

Soils



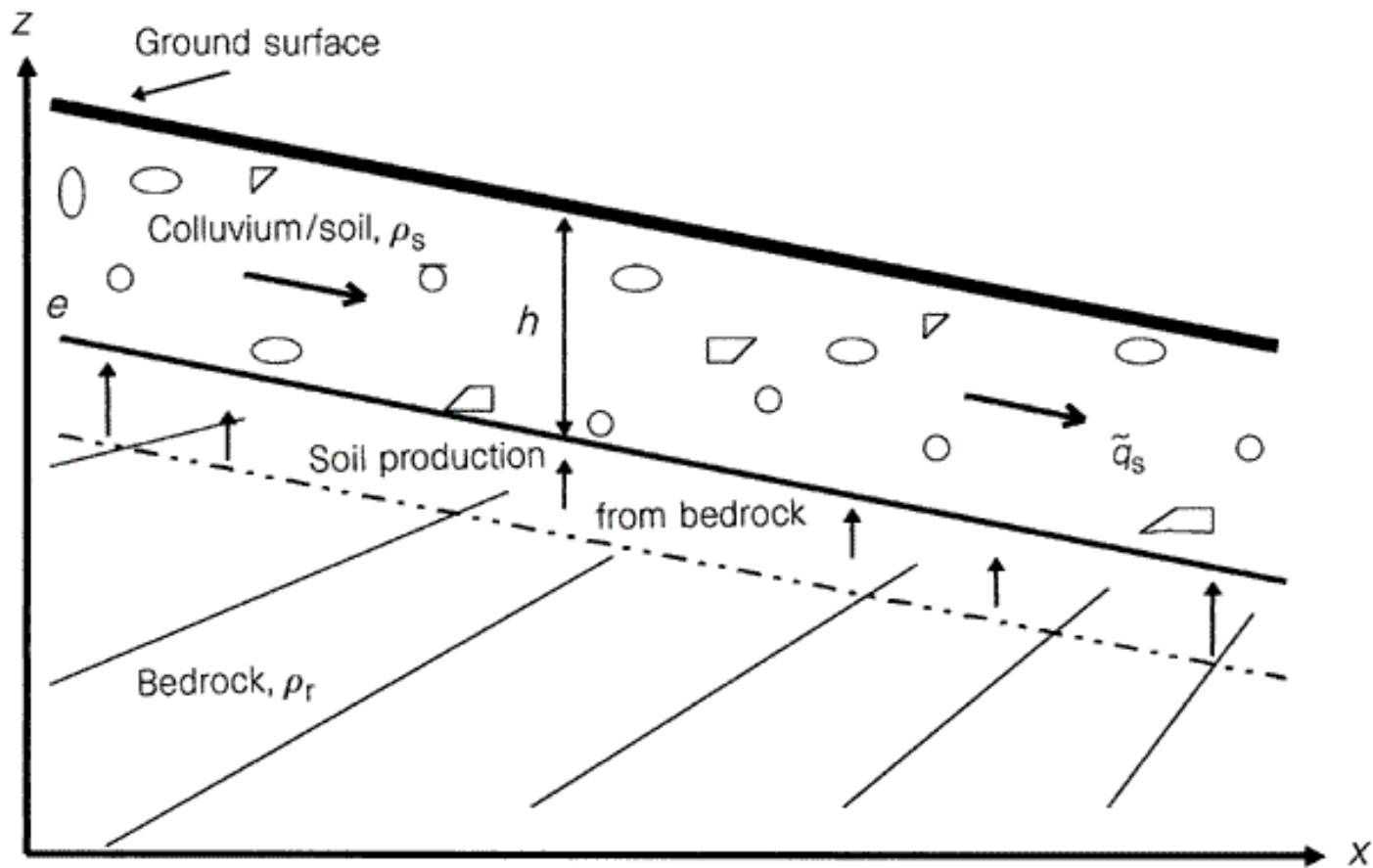
*We know more about the movement of
celestial bodies than about the soil underfoot.*

