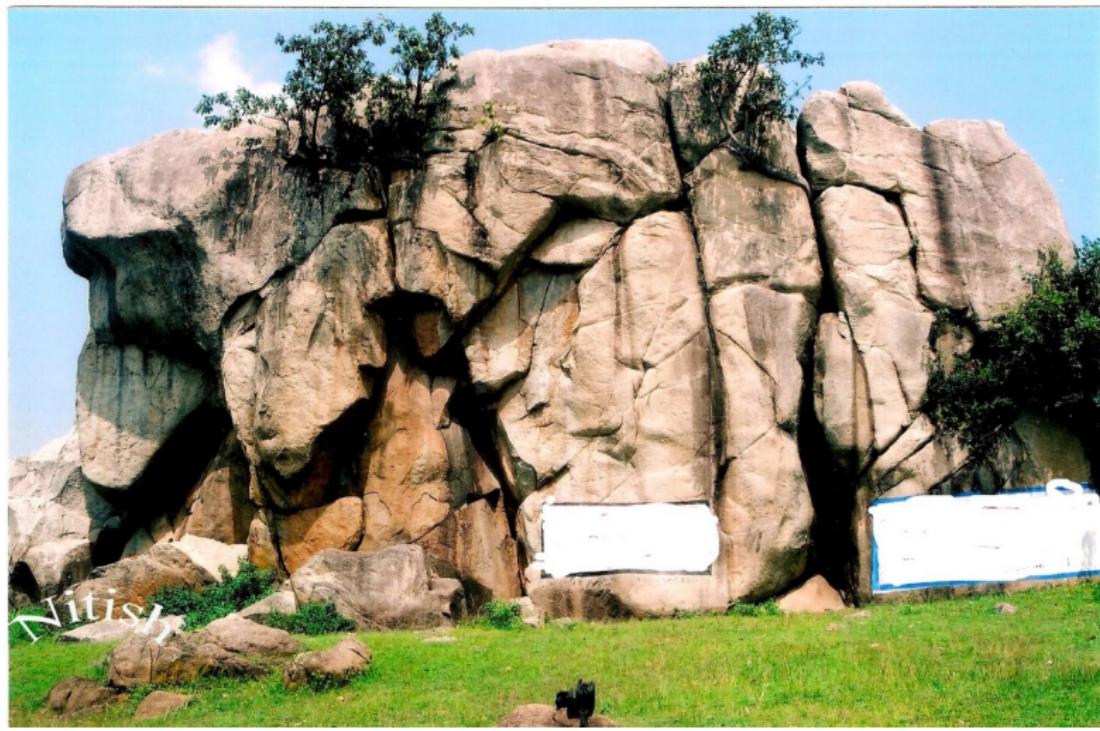
Meteorización Biológica



Meteorización Biológica



Meteorización Biológica

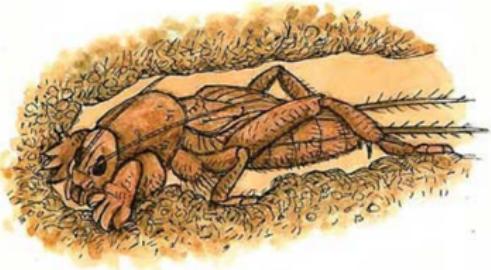
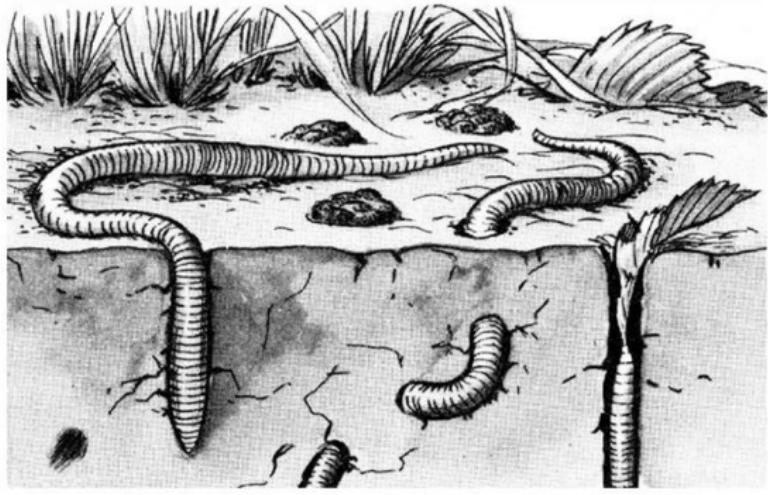


Meteorización Biológica



Figure: The ruins of Ta Prohm, one of the temples of Ankor Wat (Cambodia)

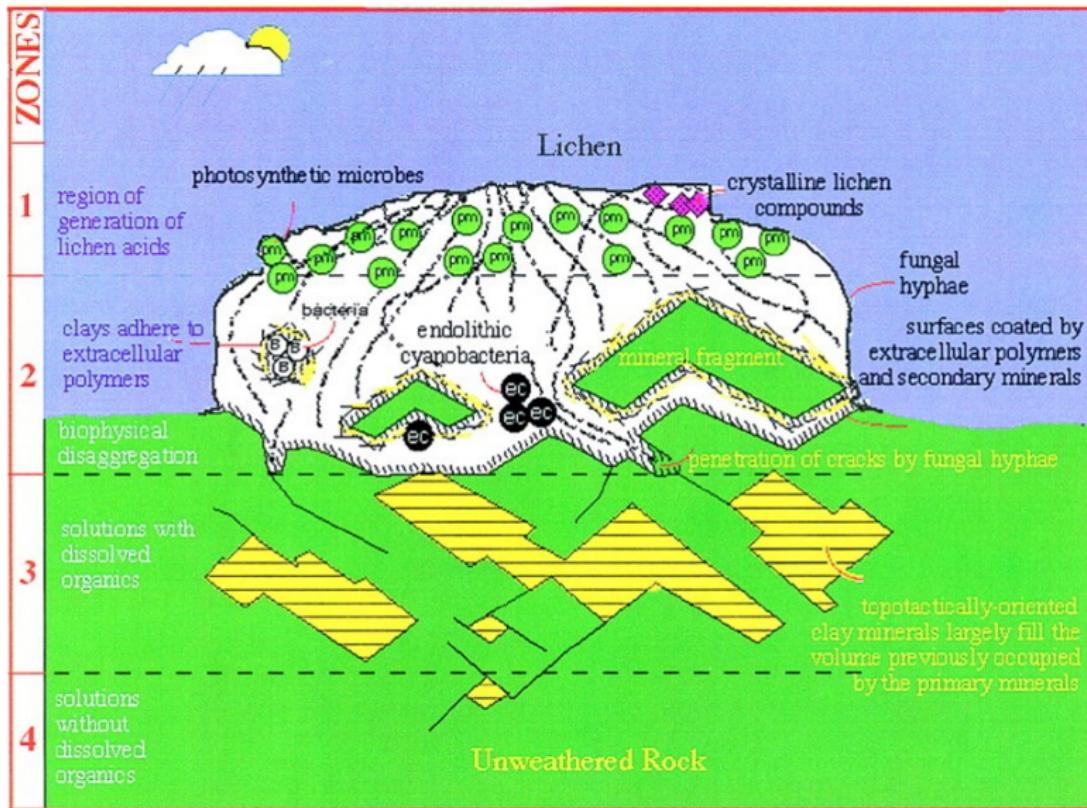
Boring



Animal Burrowing



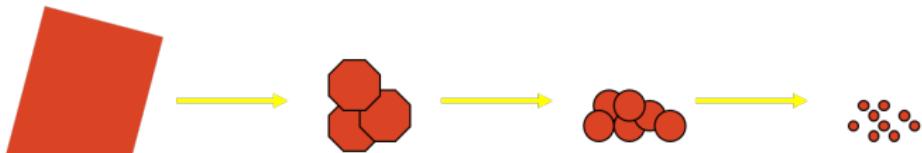
Líquenes



Líquenes



Meteorización Física



Mechanical Weathering

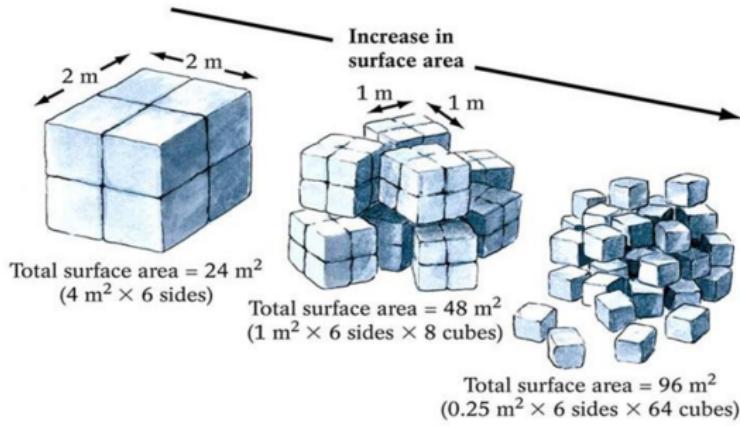
Processes:

1. Exfoliation
(horizontal fracturing due to release of pressure)
2. Freeze-thaw
(breakage as ice freezes in cracks)
3. Root wedging
(breakage as roots push into cracks)

Results:

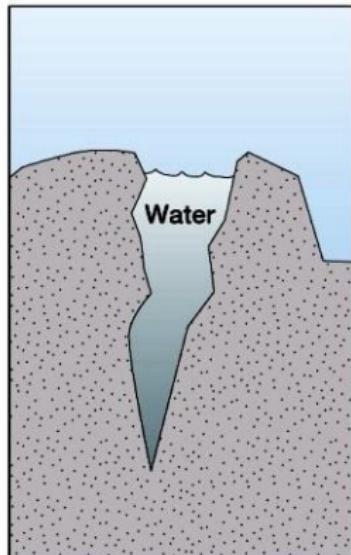
1. Smaller pieces of rock
2. Increased surface area
3. Conduits for water movement

These promote chemical weathering.

