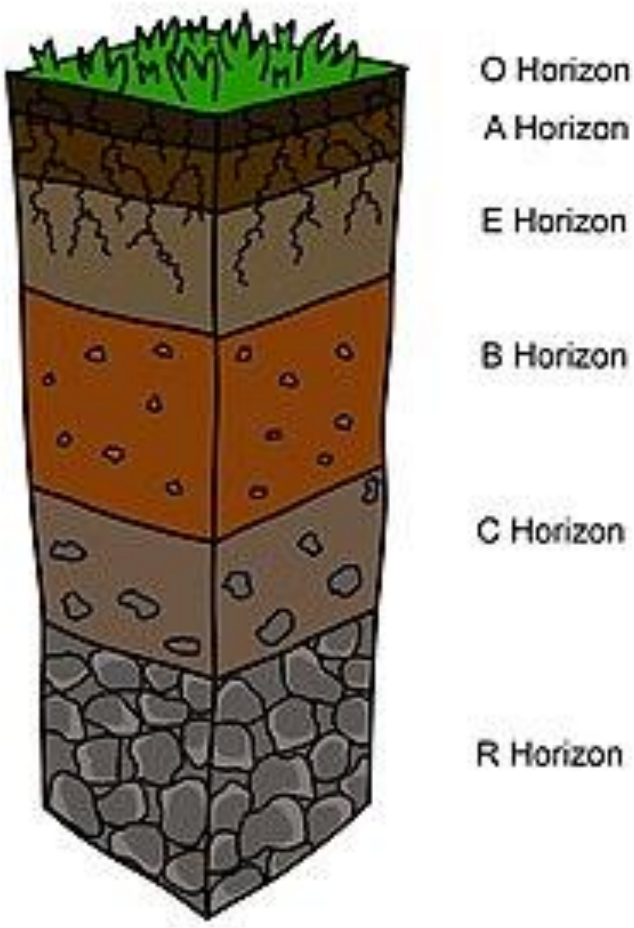


The Morphological Organization of Soils

3. The Morphological Organization of Soils

Soil morphology refers to the physical characteristics of the soil profile, which provide insights into its formation, composition, and potential uses. The morphological organization of soils is described through different horizons and structural features that define its properties.

Particle Classification

Granulometry, or soil texture, refers to the distribution of mineral particles according to their size category, assuming that the particles are spherical. This classification is independent of the nature and composition of these minerals

Sorting of Coarse Materials

Coarse materials are predominantly inorganic constituents composed of rock fragments containing one or more minerals, with their largest dimension exceeding 2 mm.

They are sorted using a sieve with openings of 2 mm in diameter.

Table 3: Categories of Coarse Elements (AFNOR Standard X 31-003, 1998)

Denomination	Dimension
Gravel	0.2 to 2.0 cm
Pebbles	2.0 to 7.5 cm
Stones	7.5 to 12 cm
Large stones	12 to 25 cm
Blocks	> 25 cm

Sorting of Fine Earth Materials

Materials that pass through a 2 mm sieve correspond to what is referred to as "fine earth."To determine the different classes of mineral particles based on their size, the Atterberg scale is used, which defines five particle size classes.

Table 4: Categories of Fine Earth Elements – *The Atterberg Scale*

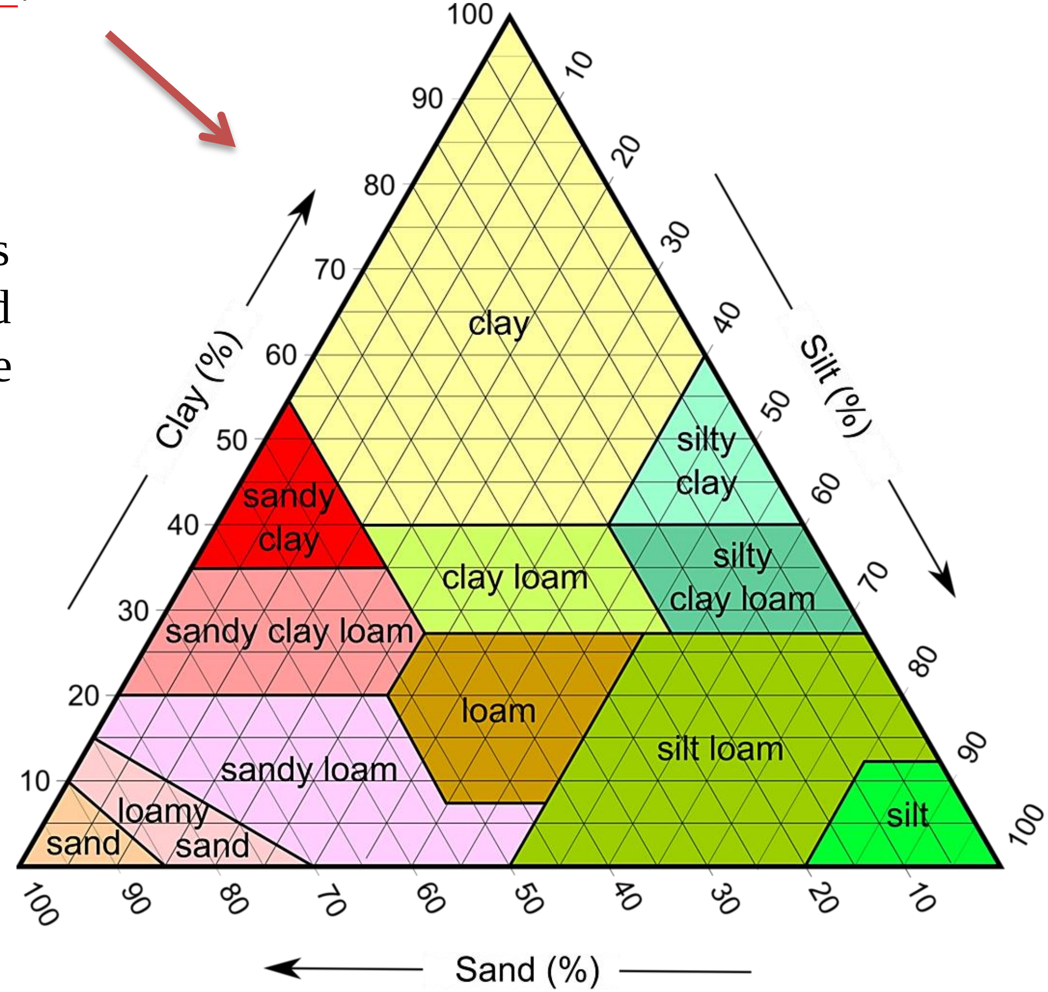
Particle Type	Size Range
Coarse Sands	200 µm to 2 mm
Fine Sands	50 to 200 µm
Coarse Silts	20 to 50 µm
Fine Silts	2 to 20 µm
Clays	< 2 µm