- Leonardo da Vinci

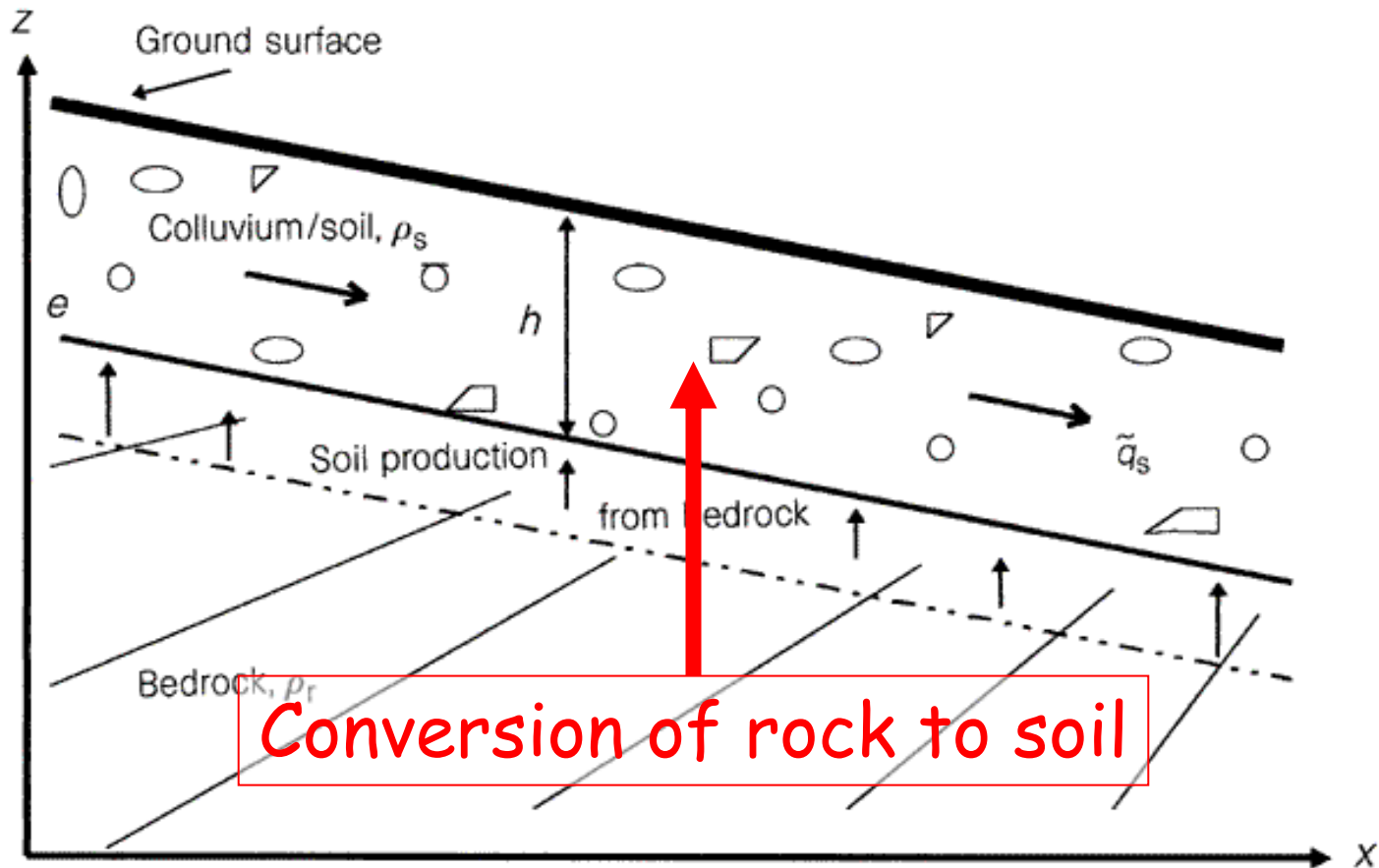
Soil: Definition

- Solid earth material that has been altered by physical, chemical and organic processes so that it can support rooted plant life.
- Engineering definition: Anything that can be removed without blasting

