GEOLOGY 408/508

FORMATION OF SOILS FROM PARENT MATERIALS

CHAPTER 2

Brady & Weil, Rev. 14th ed.

WEATHERING OF ROCKS & MINERALS

Weathering is the physical and chemical breakdown of particles

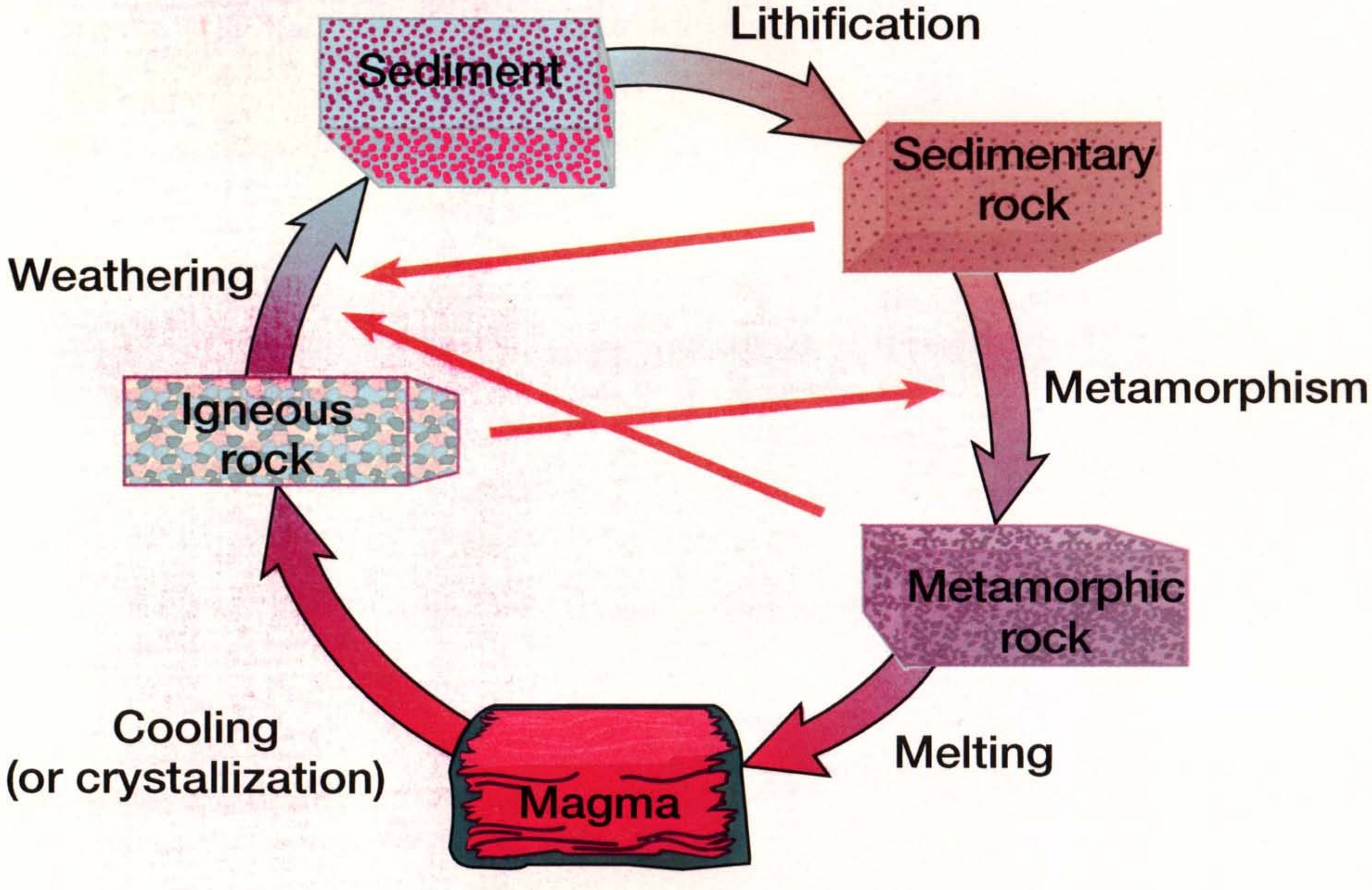
Rock classes:

Igneous - formed from cooled magma
- comprised of primary minerals
- basalt, granite, gabbro, diorite, peridotite

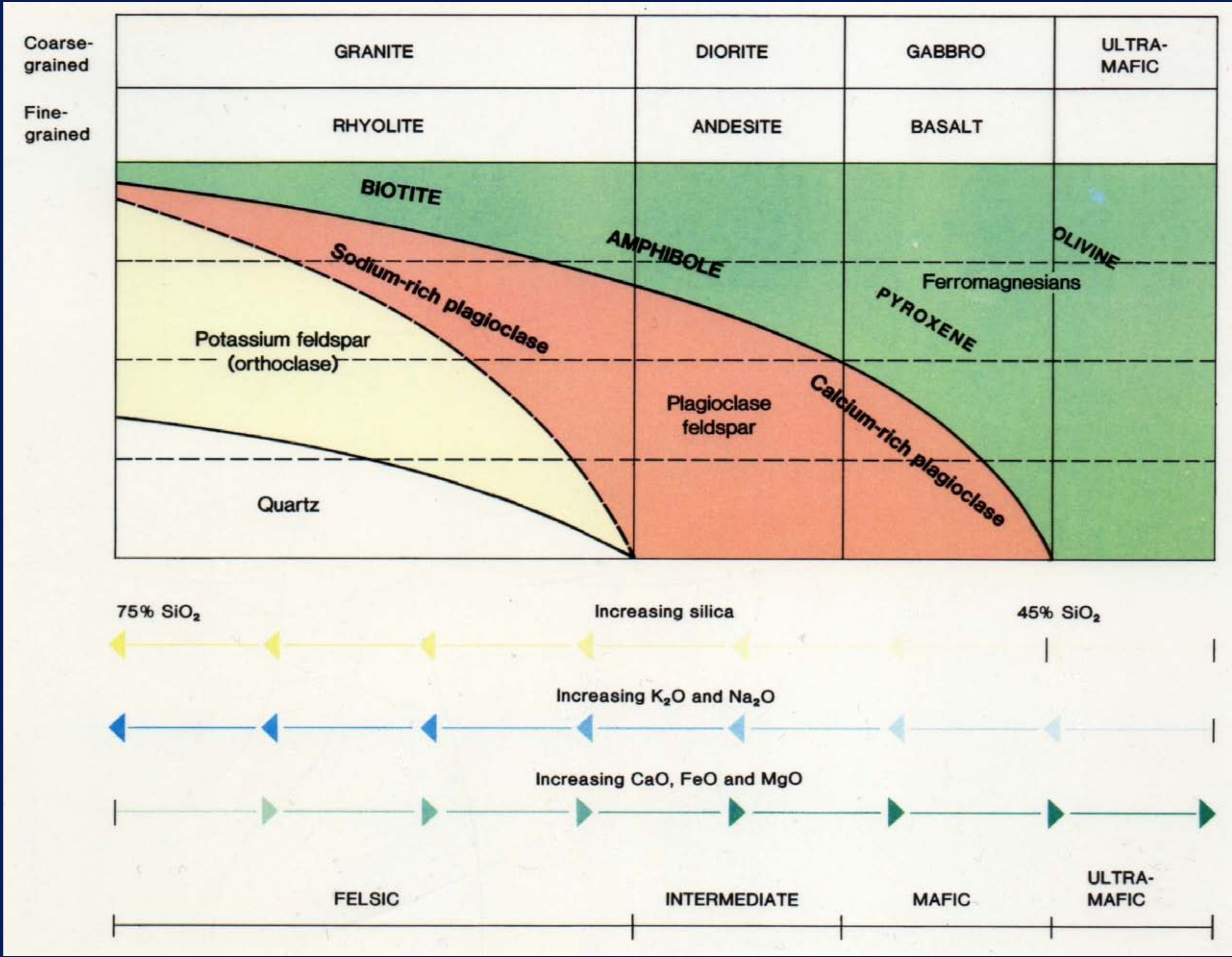
Sedimentary - compacted, cemented, weathered particles
- sandstones, shales, limestones

Metamorphic - altered by heat and/or pressure
- gneiss, schist, marble, slate, quartzite

THE ROCK CYCLE



IGNEOUS ROCK CLASSIFICATION



PHYSICAL WEATHERING (DISINTEGRATION)

Temperature

- heating and cooling cause alternate expansion and contraction of minerals
- differential expansion causes physical stress
- exfoliation - peeling of layers of rock
- ice formation

Abrasion by Water, Ice, & Wind

- stream load
- glaciers
- windblown sand and dust

Plants & Animals (minor effects)

- force of plant roots
- burrowing animals

CHEMICAL WEATHERING (DECOMPOSITION)

Hydration - binding of water molecules

$5Fe_2O_3 + 9H_2O \rightarrow Fe_{10}O_{15} \cdot 9H_2O$

hematite ferrihydrite

$CaSO_4 + 2H_2O \rightarrow CaSO_4 \cdot 2H_2O$

anhydrite gypsum

Hydrolysis - splitting of water molecule, reaction of H^+ or OH^- with mineral

$KALSi_3O_8 + HOH \Leftrightarrow HALSi_3O_8 + K^+ + OH^-$

microcline

$2HAlSi_3O_8 + 11HOH \Leftrightarrow Al_2O_3 + 6H_4SiO_{4\ (solution)}$

CHEMICAL WEATHERING (DECOMPOSITION)

Dissolution - solubilization

$CaSO_4 \cdot 2H_2O \rightarrow^{\text{dissolution}}\rightarrow \; Ca^{+2} + SO4^{-2} + 4H_2O$