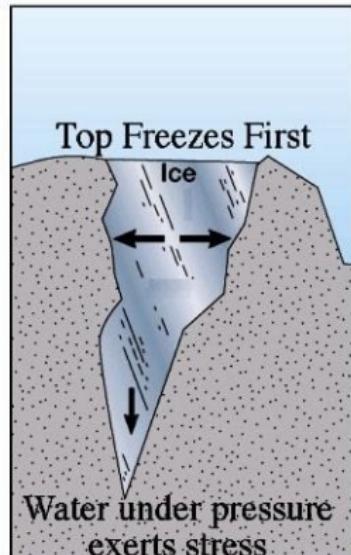


Meteorización Física

Frost Wedging



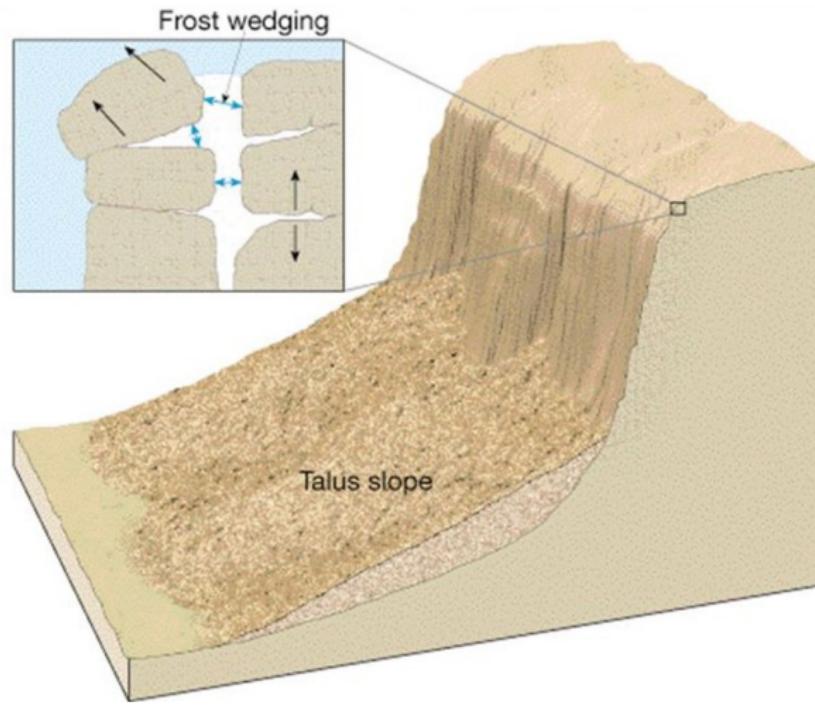
(a)



(b)

Meteorización Física

Frost Wedging



Meteorización Física

Frost Wedging



Meteorización Física

Frost Wedging



Meteorización Física

Expansión Térmica



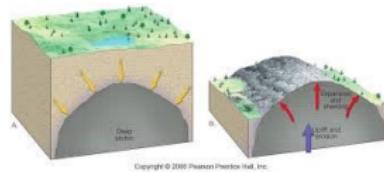
Meteorización Física

Expansión Térmica



Meteorización Física

Exfoliación

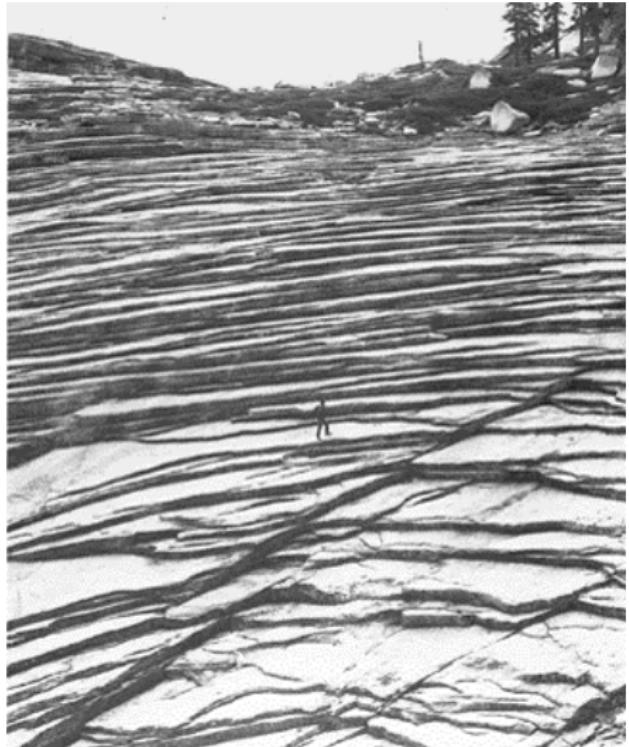


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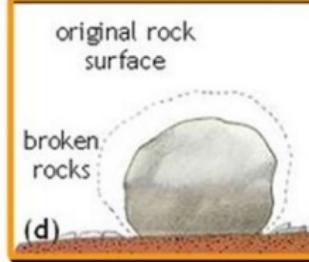
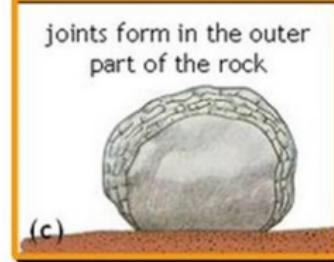
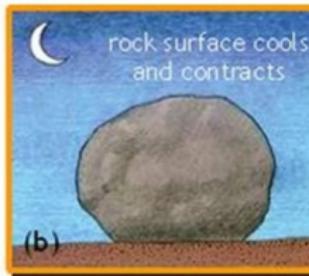
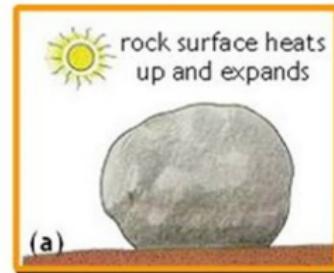
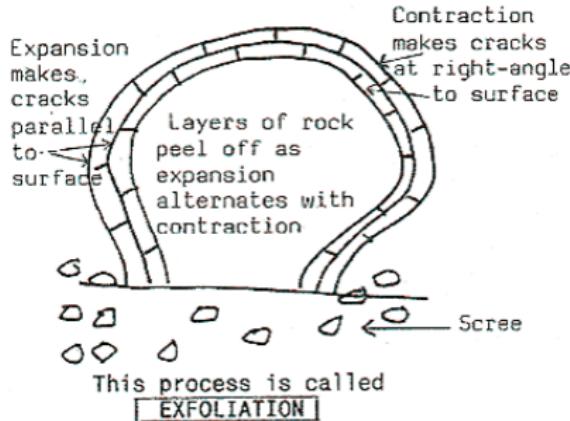
Meteorización Física

Exfoliación



Meteorización Física

"Cebolla de Huevo"



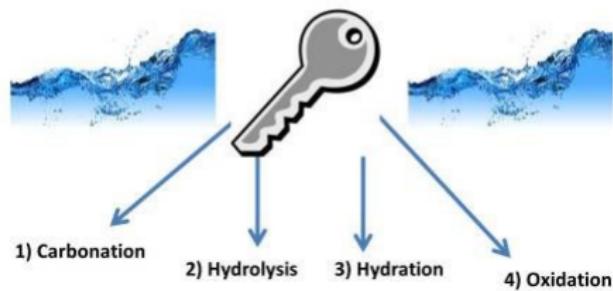
Meteorización Física

"Cebolla de Huevo"