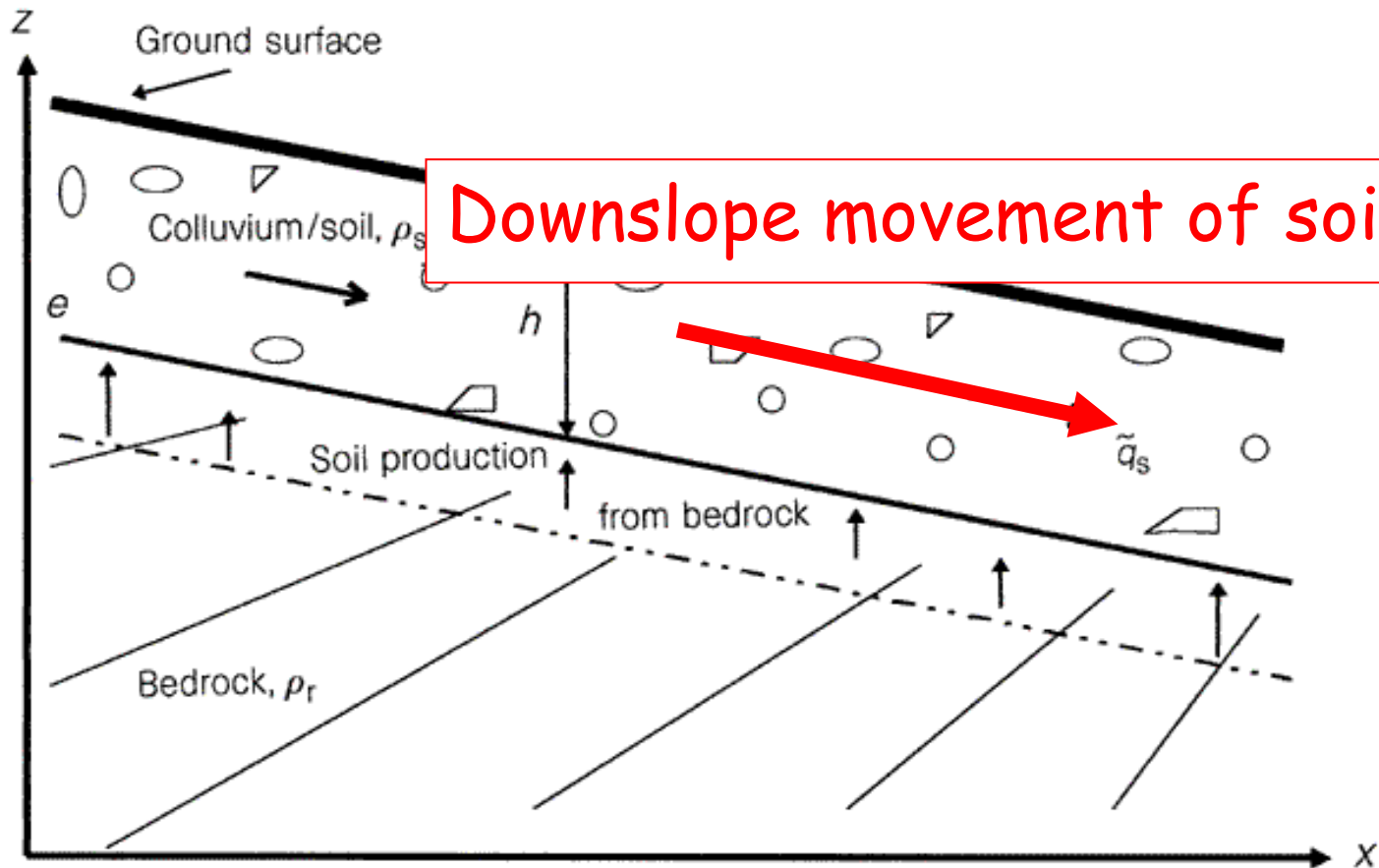
Soil Production



Soil Production: Inputs



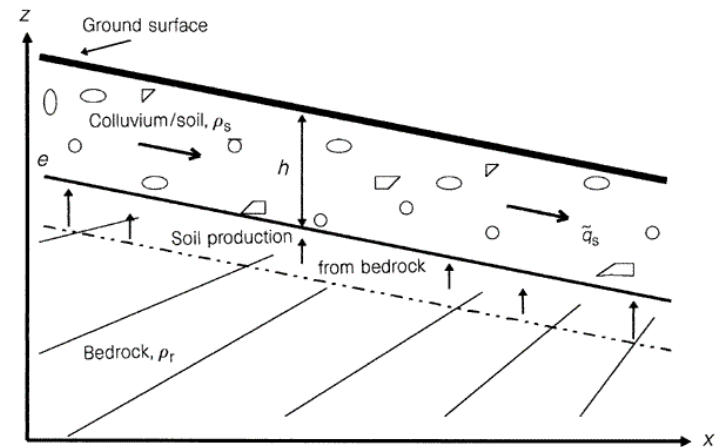
Soil Production: Outputs



Soil Thickness: Storage

Soil thickness reflects the balance between rates of soil production and rates of downslope soil movement.

- Slope
- Weathering Rate



Factors of Soil Formation

- Climate
- Organisms
- Parental Material
- Topography
- Time

Factors of Soil Formation

Climate

- Temperature and precipitation
- Indirect controls (e.g., types of plants)
- Weathering rates

The greater the rainfall amount, the more rapid the rate of both weathering and erosion.

Factors of Soil Formation

Organisms

- Types of native vegetation
- Weathering is dependent of plant growth
- Plant and animal activity produces humic acids that are powerful weathering agents.
- Plants can physically as well as chemically break down rocks.
- Plants stabilize soil profiles, Animals (including humans) tend to increase erosion.

Factors of Soil Formation

Parent Material:

- Chemistry
- Mineralogy
- Grain size

Factors of Soil Formation

Topography:

- Ground slope
- Elevation
- Aspect (e.g., north facing vs. south facing slopes)

Factors of Soil Formation

Downslope transport of soil is a function of slope:

- Erosion rate = $f(S)$

The steeper the surface slope, the more likely any eroded material is to be transported out of the system.

Factors of Soil Formation

Soils on hillslopes reach an equilibrium thickness, often about 1 m.