Carbonation and Other Reactions

$CO_2 + H_2O \rightarrow\leftarrow H_2CO_3$

$H_2CO_3 \rightarrow^{\text{dissociation}}\leftarrow H^{+} + HCO_3^{-}$

$H_2CO_3 + CaCO_3 \rightarrow^{\text{carbonation}}\leftarrow Ca^{+2} + 2HCO_3^{-}$

CHEMICAL WEATHERING (DECOMPOSITION)

Oxidation-Reduction - loss/gain of electrons:

$$4FeO + O_2 + 2H_2O \xrightarrow{\text{oxidation}} \xleftarrow[\text{reduction}]{} 4FeOOH$$

$$2FeS_2 + 7.5O_2 + H_2O \rightarrow 2Fe^{+3} + 4SO_4^{-2} + 2H^+$$

(H_2SO_4)

Complexation - inorganic/organic complexes:

$$K_2[Si_6Al_2]Al_4O_{20}(OH)_4 + 6\ C_2H_4O_2 + 8H_2O \rightarrow$$

$$2K^+ + 8OH^- + 6C_2H_4Al^+ + 6Si(OH)_4^0$$

FACTORS INFLUENCING SOIL FORMATION

1. Parent materials (geologic or organic precursors to the soil

2. Climate (primarily precipitation & temperature)

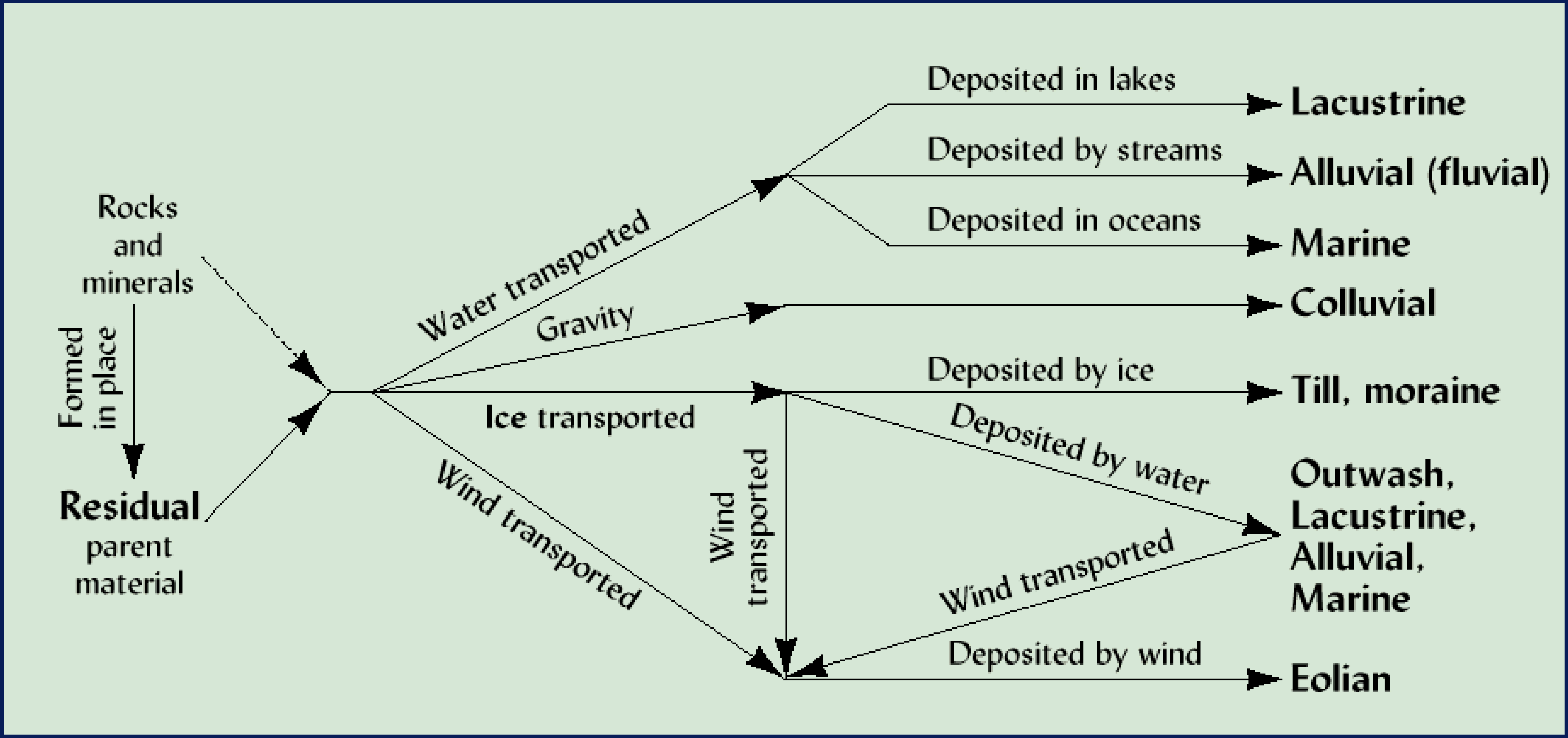
3. Biota (living organisms, especially native vegetation, microbes, soil animals & humans

4. Topography (slope, aspect & landscape position)

5. Time (the period of time since the parent materials became exposed to soil formation factors)

PARENT MATERIALS

Classification:



How various kinds of parent material are formed, transported, and deposited. **(FIGURE. 2.10)**