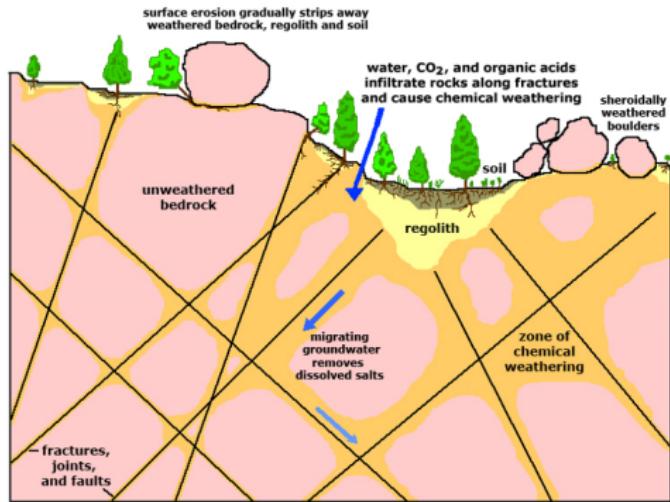


Meteorización Química

Water is the key to nearly all the 4 types of chemical weathering



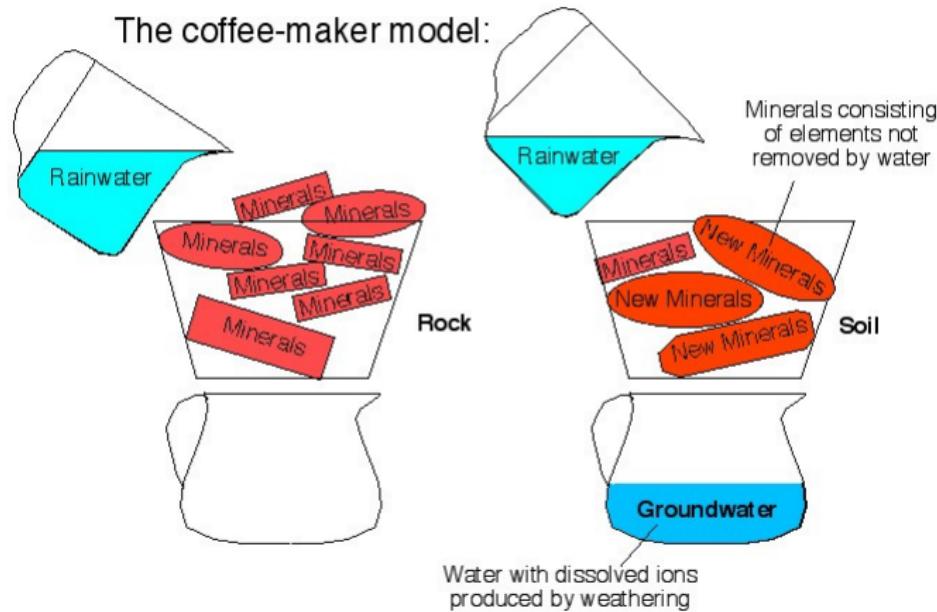
Meteorización Química



Meteorización Química

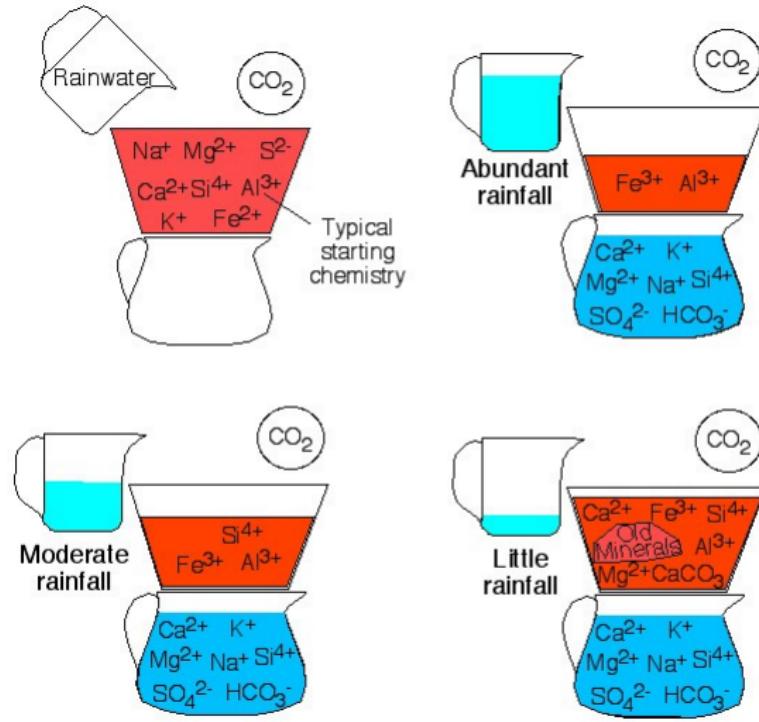
Chemical weathering -
Removal of chemical constituents from rock
Generation of new minerals

The coffee-maker model:



Meteorización Química

Condiciones Climáticas



Relative mobility of cations



An abridged Earth Scientist's Periodic Table of the Elements and their Ions											
H⁺ 1 Hydrogen ion	Li⁺ 3 Lithium	Be²⁺ 4 Beryllium	B³⁺ 5 Boron as borate (B(OH) ₃) or B(OH) ₄ ⁻	C⁴⁺ 6 Carbon as CO ₂ , bicarbonate (HCO ₃ ⁻), & carbonate (CO ₃ ²⁻)	N⁵⁺ 7 Nitrogen as nitrate (NO ₃ ⁻)	O²⁻ 8 Oxygen as in oxides	F⁻ 17 Fluorine as Fluoride				
Na⁺ 11 Sodium	Mg²⁺ 12 Magnesium	Al³⁺ 13 Aluminum	Si⁴⁺ 14 Silicon as silicate (SiO ₄ ⁴⁻)	P⁵⁺ 15 Phosphorus as phosphate (PO ₄ ³⁻)	S⁶⁺ 16 Sulfur as sulfate (SO ₄ ²⁻)	S²⁻ 16 Sulfur as sulfide	Cl⁻ 17 Chlorine as Chloride				
K⁺ 19 Potassium	Fe²⁺ 26 Ferrous Iron	Fe³⁺ 26 Ferric Iron (oxidized iron)	Ti⁴⁺ 22 Titanium	V⁵⁺ 23 Vanadium as Vanadate	Cr⁶⁺ 24 Chromium as Chromate (CrO ₄ ²⁻)						
Ca²⁺ 20 Calcium	Sc³⁺ 21 Scandium										
Rb⁺ 37 Rubidium	Sr²⁺ 38 Strontium	Y³⁺ 39 Yttrium	Zr⁴⁺ 40 Zirconium	Nb⁵⁺ 41 Niobium	Mo⁶⁺ 42 Molybdenum e.g., as molybdate						

Most abundant elements in Earth's crust are shown with large chemical symbols.