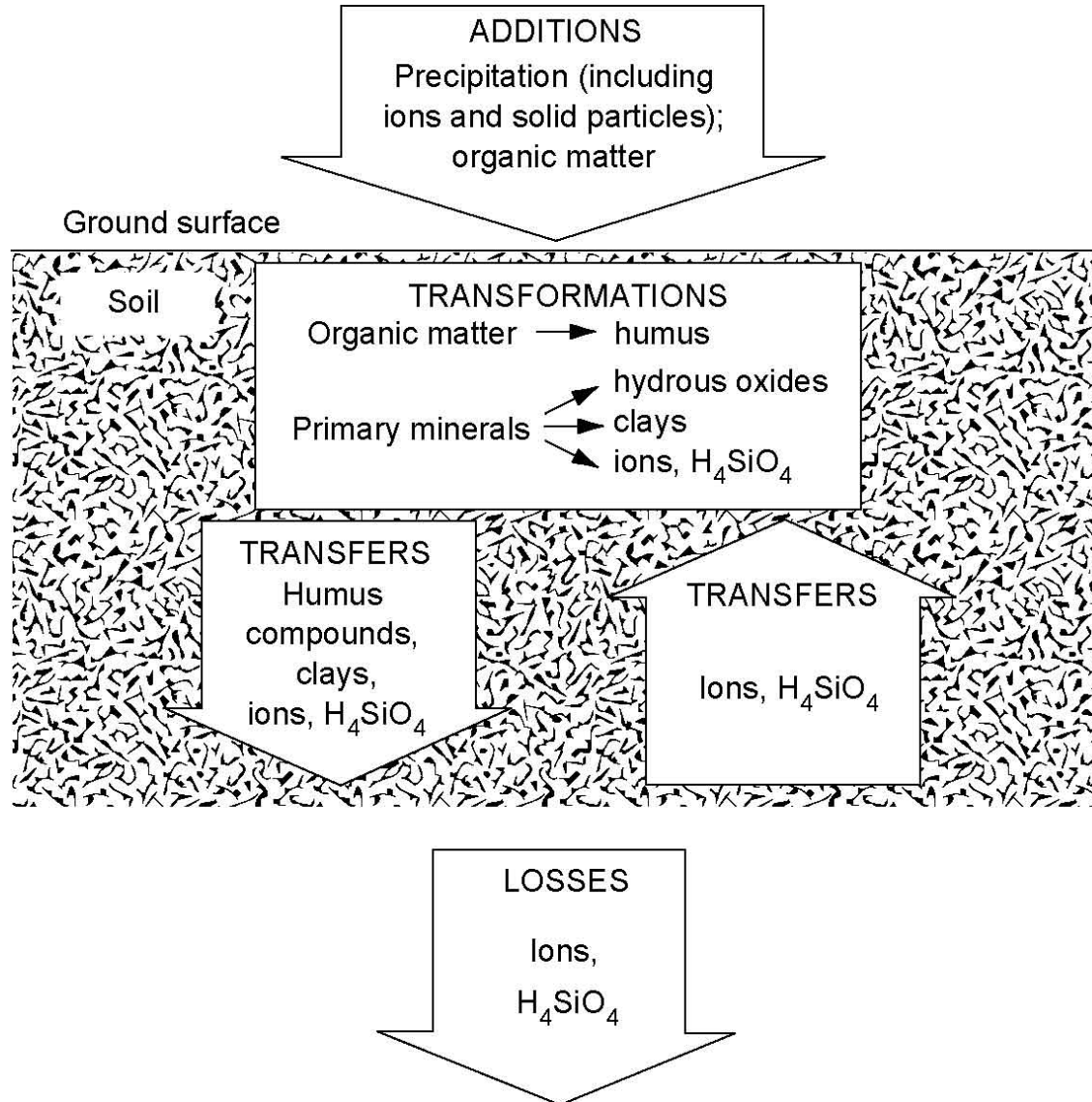
Soils on flat surfaces, such as floodplains or plateaus, tend to thicken through time due to weathering rates being greater than sediment transport rates.

Factors of Soil Formation

Time

- Development and destruction of soil profiles
- Typical reaction rates are slow, the longer a rock unit has been exposed, the more likely it is to be weathered.

Soil Development



Additions to Soils

- Inputs from outside ecosystem
 - Atmospheric inputs
 - Precipitation, dust, deposition
 - Horizontal inputs
 - Floods, tidal exchange, erosion, land-water movement
- Inputs from within ecosystem
 - Litterfall and root turnover

Transformations

- Decomposition of organic matter
- Humification to form complex organic matter
- Weathering of rocks
 - Physical weathering
 - Fragmentation of rock
 - Freeze-thaw; drying-wetting; fire
 - Physical abrasion
 - Abrasion by glaciers
 - Chemical weathering
 - Dissolves primary minerals
 - Forms secondary minerals

Decomposition

- Breakdown of soil organic matter to form soluble compounds that can be absorbed or leached
- Depends on
 - Quantity of input
 - Location of input (roots vs. leaves)
 - Environment
 - Temperature
 - Moisture