ALLUVIAL STREAM DEPOSITS

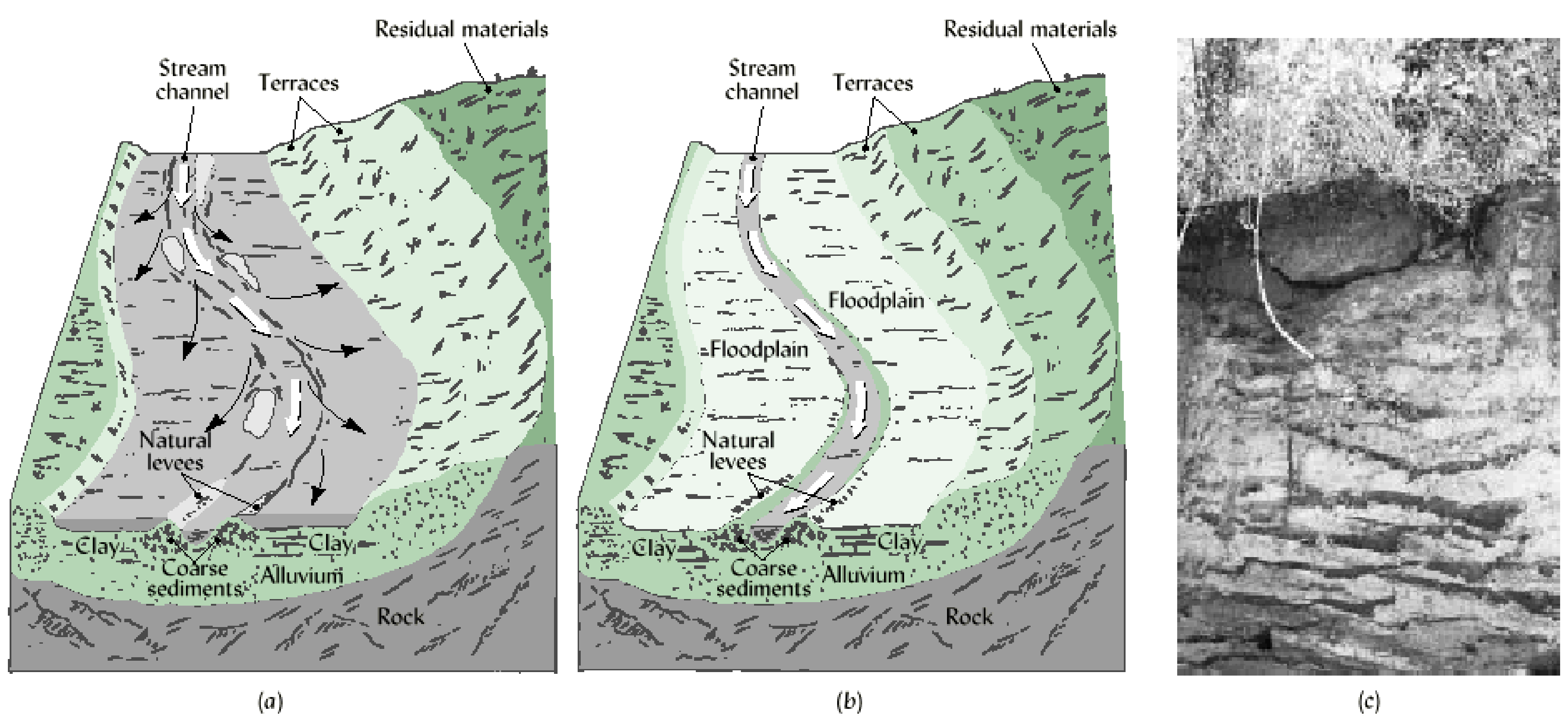


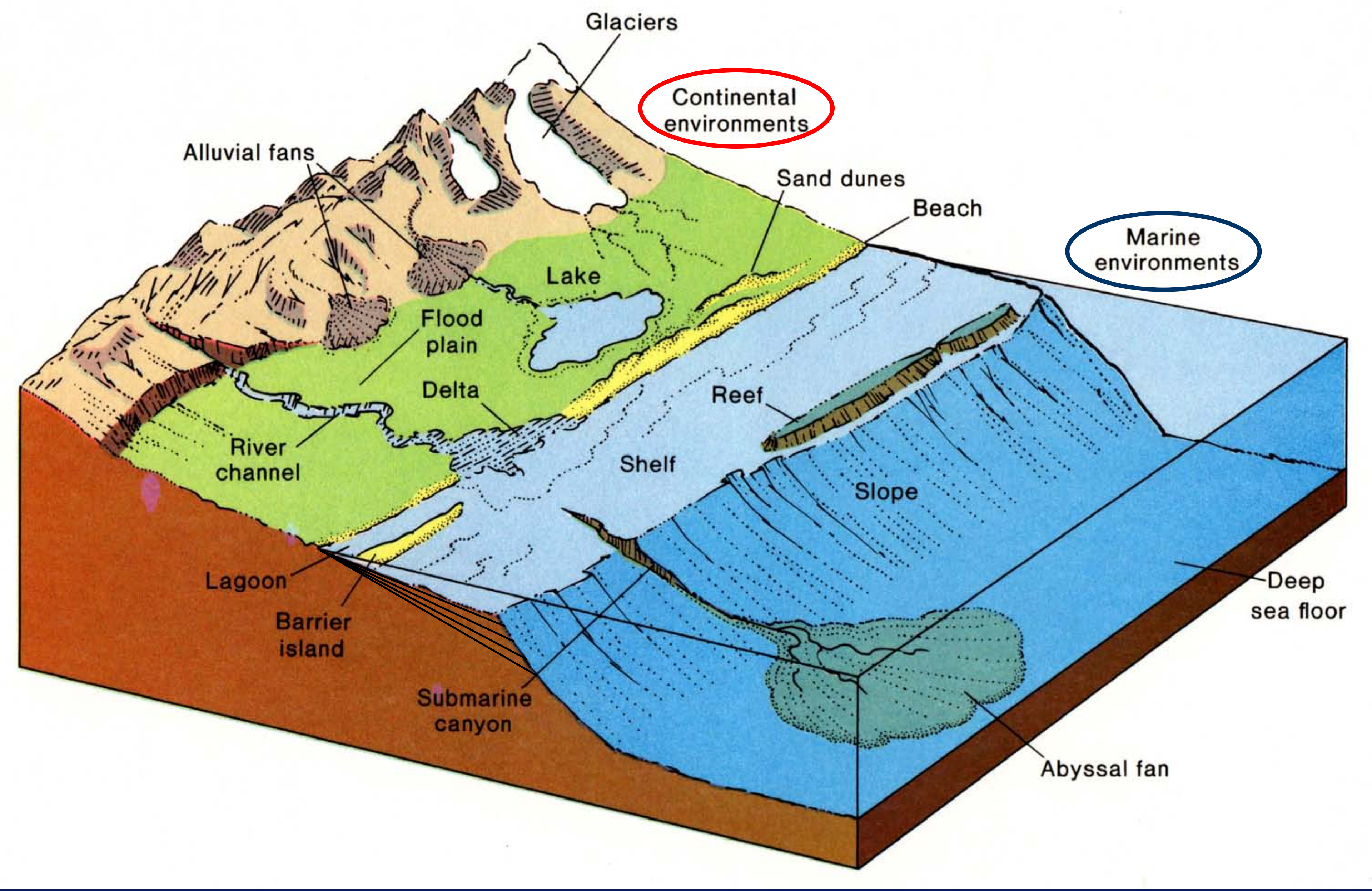
Illustration of floodplain development.

(a) A stream is at flood stage, has overflowed its banks, and is depositing sediment in the floodplain; with particles fining outward away from stream channel.

(b) After the flood the sediments are in place and vegetation is growing.

(c) Contrasting layers of sand, silt, and clay characterize the alluvial floodplain. Each layer resulted from separate flooding episodes. (FIGURE 2.13)

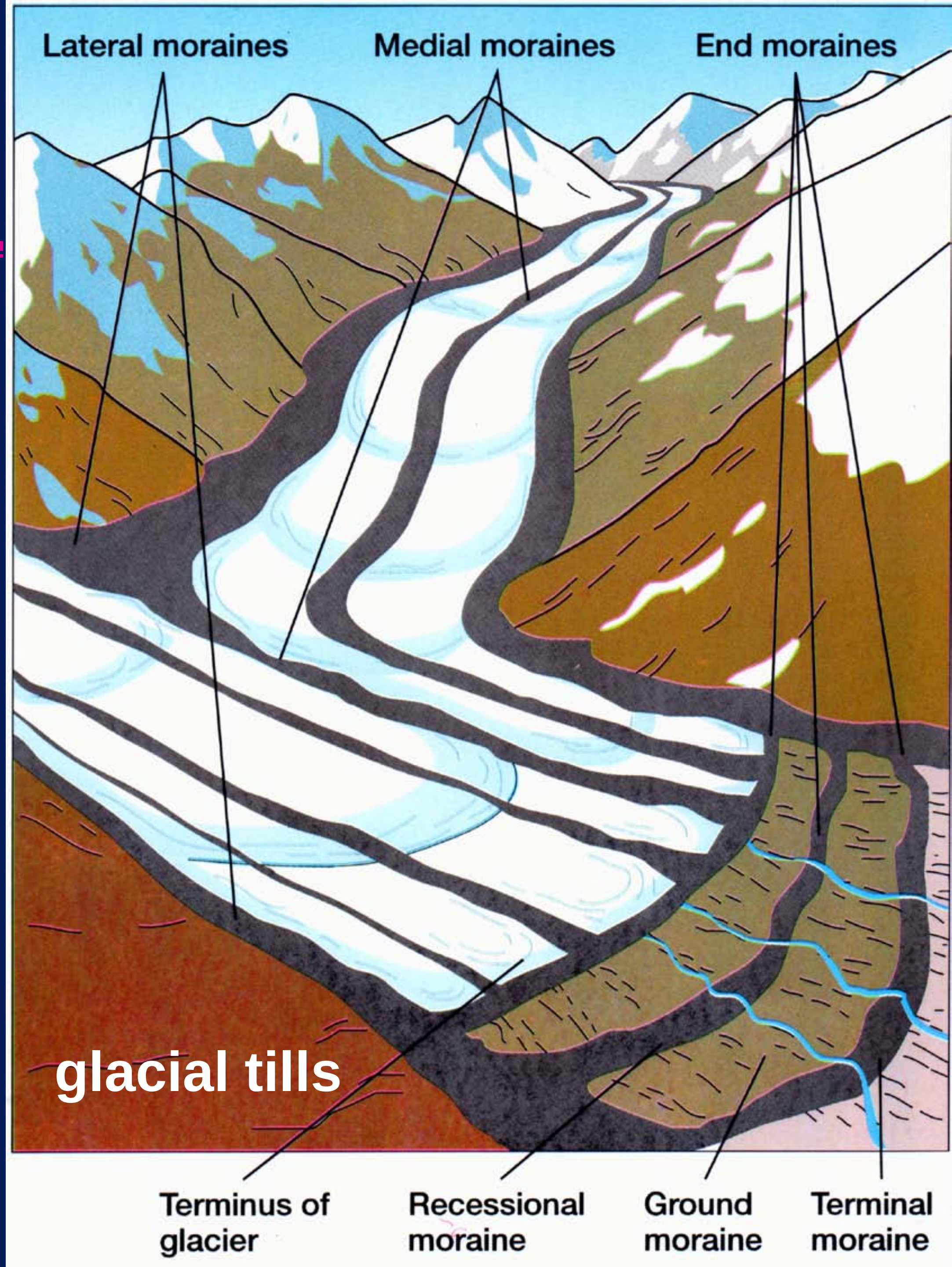
DEPOSITIONAL ENVIRONMENTS



VALLEY GLACIAL DEPOSITS

Other Features:

Eskers
Outwash plain
Drumlins
Deltas
Lacustrine deposits



PARENT MATERIALS TRANSPORTED BY WIND

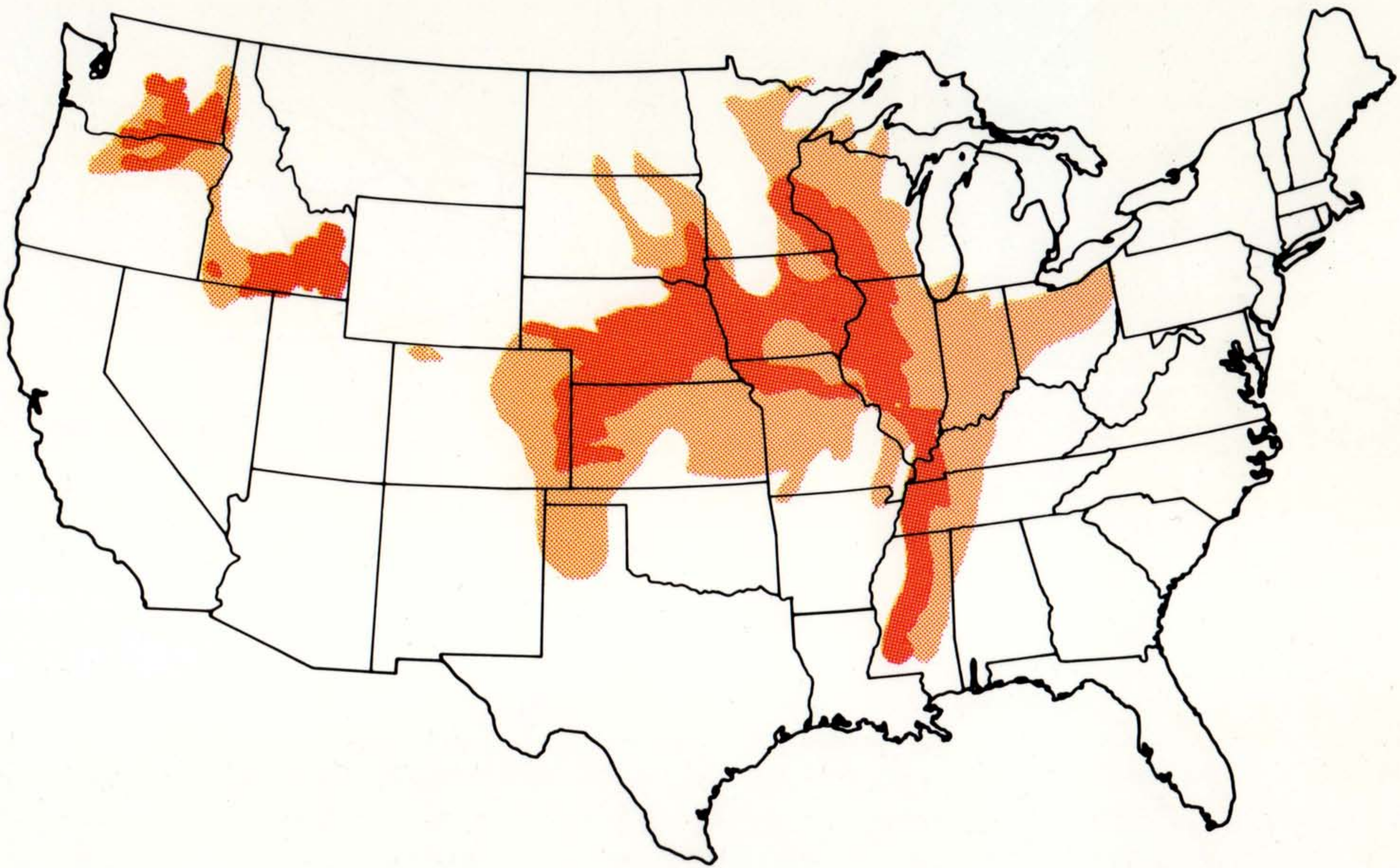
Dune sand: found along coastlines and in deserts