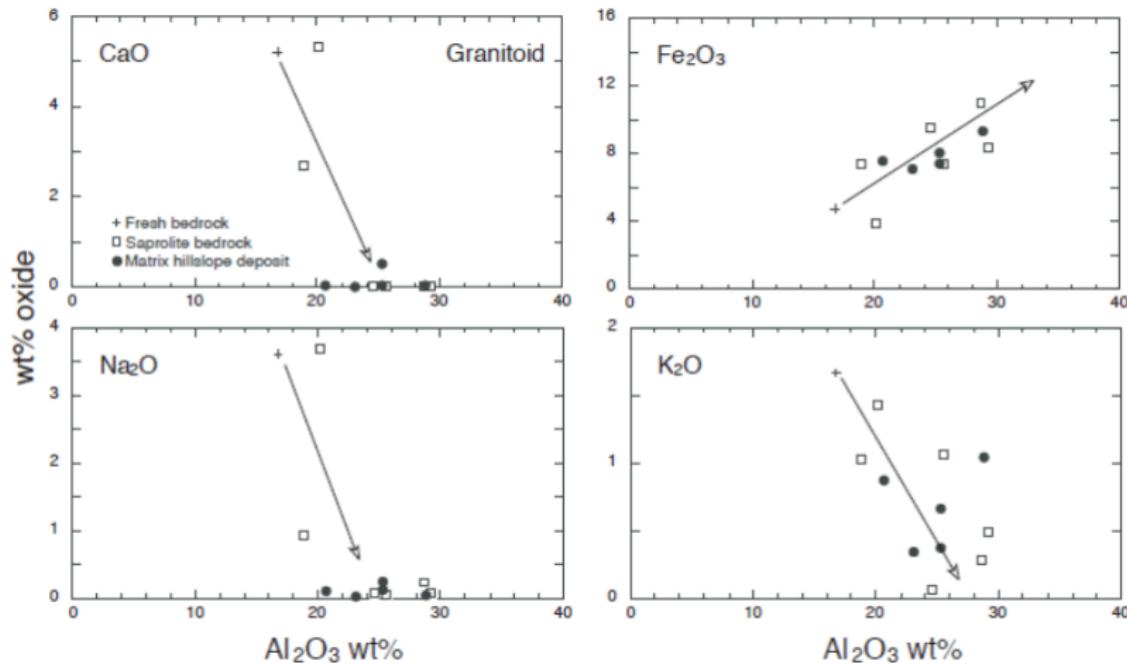
LBR 3/2002 rev. 11/2003

Ions that tend to remain in soils during weathering

Ions commonly leached and carried away by groundwater

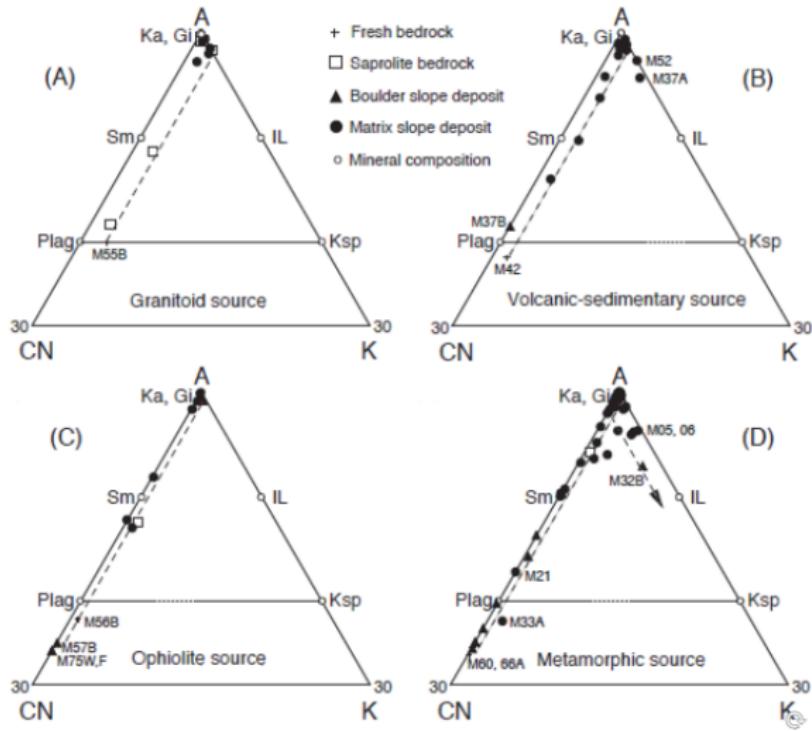


Tren de Meteorización



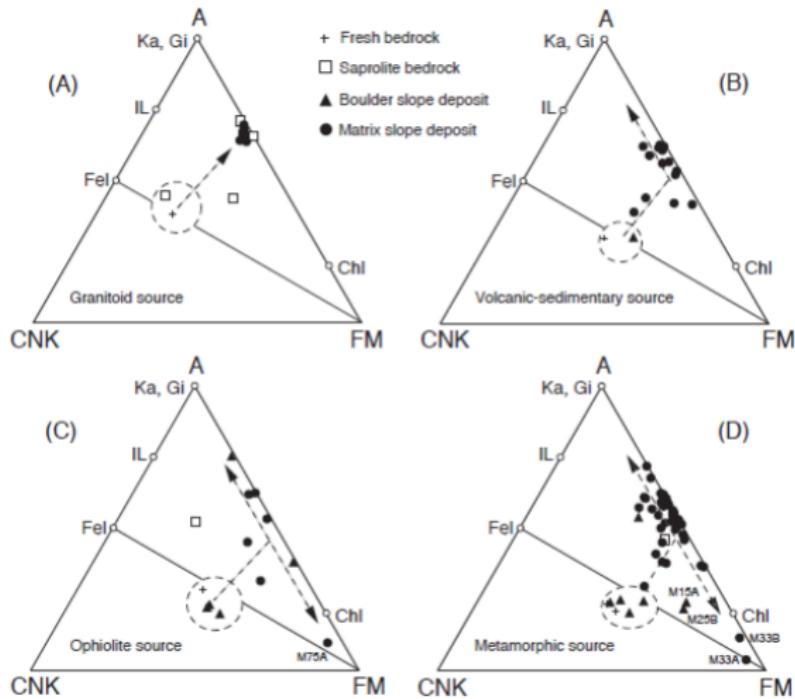
Fuente: Aristizábal et al (2005)

Tren de Meteorización



Fuente: Aristizábal et al (2005)

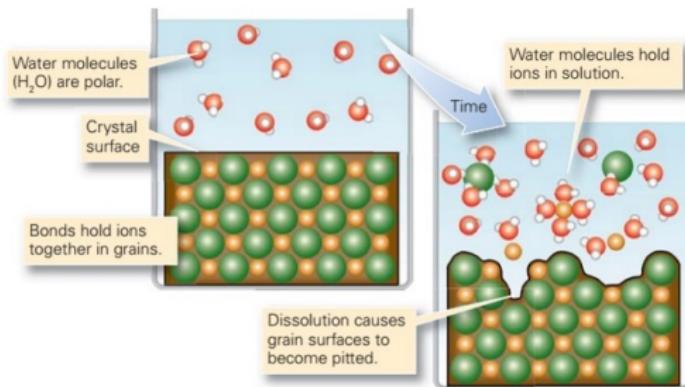
Tren de Meteorización



Fuente: Aristizábal et al (2005)

Meteorización Química

Disolución



(a) Dissolution occurs when water molecules pluck ions off of grain surfaces.



Water seeping into joints in limestone produced troughs.

(b) Dissolution along joints in Ireland.

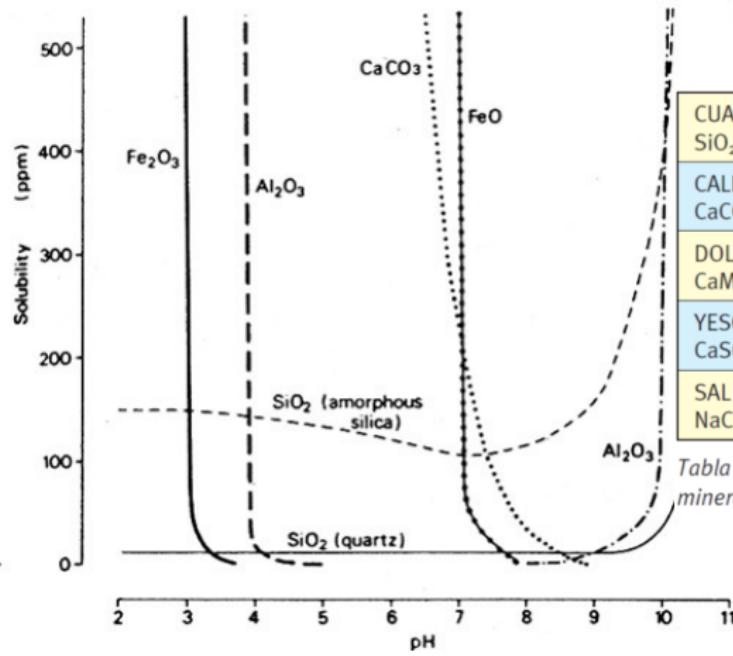
Meteorización Química

Ambiente Cárstico



Figure: Cavernas del Drach (España)

Meteorización Química en solución



CUARCITAS Cuarzo (sílice-amorfo)	Sol. (mg/L)
$\text{SiO}_2 + 2\text{H}_2\text{O} == \text{Si}(\text{OH})_4$	12-120
CALIZAS Calcita ($\text{PCO}_2 = 10^{-3}, 10^{-1}$ atm)	100-500
$\text{CaCO}_3 == \text{Ca}^{2+} + \text{CO}_3^{2-}$	
DOLOMÍAS Dolomita ($\text{PCO}_2 = idem$)	90-480
$\text{CaMg}(\text{CO}_3)_2 == \text{Ca}^{2+} + \text{Mg}^{2+} + 2\text{CO}_3^{2-}$	
YESOS Yeso	2400
$\text{CaSO}_4 \cdot 2\text{H}_2\text{O} == \text{Ca}^{2+} + \text{SO}_4^{2-} + 2\text{H}_2\text{O}$	
SAL GEMA Halita	360000
$\text{NaCl} == \text{Na}^+ + \text{Cl}^-$	

Tabla I. Algunas reacciones de solubilización de distintos minerales formadores de rocas.

Meteorización Química

Ambiente Cárstico



Figure: Cavernas de Tepuy (Venezuela) karstificación en cuarcitas

Pseudocarst

El término **flysch** define una alternancia de estratos duros (de caliza o arenisca) con otros blandos (de lutitas y margas), formados en ambientes turbidíticos.