Soil Horizons and Profiles

Soil Horizons

- Layers in Soil
- Not Deposited, but Zones of Chemical Action

Soil Profile

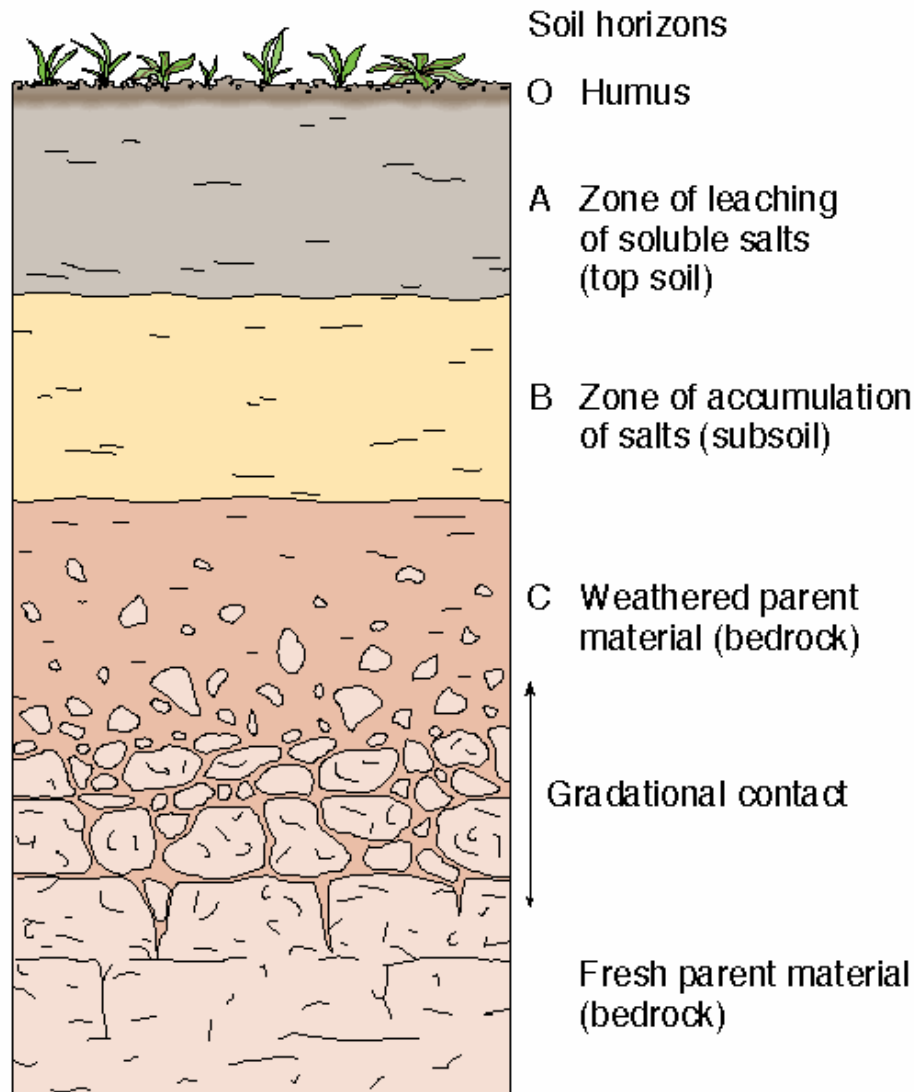
- Suite of Horizons at a Given Locality

Soil Profiles

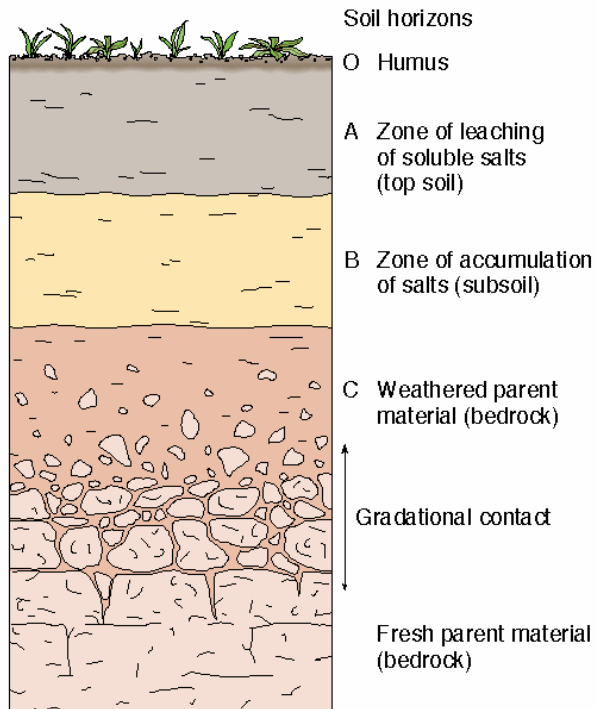
Over time different levels of a soil can differentiate into distinct horizons that create soil profiles.

- Chemical reactions and formation of secondary minerals (clays).
- Leaching by infiltrating water.
- Deposition and accumulation of material leached from higher levels in the soil.