Loess: primarily silt with some clay and very fine sand

Aerosolic dust: very fine particles (≈1-10 μm); travel thousands of km; significant for $CaCO_3$ transport

Volcanic ash: cinders near volcano; ash downwind

LOESS DEPOSITS IN THE US



ORGANIC DEPOSITS

Peat - unconsolidated material consisting largely of undecomposed or slightly decomposed organic matter

Types of Peat Materials:

1. **Moss peat - remains of mosses such as sphagnum**

2. **Herbaceous peat - residues of herbaceous plants such as sedges, reeds a & cattails**

3. **Woody peat - remains of woody plants**

4. **Sedimentary peat - remains of aquatic plants & animals**

Stages in the development of a typical woody peat bog and the area after clearing and draining.

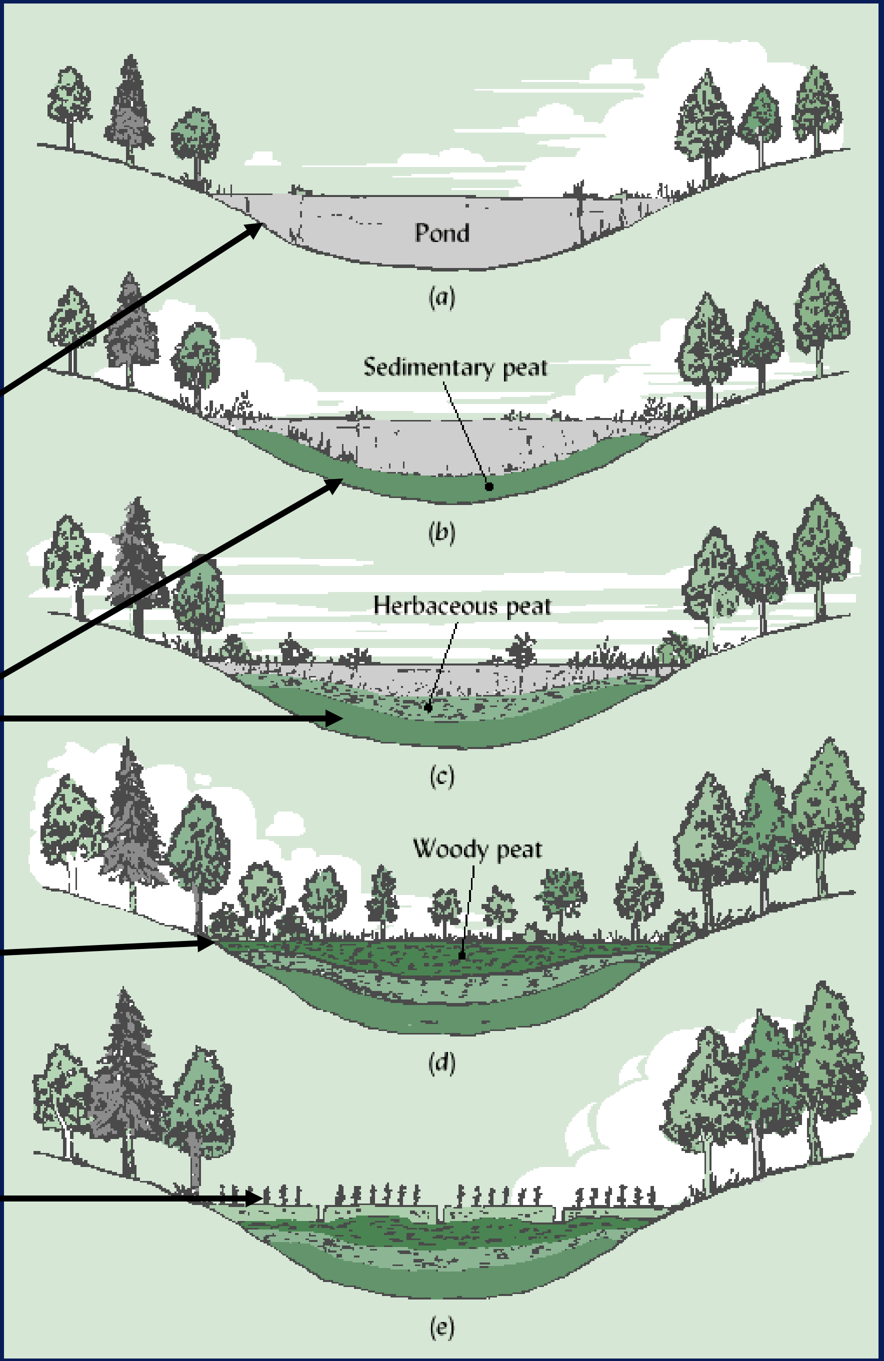
(a) Nutrient runoff from the surrounding uplands encourages aquatic plant growth, especially around the pond edges.

(b, c) Organic debris fills in the bottom of the pond.

(d) Eventually trees cover the entire area.

(e) If the land is cleared and a drainage system installed, the area becomes a most productive muck soil.

(FIGURE 2.22)



CLIMATE

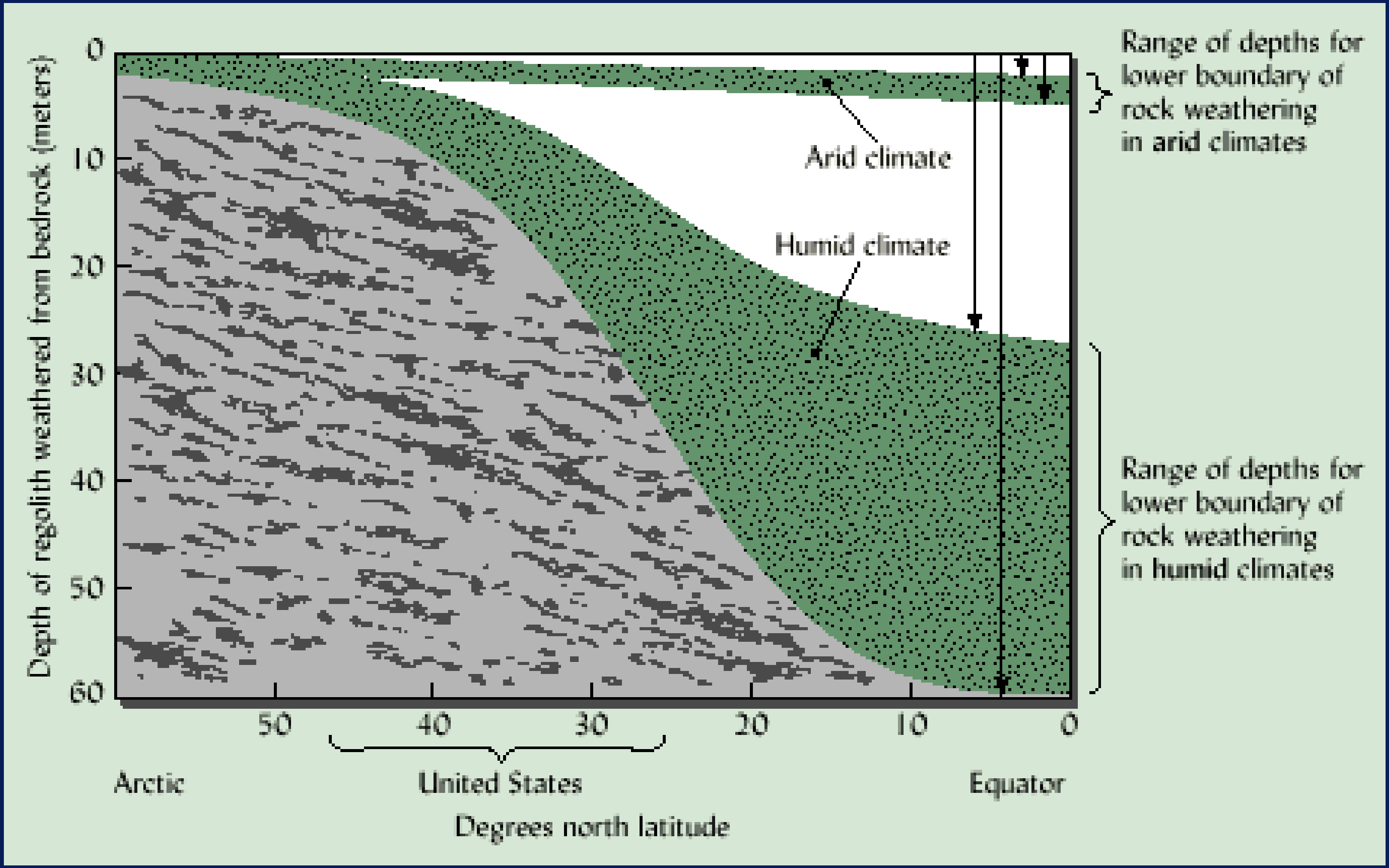
Climate is probably the most influential of the four factors acting on parent material - determines nature and intensity of weathering