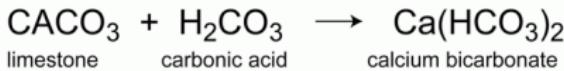
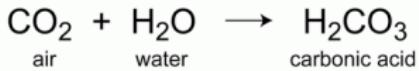
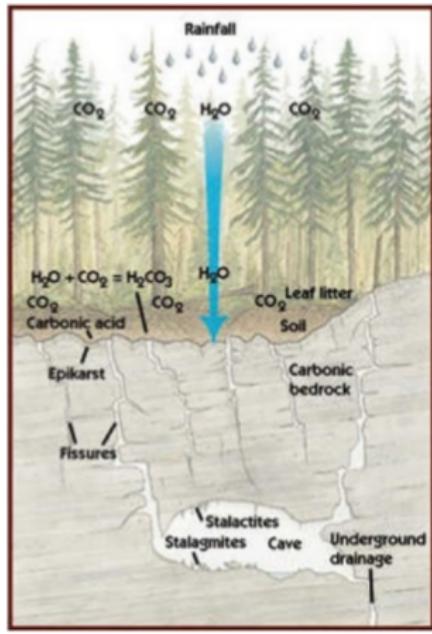
Pseudocarst



Figure: Cavidades en rocas volcánicas Isla El Hierro (España)

Ambiente Cárstico

Carbonatación



Ambiente Cárstico

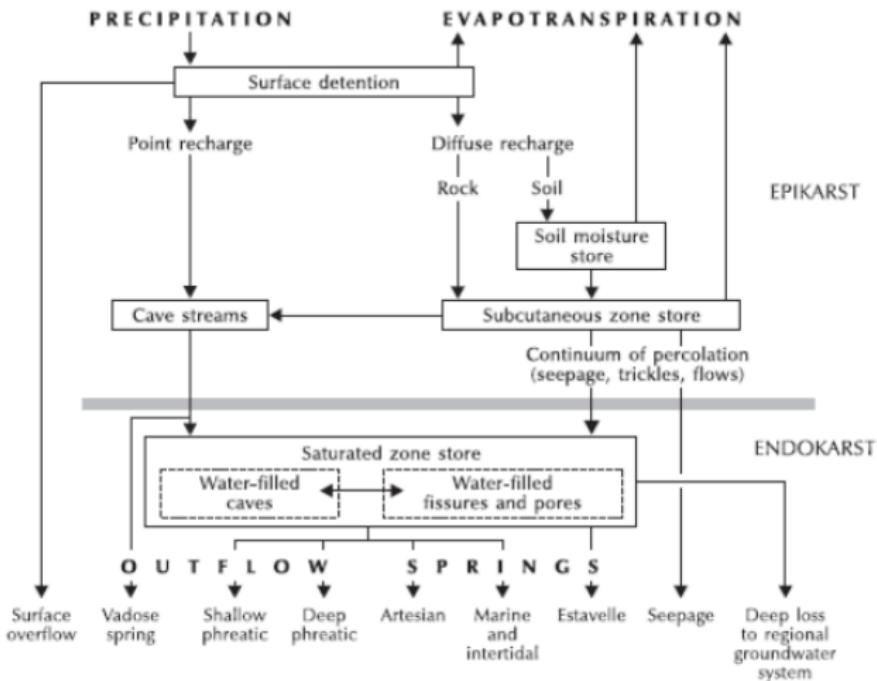
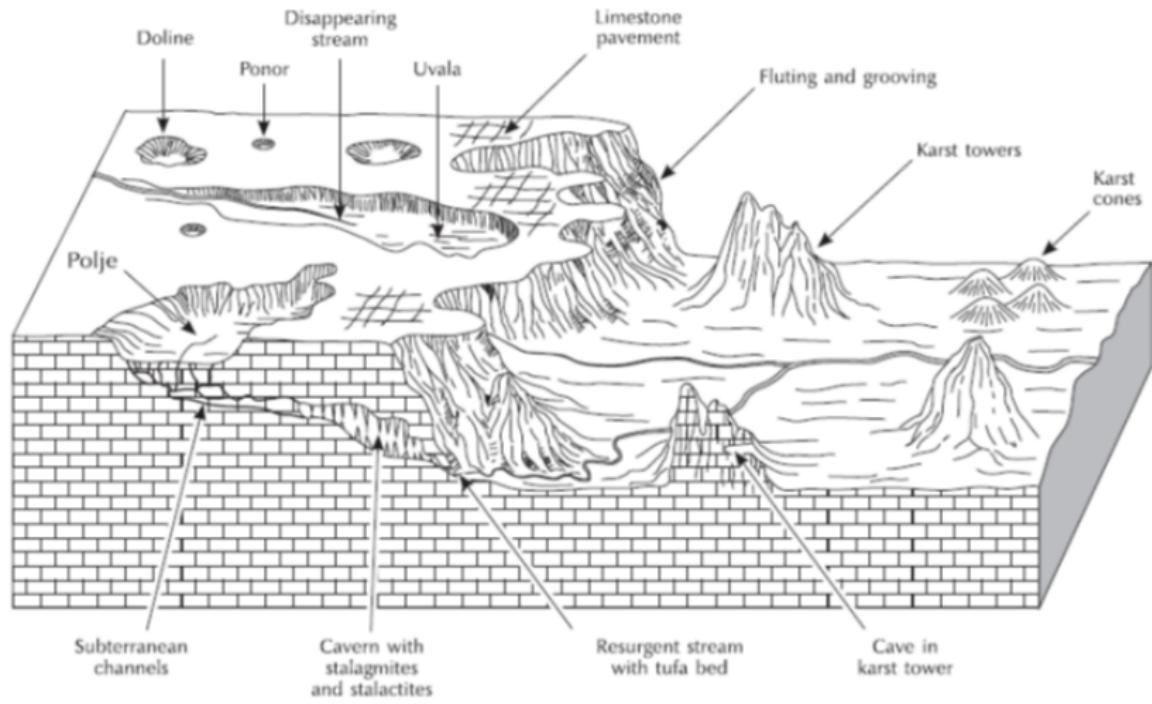


Figure 8.4 The karst drainage system: storages and flows.

Source: Adapted from Ford and Williams (1989, 169)

Geoformas Cársticas



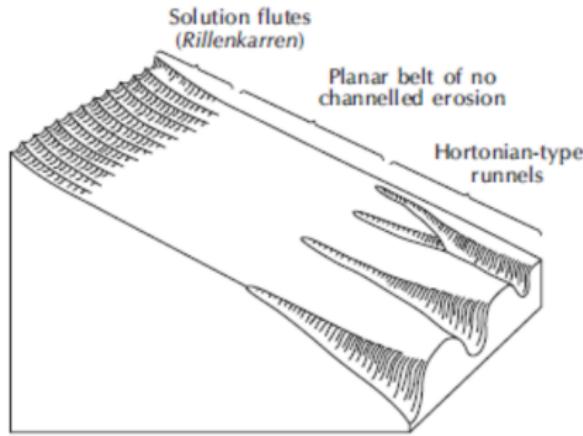
Pavimento Cárstico



Karren (Lapiaz)



Rillenkarren



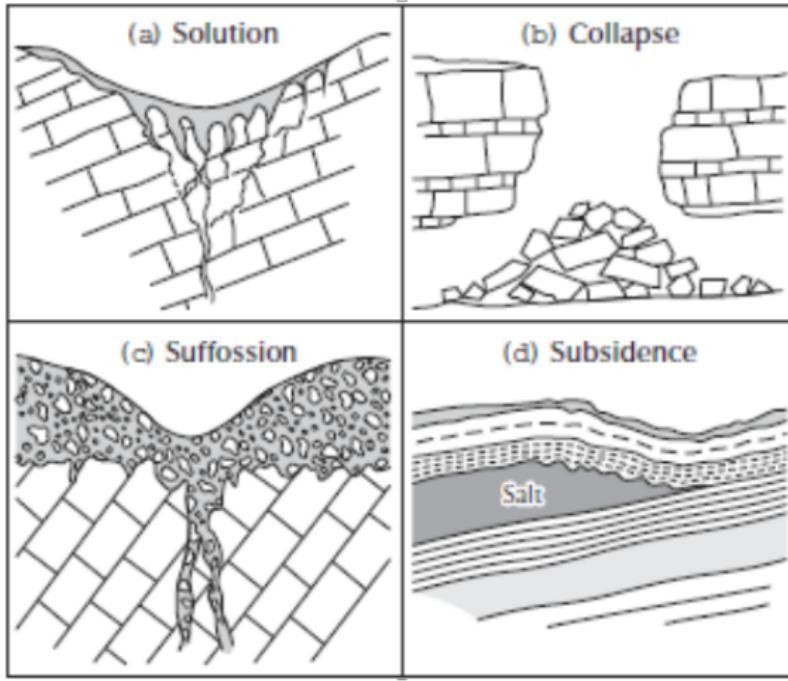
Dolinas



Dolinas



Origen de Dolinas



Uvalas

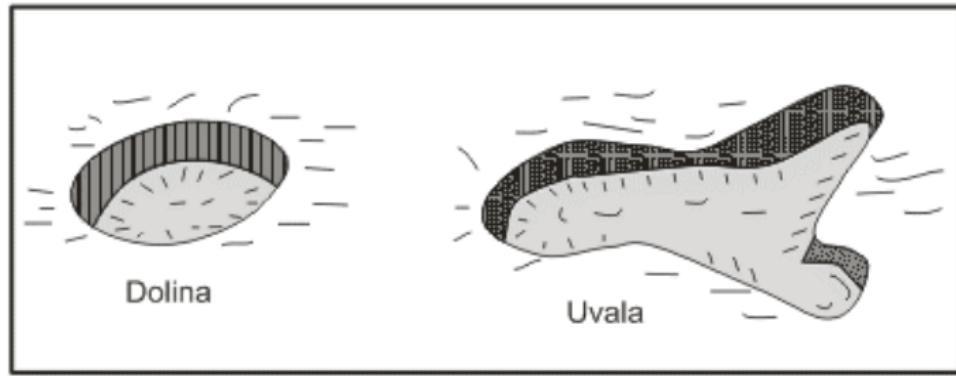


Fig. 2.55 - Características gerais das dolinas e uvalas.