Soil Profiles



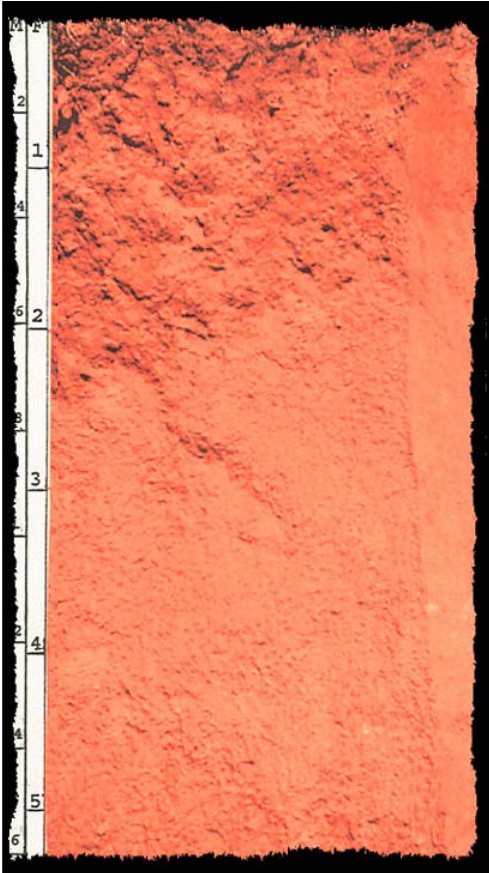
Cookport soil, Pennsylvania



Physical weathering breaks rocks into small mineral particles.



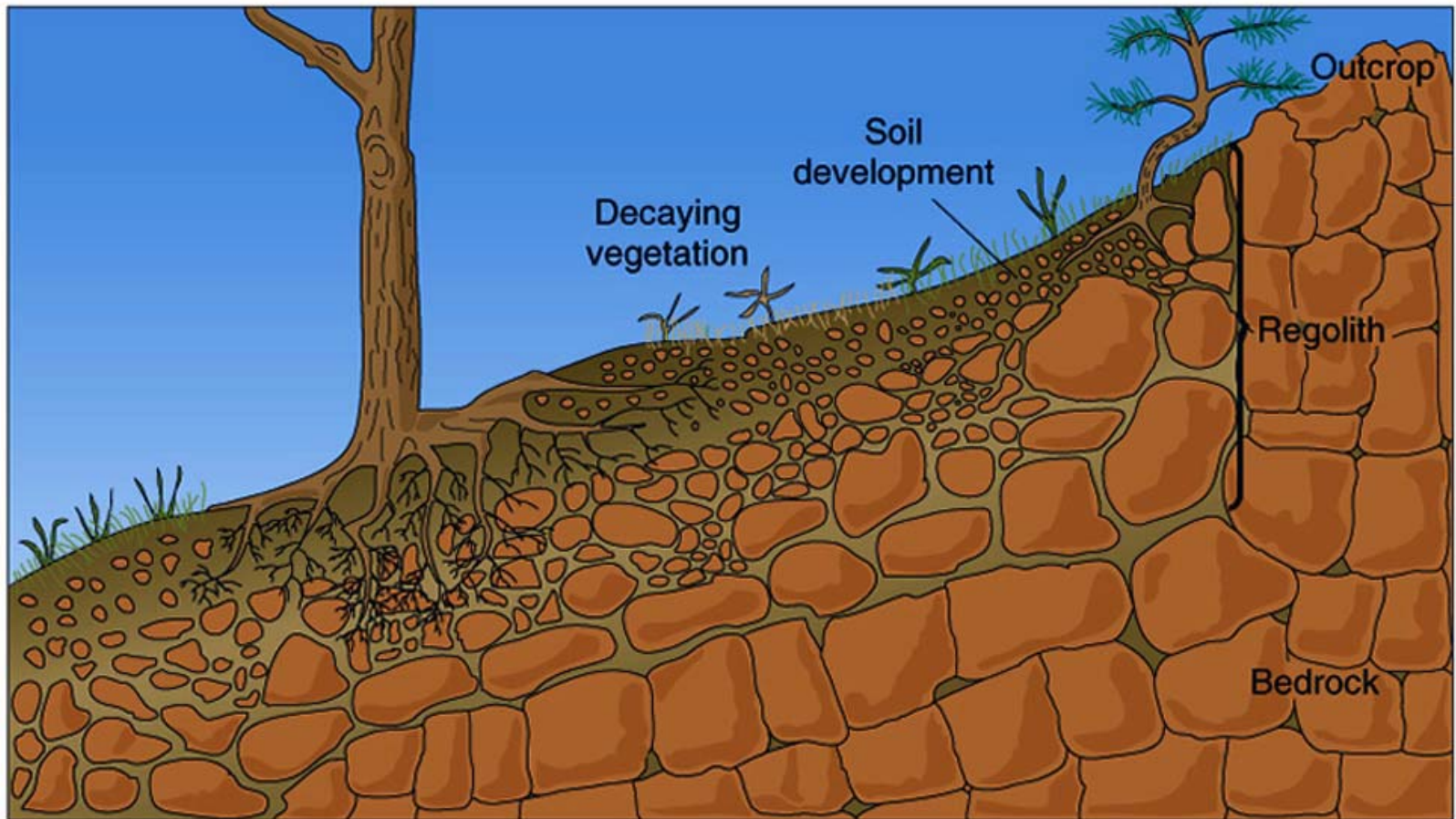
Chemical weathering dissolves and changes minerals at the Earth's surface.