Effective precipitation - amount that enters and percolates downward through the profile [See Box 2.1]

Temperature - for every 10˚ rise in temperature, rates of biochemical reactions more than double

Temperature & moisture both influence plant growth, OM content of soils

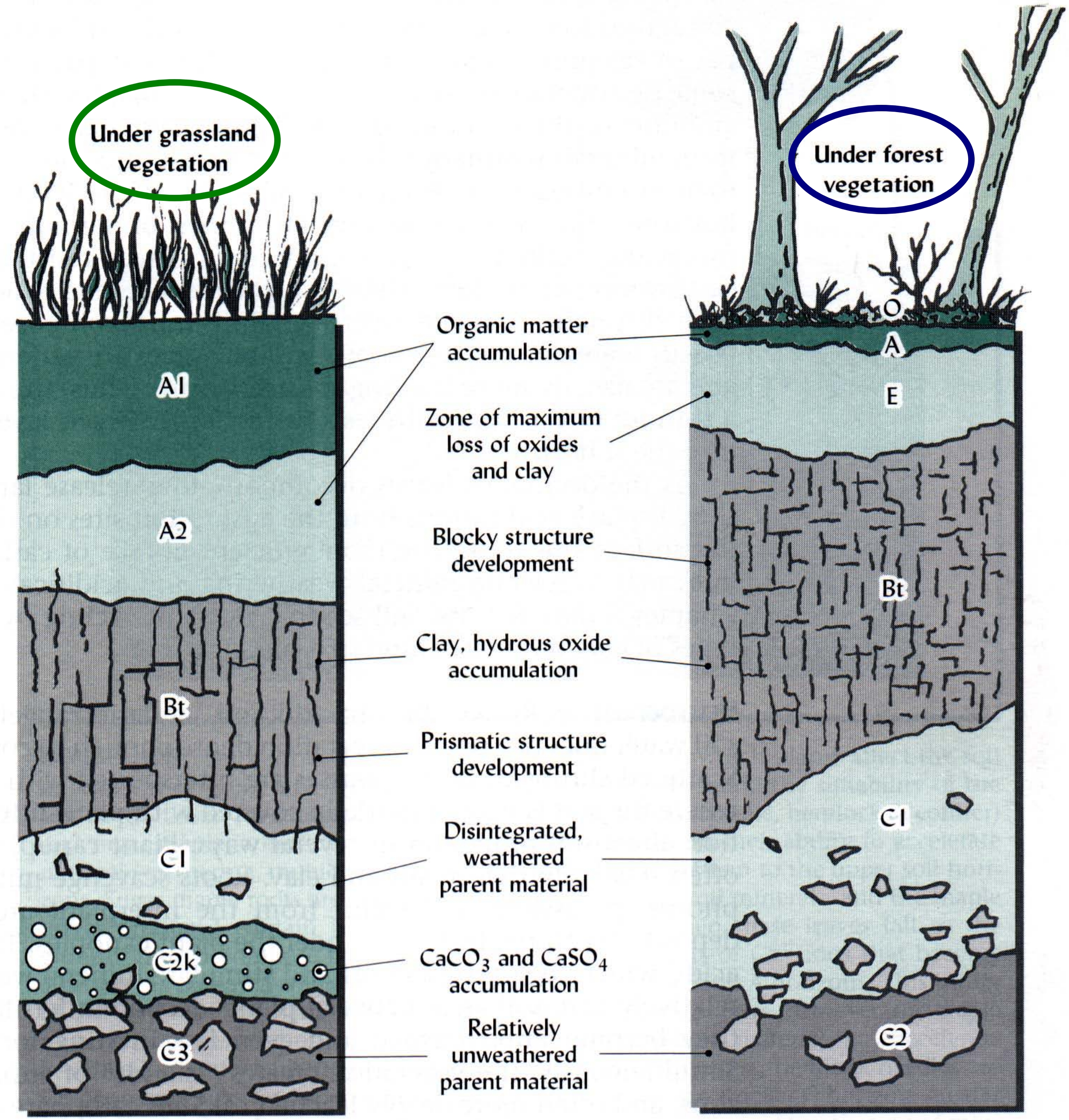
EFFECTS OF TEMPERATURE & VEGETATION



A generalized illustration of the effects of two climatic variables, temperature and precipitation, on the depths of regolith weathered in bedrock.

(FIGURE 2.24)

VEGETATIONAL INFLUENCES ON SOIL DEVELOPMENT



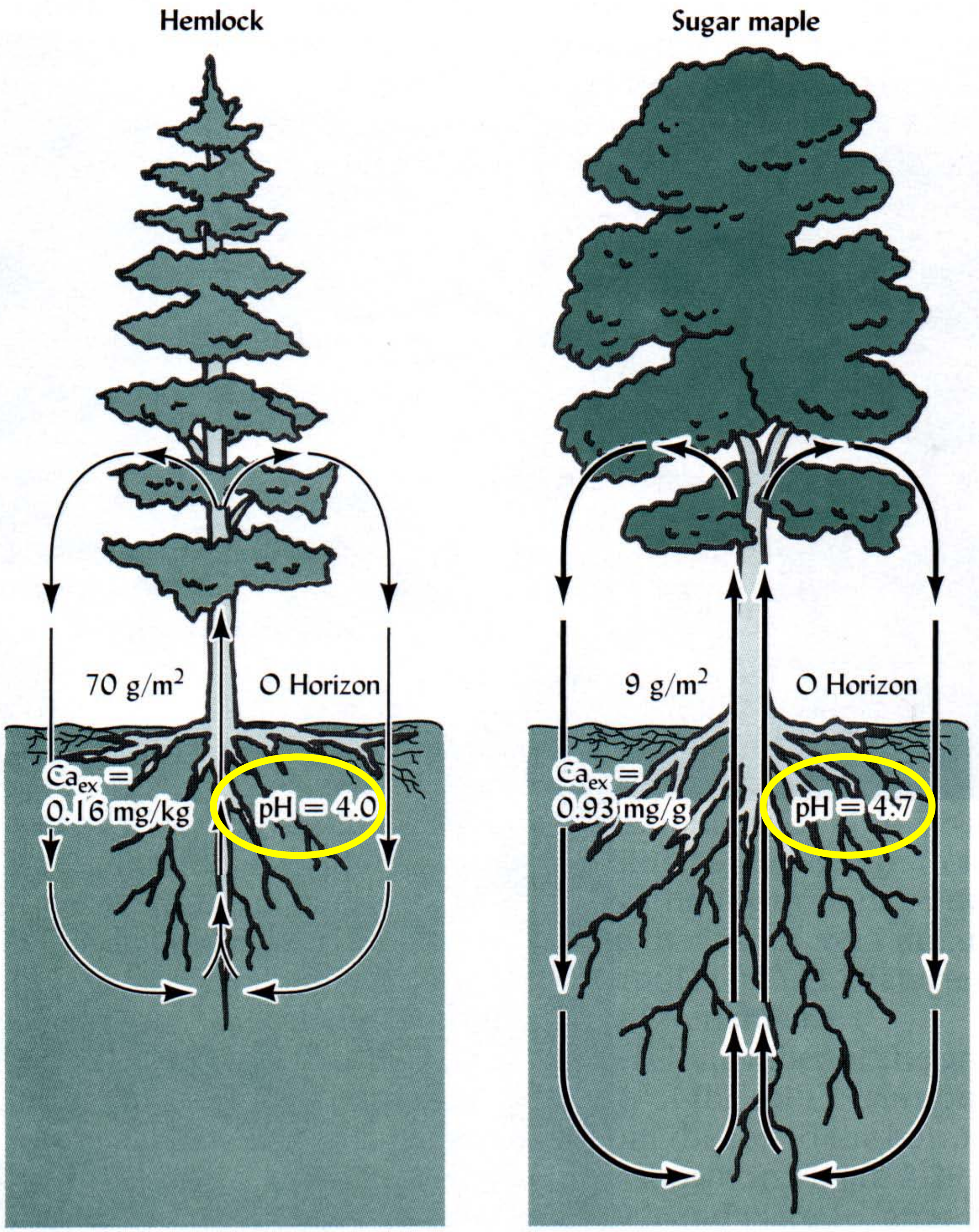
(FIGURE 2.26)