Uvalas

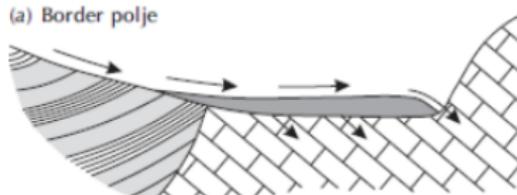


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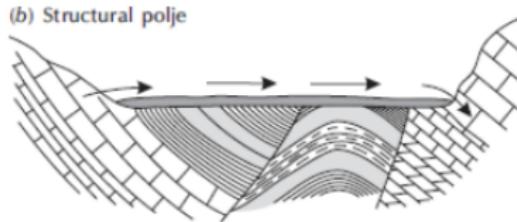
Polje

Depresión cerrada alongada con piso plano

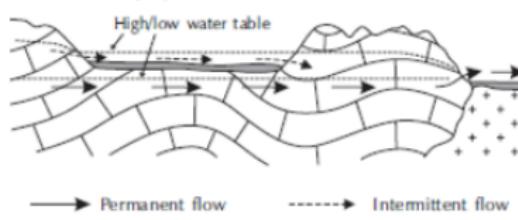
(a) Border polje



(b) Structural polje



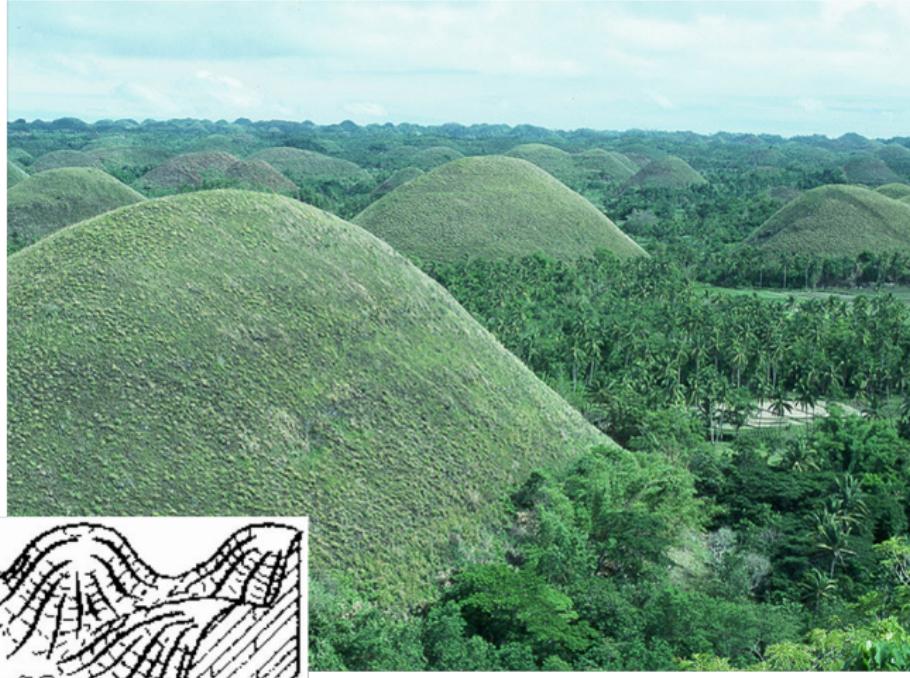
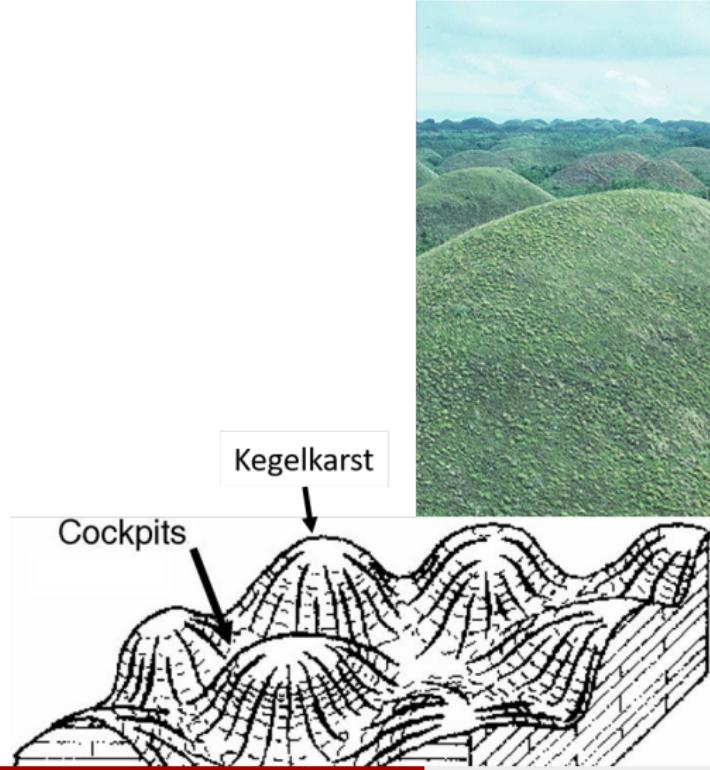
(c) Baselevel polje



Polje



Conos (Kegelkarst)



Conos (Kegelkarst)

Tower karst (Turmkarst)

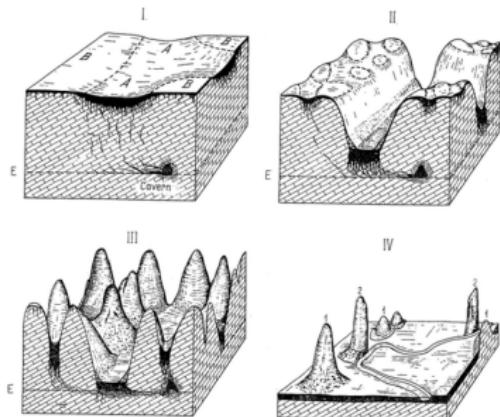


Fig. 45. Four-phase genetic pattern of the erosion of karst surfaces in the tropics

Phase I: Soil and related waste is removed from the hummocks and deposited in the depressions of a pre-karst surface, resulting in more intense karstification in the areas marked A as compared to the areas marked B (E represents the baselevel of erosion)

Phase II: Intense karst corrosion under the soil cover in the A-areas causes the karst surface to be lowered increasingly faster than under the B-areas; the B-areas become progressively dissimilar to the A-areas too, owing to cumulative effects (e.g. to sub-area erosion, the focal point of our considerations)

Phase III: Phase of evolution of the tropical cone karst. The B-areas themselves are so reduced in size that they are divided into peaks and ridges where the rate of vertical erosion is low, as any soil formed is soon swept off the steep hillsides. The karst cones thus evolves as a permanent form of the tropical karst, whose base, placed where soil may accumulate, can erode ten times faster at its summit

Phase IV: Lateral erosion and corrosion of the rivers forming in the A-areas at the baselevel of erosion develop the karst cones into karst towers by undercutting. In the process the formerly underground streams develop surface beds in the A-areas and these latter are widened into intermontane plains, while the ground plans of the karst inselbergs left over from the former B-areas are gradually reduced (1 - cones karst; 2 - tower karst)



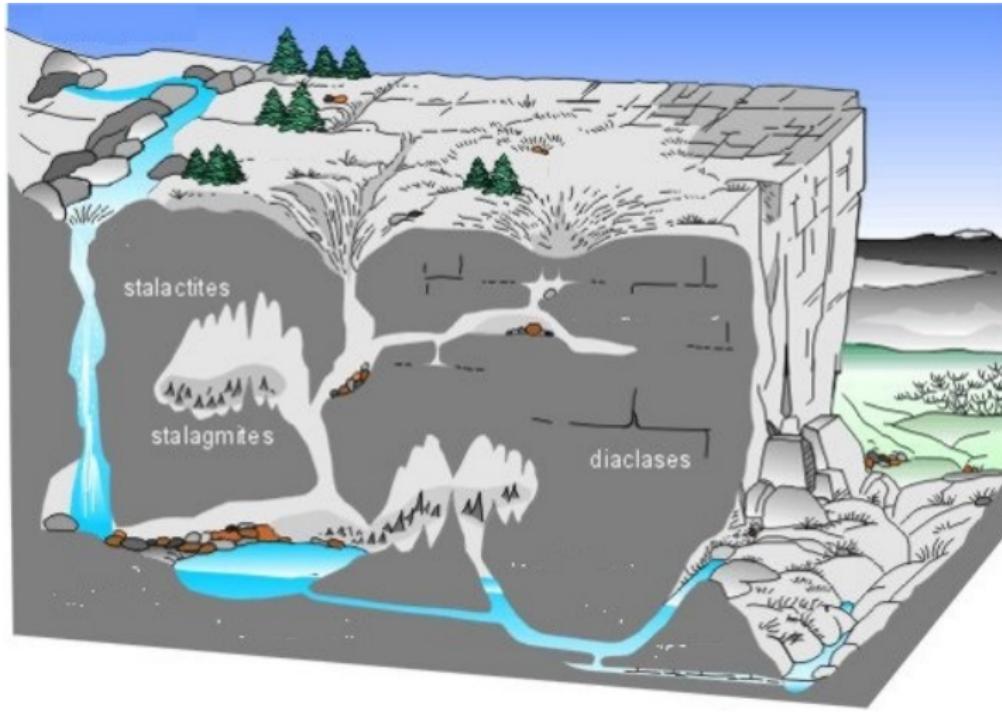
Conos (Kegelcarst)