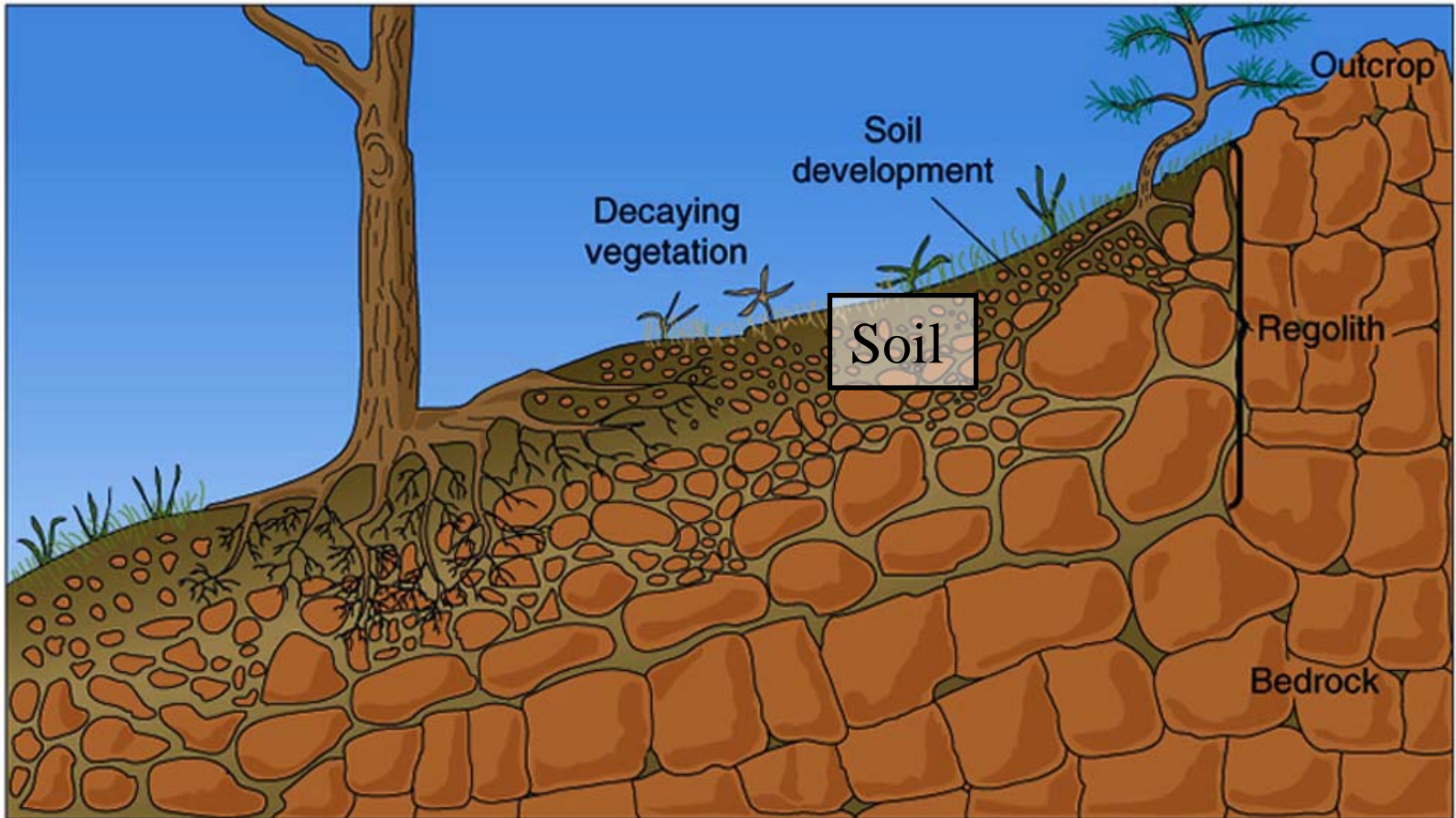
Decomposing organic material from plants and animals mixes with accumulated soil minerals.