NUTRIENT CYCLING

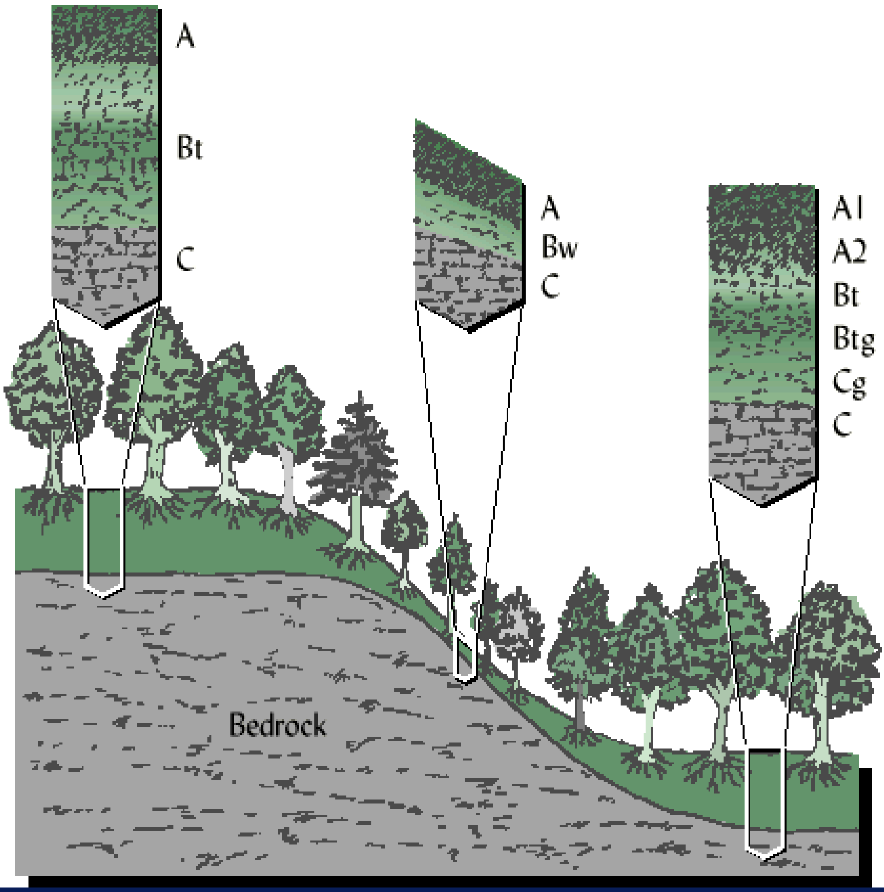
CONIFER VS DECIDUOUS VEGETATION

Conifers:
- low nutr. req'mts
- uptake low
- leaf decomp slow

Deciduous:
- higher nutr. Req'mt
- higher uptake
- leaf decomp fast

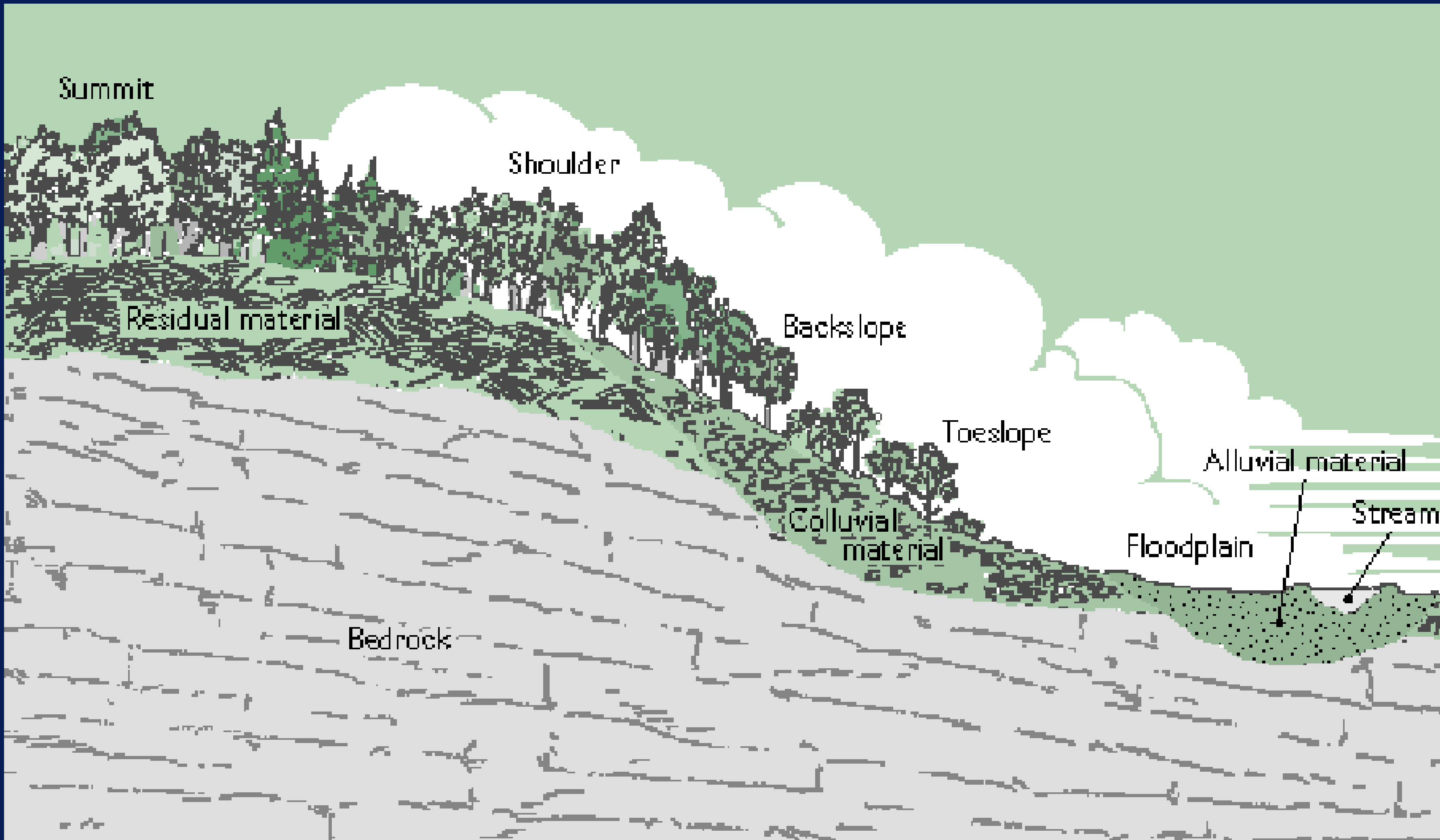


TOPOGRAPHY



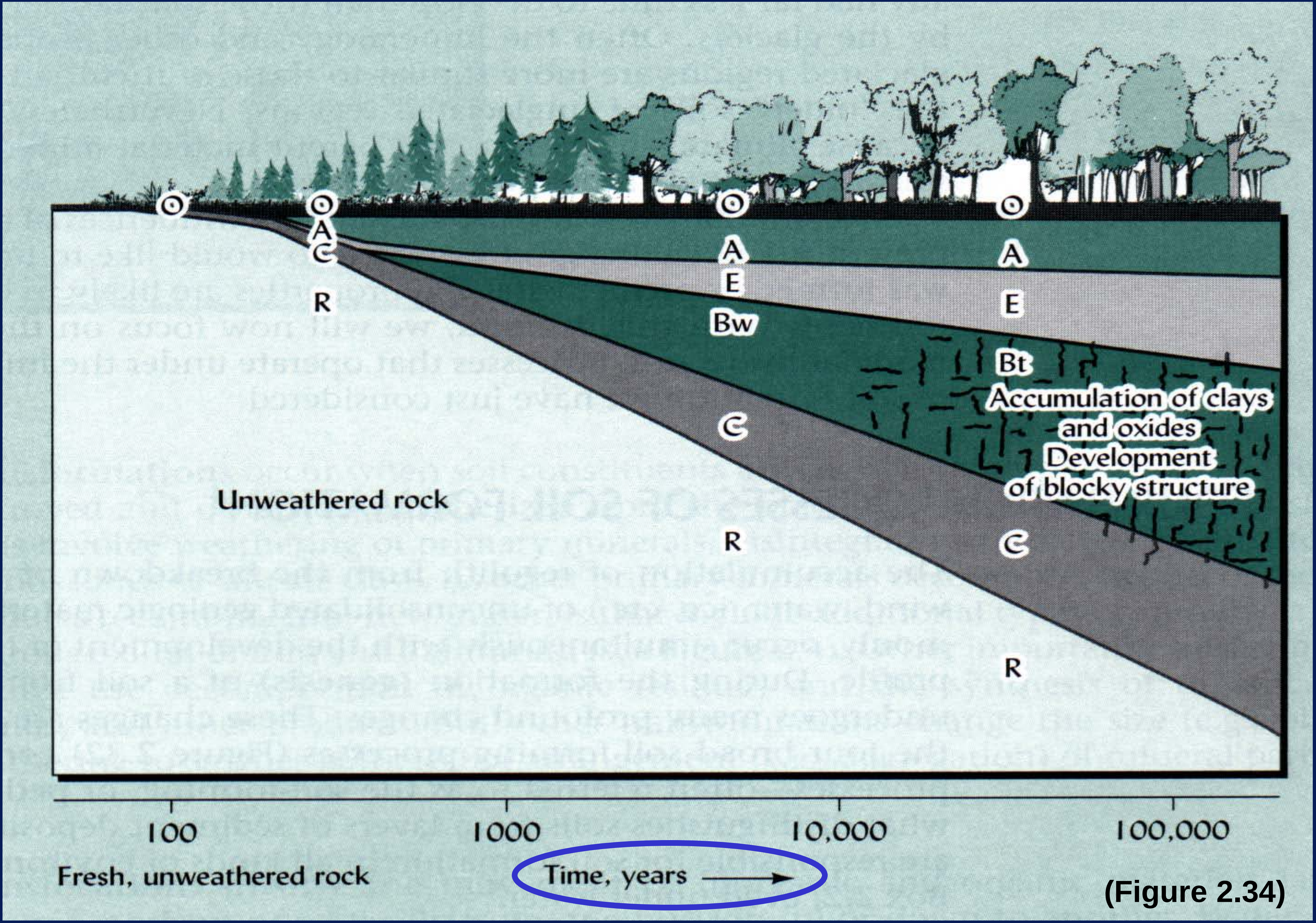
Topography influences soil properties, including soil depth. The diagram on the left shows the effect of slope on the profile characteristics and the depth of a soil on which forest trees are the natural vegetation. The photo on the right illustrates the same principle under grassland vegetation.
(FIGURE 2.32)