Pinnacle

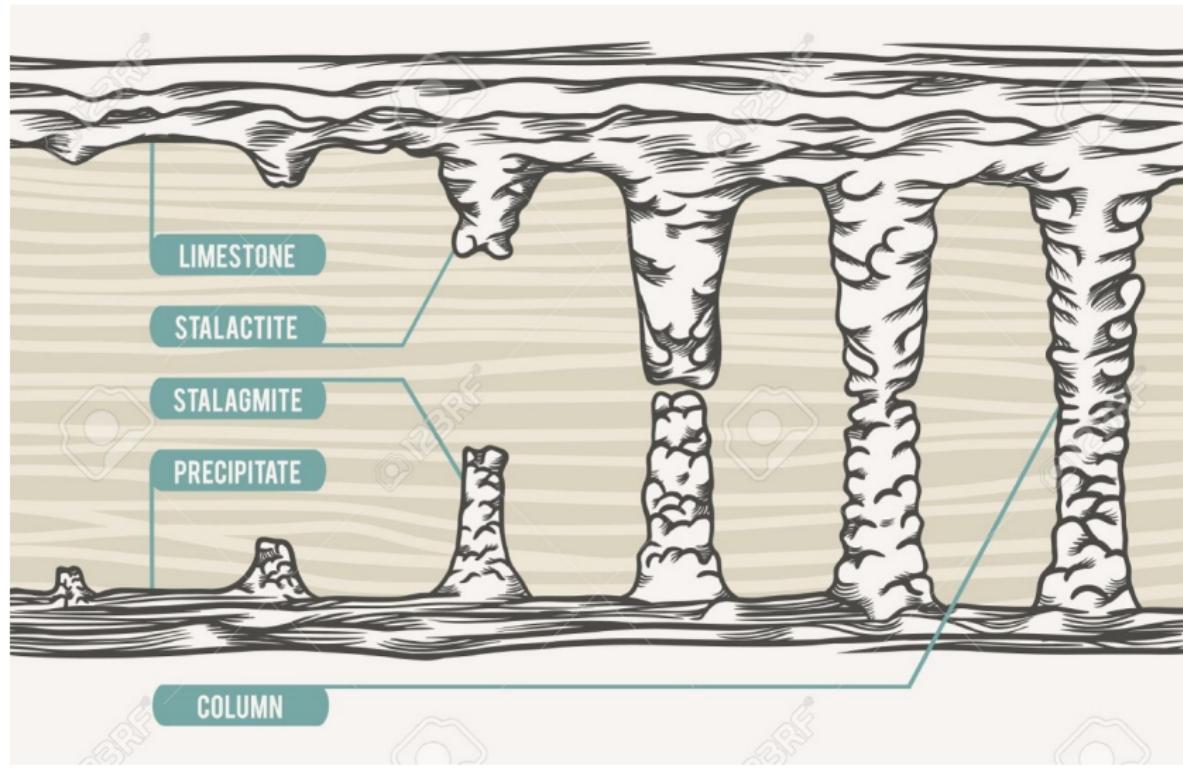


Endocarst

Espeleotemas



Espeleotemas



Espeleotemas



Estalactita



Estalagmita



Columna

Espeleotemas



Espeleotemas



Espeleotemas

Gour dique que forma represamientos escalonados



Moonmilk

materiales carbonatados, como calcita, hidromagnesita, y monohidrocalcita

Helictitas crecen en cualquier dirección por capilaridad



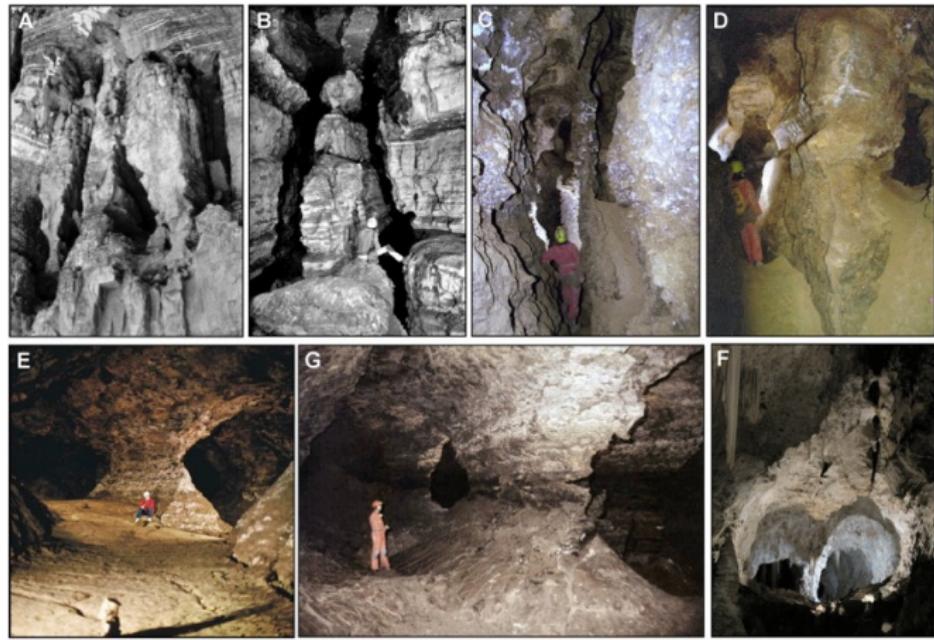
Estalactita tipo bandera, el agua no circula por el interior de las mismas, sino por el exterior



Frostwork: espeleotema acicular de aragonito

Carst Hipogénico

Se forma por la liberación y ascenso de fluidos profundos o gases corrosivos capaces de generar karstificación y espeleogenesis.



Gnamas



Gnamas



Meteorización Química

Hidratación - Hidrólisis

Chemical Weathering: Hydration/Hydrolysis

- Chemical reaction with water contact
 - Hydration
 - Water molecules are added to the composition of the material causing expansion and weakness that leads to breakage
 - Hydrolysis
 - Water dissolves and leaches out material that comes to the surface, turns to powder, and rubs off

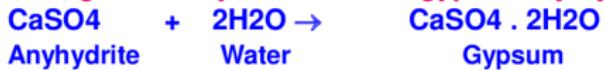


Meteorización Química

Hidratación - Hidrólisis

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

CaSO_4 or anhydrite, gets slowly converted to gypsum by hydration :

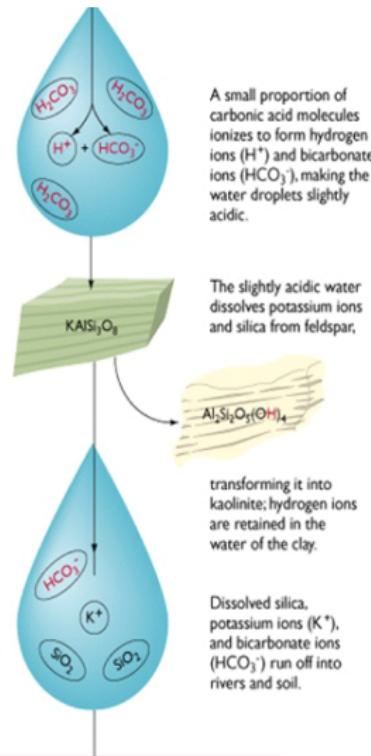


- Hydrolysis: the process of exchange of ions.
 - combination of hydrogen and oxygen in water with rock to form new substances



Meteorización Química

Hidrólisis



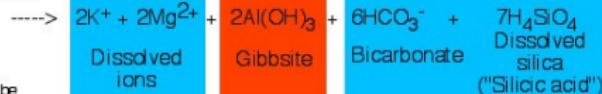
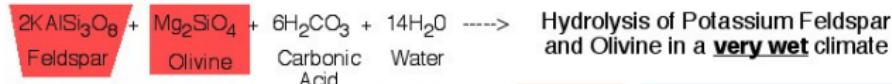
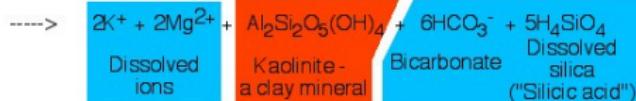
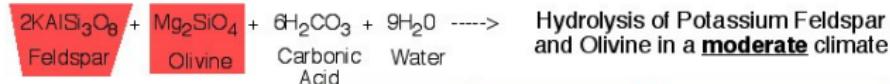
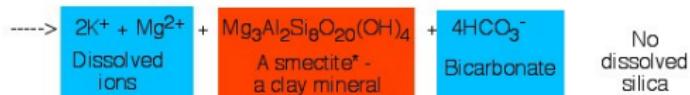
Meteorización Química

Hidrólisis



Meteorización Química

Hidrólisis



*Clay mineralogists: This "smectite" would be something like a dehydrated weird beidellite. Leave me alone - this is for introductory students in a general class!