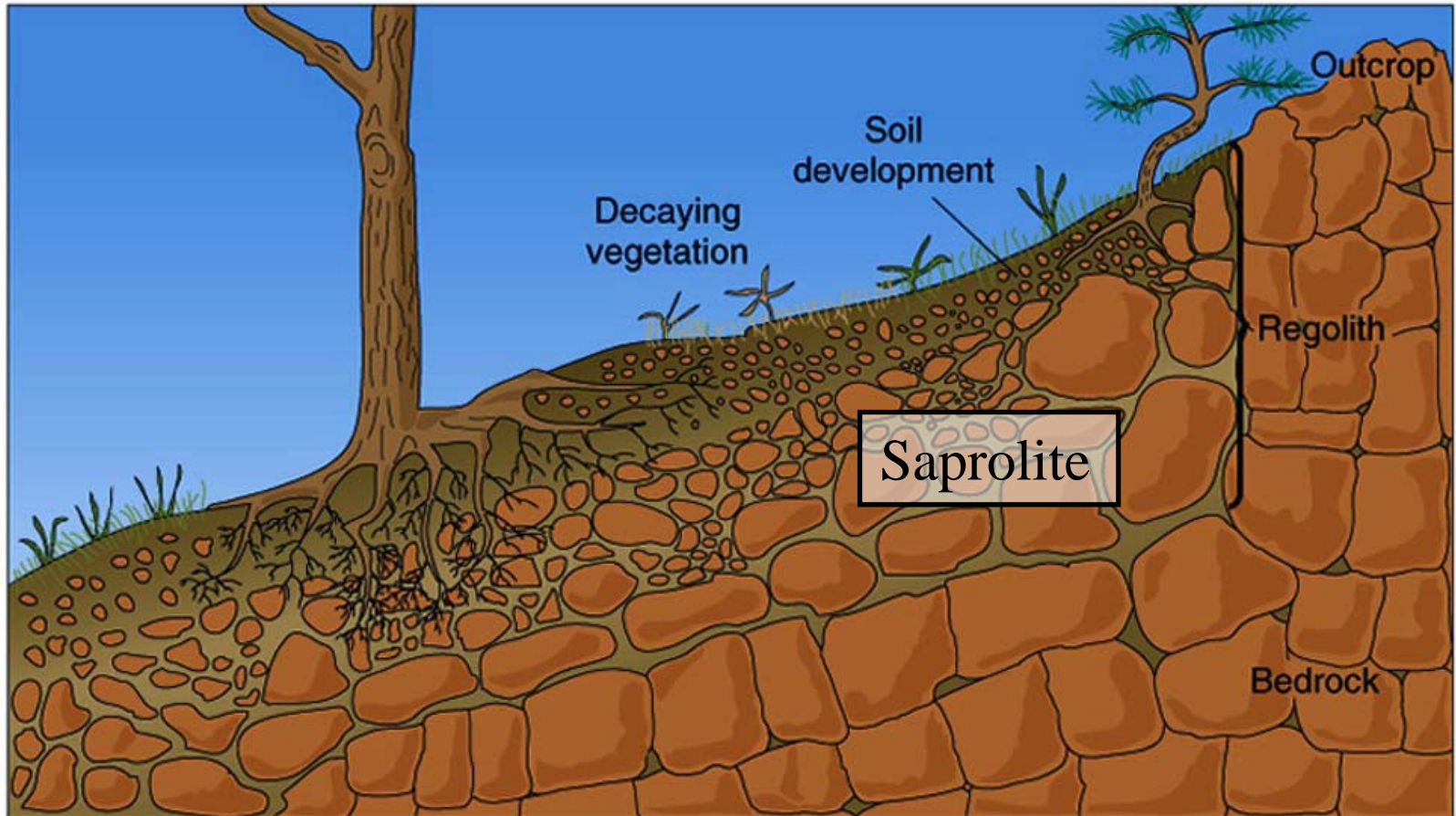
Parent material (bedrock) undergoes weathering to become regolith (soil + saprolite).



Soil is a mixture of mineral and organic matter lacking any inherited rock structure.



Saprolite is weathered rock that retains remnant rock structure.





Saprolite

Limits of Soil Development

Balance Between:

- Downward Lowering of Ground Surface
- Downward Migration of Soil Horizons

If erosion rapid or soil evolution slow, soils may never mature beyond a certain point.

Extremely ancient soils may have lost everything movable

Rates of Soil Development

U.S. Department of Agriculture estimates that it takes 500 years to form an inch of topsoil.

That's less than 0.01 mm yr^{-1}

Erosion of Natural Capital

Modern rates of soil loss are 100 to 1000 times rates of soil formation (typically mm yr^{-1} to cm yr^{-1} in agricultural settings).

Sets up a fundamental problem due to the erosion of natural capital!

Soil and the Life-Cycle of Civilizations

How long would it take to erode 1 m thick soil?

Thickness of soil divided by the difference between Rate of soil production and erosion.

$$\frac{1 \text{ m}}{1\text{mm} - .01 \text{ mm}} \approx 1000 \text{ years}$$

This is about the life-span of most major civilizations...

Man—despite his artistic pretensions, his sophistication, and his many accomplishments—owes his existence to a six-inch layer of topsoil and the fact that it rains.

- Author Unknown

A nation that destroys its soils, destroys itself.

- President Franklin D. Roosevelt, Feb. 26, 1937.



National Archives: 114 SC 5089