TOPOGRAPHY & PARENT MATERIAL INTERACTION



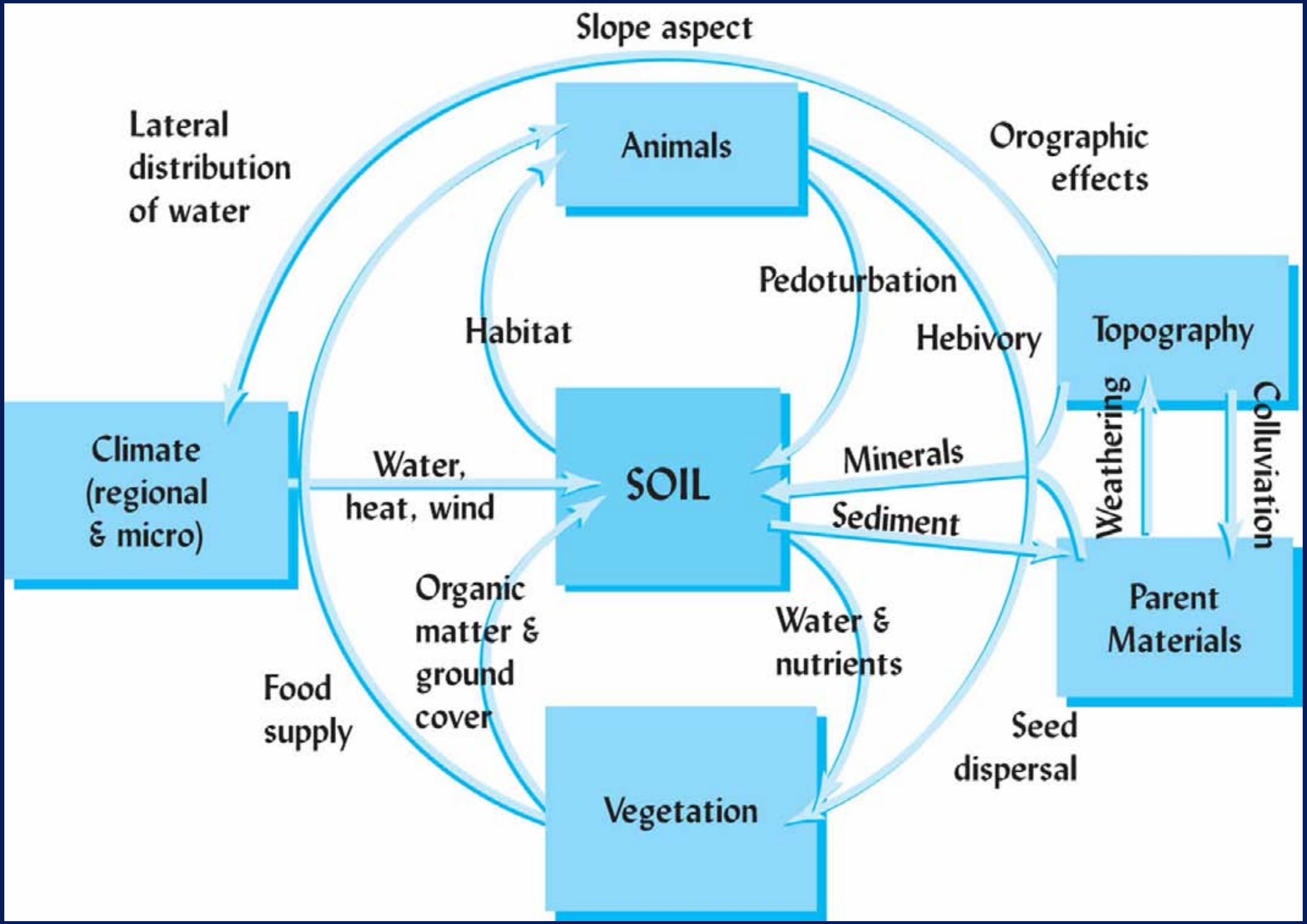
An interaction of topography and parent material as factors of soil formation. (FIGURE 2.33)

SOIL DEVELOPMENT OVER TIME FROM IGNEOUS ROCK



(Figure 2.34)

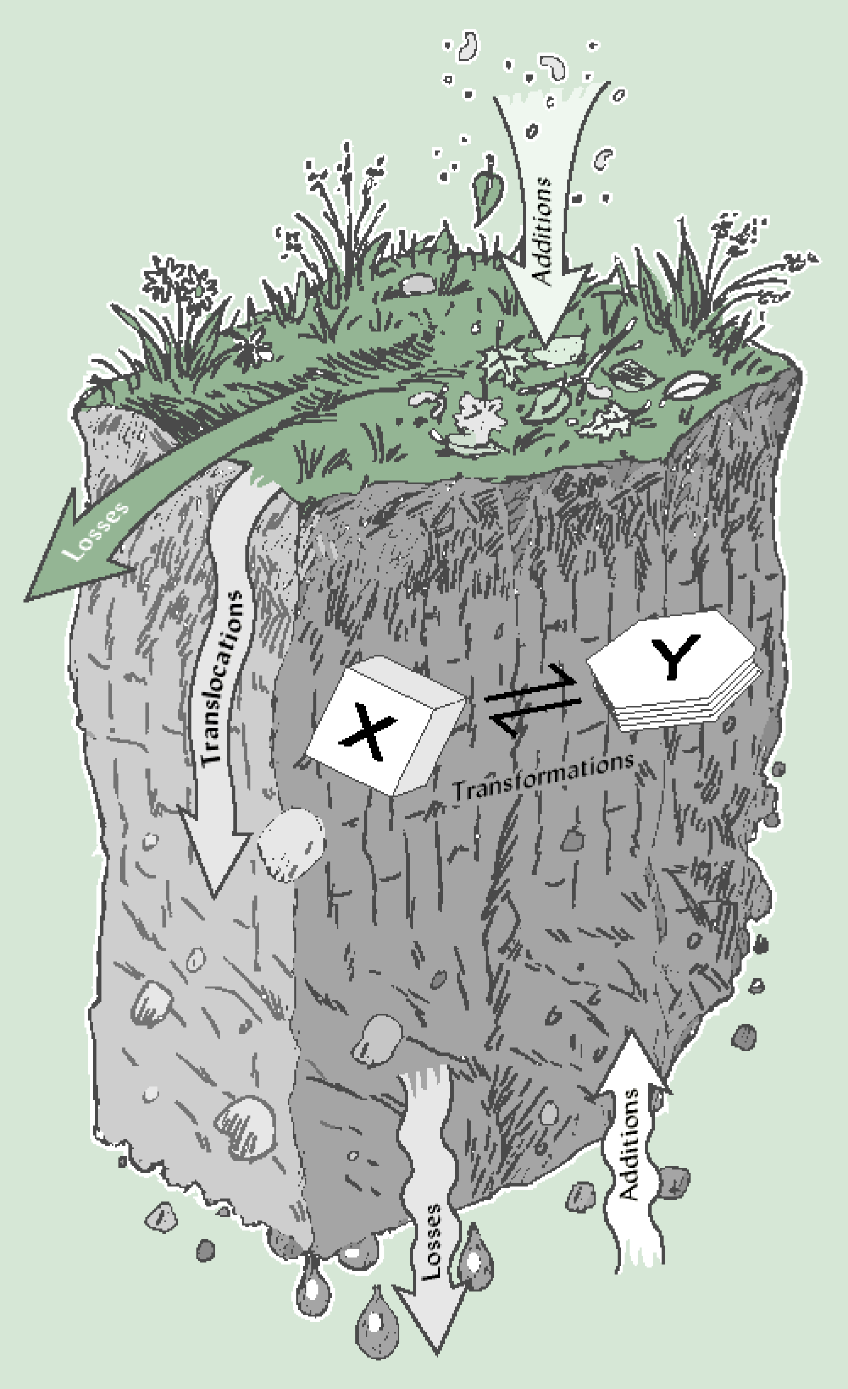
Interaction of Factors of Soil Formation



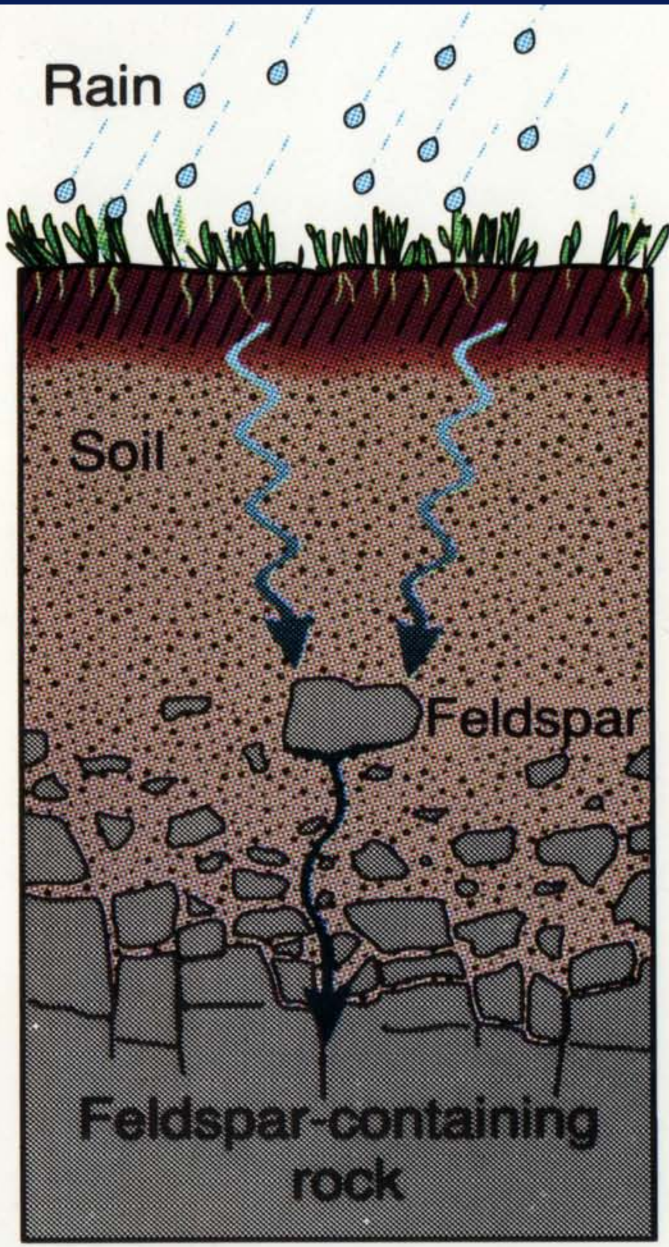
Parent material, topography, climate, and organisms (vegetation and animals) do not act independently. Their effects are highly interactive. The influence of each factor shown is modified by the length of *time* it has been acting, although time as a soil-forming factor is not shown here. [Adapted from Monger et al. (2005)] (FIGURE 2.35)