LBR 3/2002

Meteorización Química

Oxidación

An abridged Earth Scientist's Periodic Table of the Elements and their Ions											
H^+ 1 Hydrogen ion	Li ⁺ 3 Lithium	Be ²⁺ 4 Beryllium	B ³⁺ 5 Boron as borate ($B(OH)_3$ or $B(OH)_4^-$)	C ⁴⁺ 6 Carbon as CO_2 , bicarbonate (HCO_3^-) & carbonate (CO_3^{2-})	N ⁵⁺ 7 Nitrogen as nitrate (NO_3^-)	C ⁴⁺ 6 Carbon as, e.g., in methane (CH_4)	N ³⁻ 7 Nitrogen as, e.g., in ammonia (NH_3)	O ²⁻ 8 Oxygen as in oxides & water (H_2O or OH^-)	F ⁻ 17 Fluorine as Fluoride		
Na ⁺ 11 Sodium	Mg ²⁺ 12 Magnesium	Al ³⁺ 13 Aluminum	Si ⁴⁺ 14 Silicon as silicate (SiO_4^{4-})	P ⁵⁺ 15 Phosphorus as phosphate (PO_4^{3-})	S ⁶⁺ 16 Sulfur as sulfate (SO_4^{2-})			S ²⁻ 16 Sulfur as sulfide (as in H_2S)	Cl ⁻ 17 Chlorine as Chloride		
K ⁺ 19 Potassium	Fe ²⁺ 26 Ferrous Iron	Fe ³⁺ 26 Ferric Iron (oxidized Iron)	Ti ⁴⁺ 22 Titanium	V ⁵⁺ 23 Vanadium as Vanadate	Cr ⁶⁺ 24 Chromium as Chromate (CrO_4^{2-})						
Rb ⁺ 37 Rubidium	Sr ²⁺ 38 Strontium	Y ³⁺ 39 Yttrium	Zr ⁴⁺ 40 Zirconium	Nb ⁵⁺ 41 Niobium	Mo ⁶⁺ 42 Molybdenum e.g., as molybdate						

Most abundant elements in Earth's crust are shown with large chemical symbols.

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Oxidation

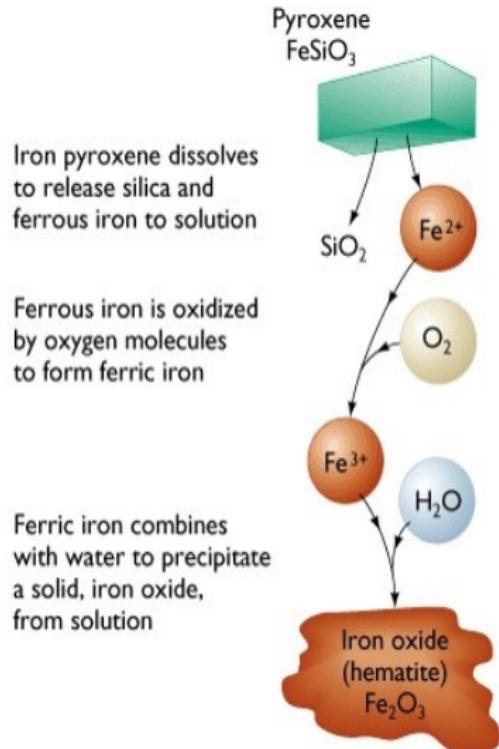
(an increase in charge as electrons are removed, typically to reduce the charge on Oxygen from 0 to -2)

Reduction

(a decrease in charge as electrons are added)

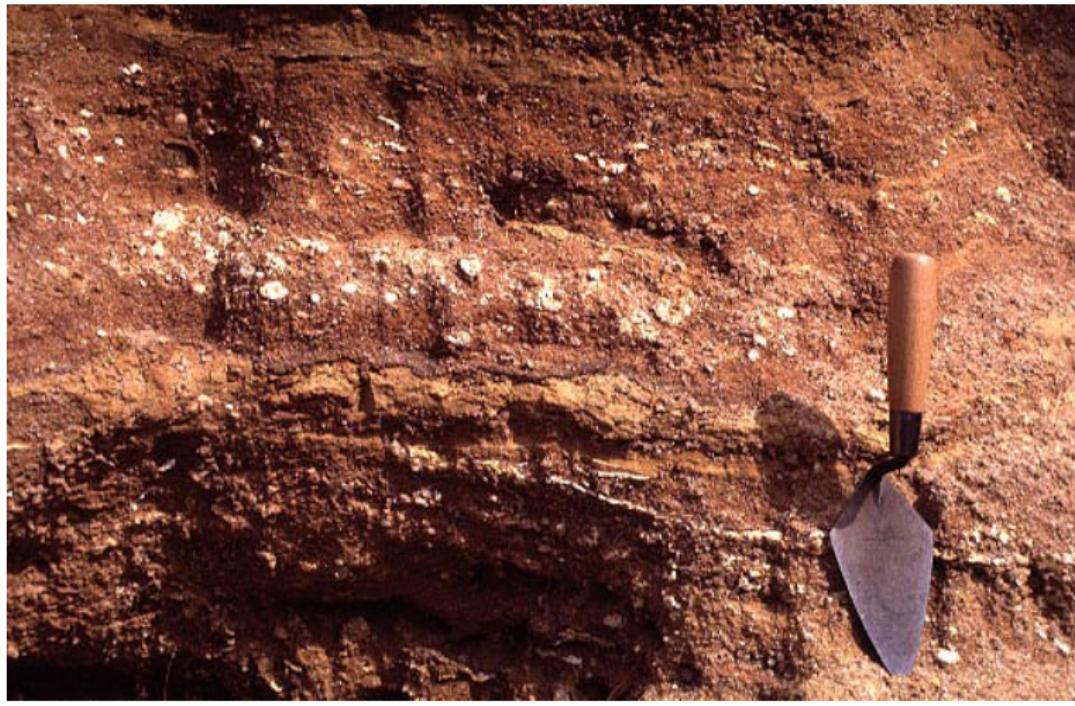
Meteorización Química

Oxidación



Meteorización Química

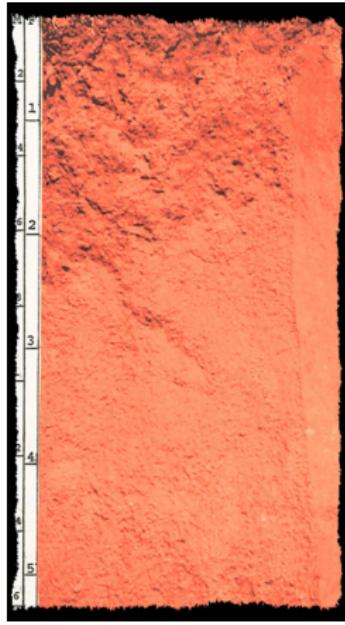
Oxidación



Meteorización Química

Oxisoles

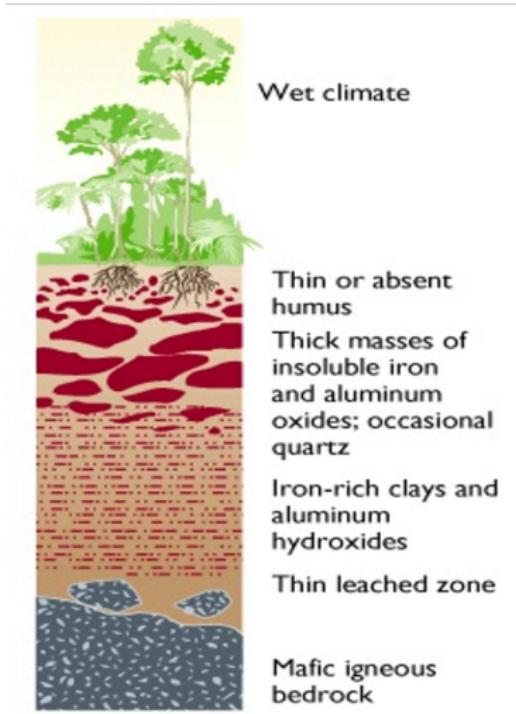
Suelos con intensa lixiviación y oxidación ricos en suelos residuales con hierro



Meteorización Química

Oxisoles

Oxisuelos muy desarrollados, se forman en ambientes húmedos y tropicales



Meteorización Química

Duricrust

Capas duras formadas por la concentración de componentes específicos durante la meteorización

Mecanismo de formación

Lixiviación

- ✓ Ferricrete: Fe duricrust
- ✓ Alcrete: Al duricrusts

Acumulación

Silcrete: silica

Calcrete: Ca duricrust

Gypcrete: gypsum