PROFILE PROCESSES

A schematic illustration of additions, losses, translocations, and transformations as the fundamental processes driving soil-profile development. **(FIGURE 2.36)**



SOIL FORMATION REACTIONS OF FELDSPARS



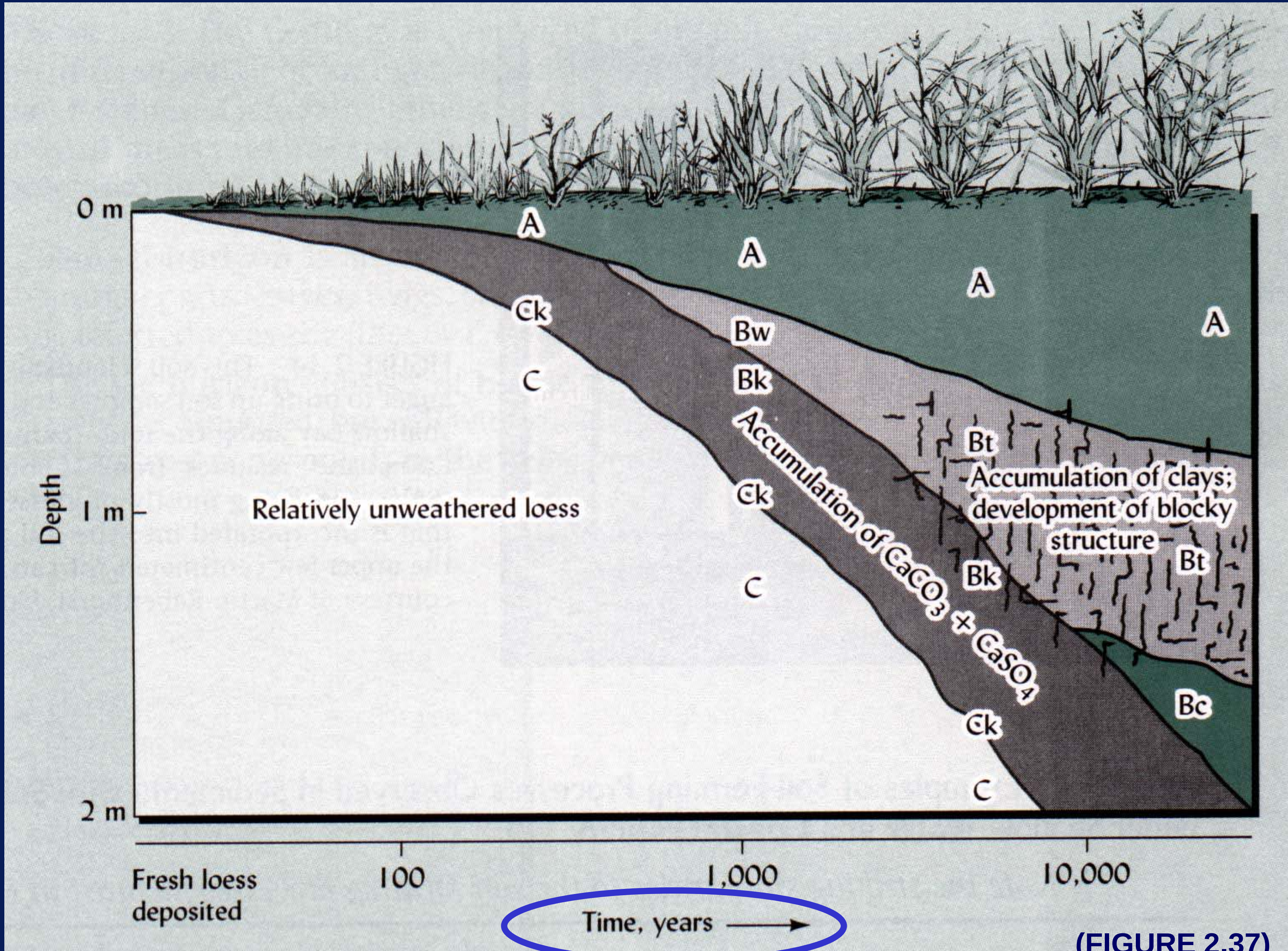
Rain picks up CO_2 from the atmosphere and becomes acidic

Water percolating through the ground picks up more CO_2 from the upper part of the soil, becoming more acidic

A feldspar crystal, loosened from the rock below, slowly alters to a clay mineral as it reacts with the acidic water

The water carries away soluble ions and SiO_2 to the ground-water supply or to a stream

SOIL FORMING PROCESSES IN ACTION

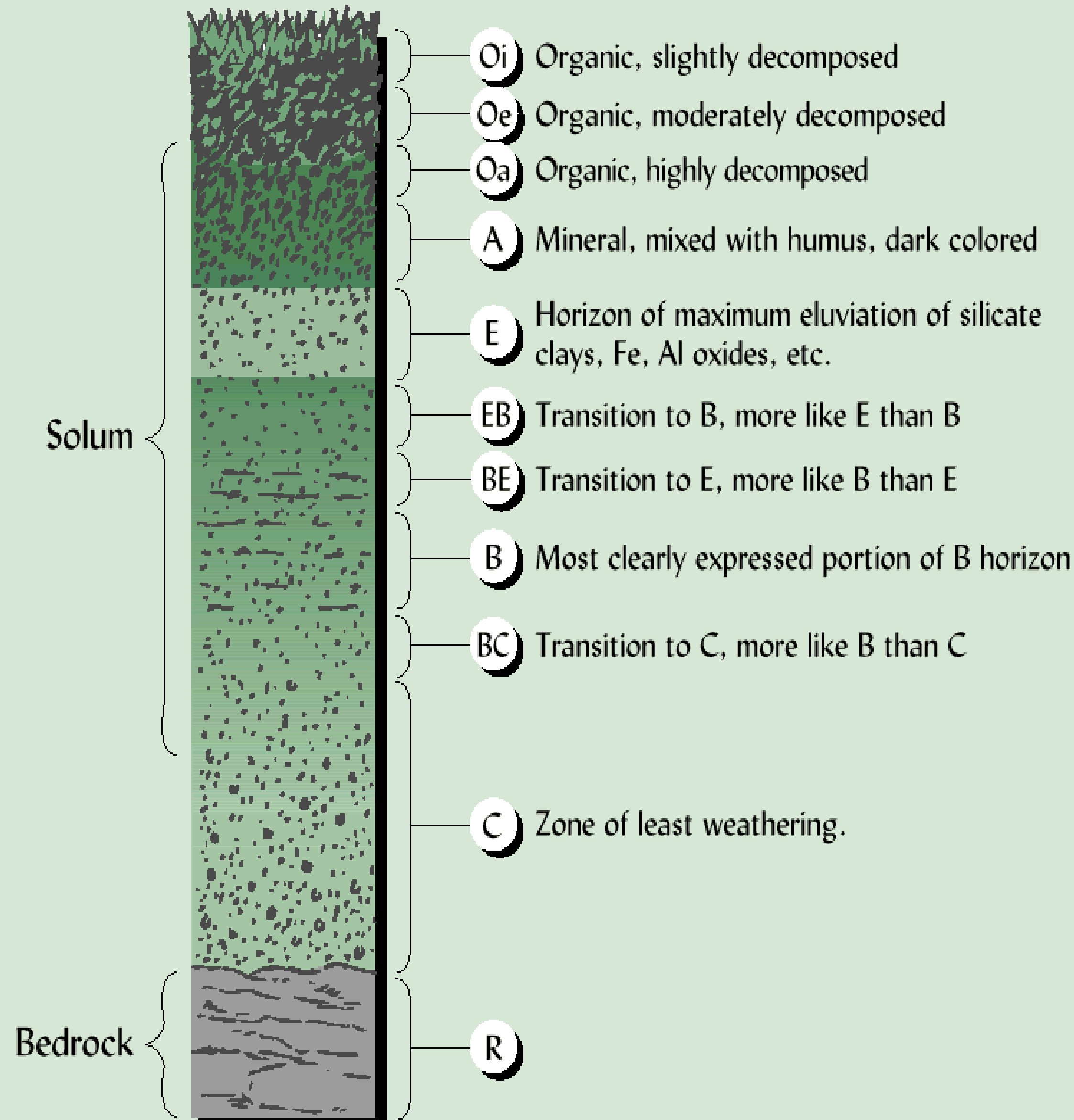


(FIGURE 2.37)

Hypothetical mineral soil profile showing the major horizons that may be present in a well-drained soil in the temperate humid region.

Any particular profile may exhibit only some of these horizons, and the relative depths vary. In addition, however, a soil profile may exhibit more detailed sub-horizons than indicated here.

The solum includes the A, E, and B horizons plus some cemented layers of the C horizon.



(FIGURE 2.40)

Atlantic Coastal Plain Alluvial Soil

Notable Features:

- Young soil
- Multiple layers of PM
- Buried soil

(Figure 2.42)