Soil Texture:

Soil texture differs mainly in terms of its behavior regarding moisture, its response to climate, its water storage capacity, and its ability to retain nutrients.

When the percentages of **sand, silt, and clay** are determined, the soil type can be identified using the soil texture triangle .

Each sample is positioned based on its weight percentage of sand, silt, and clay, with the sum of the three normalized to 100%.



Properties of Soil Mineral Particles:

To understand the properties of mineral particles, consider the following example:

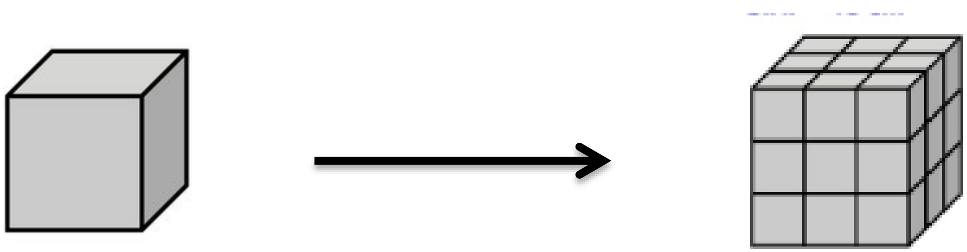
For a cube with a side length of 1 cm, its specific surface area is **6 cm^2.**

If this cube is subdivided into smaller cubes with a side length of 1 mm,

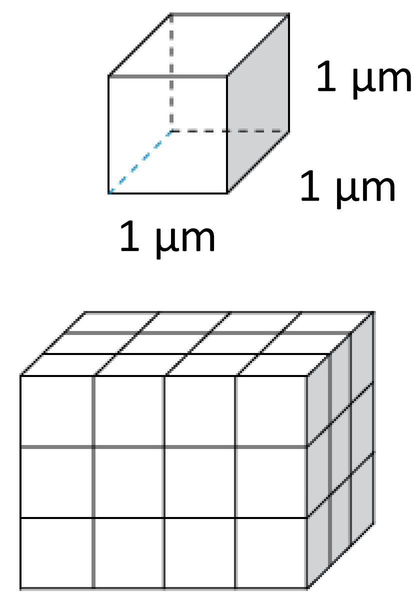
the total specific surface area (the total surface area of all 1 mm cubes) becomes **60 cm^2.**

If further subdivided into cubes of 1 µm per side,

the total specific surface area increases to **6 m^2.**



6 cm^2 **6 m^2.**



It is observed that the finer a particle is fragmented, the greater its specific surface area.

Clays, being the smallest particles, have the highest specific surface area and are the most active particles.

- The specific surface area of **1 gram of sand** = **44.6 cm^2**
- The specific surface area of **1 gram of silt** = **445 cm^2**
- The specific surface area of **1 gram of clay** = **2,200,000 cm^2**

Retention Capacity:

- **1 gram of sand** can retain **5 meq/g** of ions (milliequivalents per gram).
- **1 gram of silt** can retain **15 meq/g** of ions.
- **1 gram of clay** can retain **150 meq/g** of ions.

There is a proportional relationship between particle fineness and their retention capacity for elements.

Soil Properties in Different Textures:

•**Sandy Texture:** A soil is considered sandy if it contains at least 60-65% sand and a maximum of 15% clay. Soils with this texture are called *light soils*. They have low cohesion, are well-aerated, and are highly susceptible to wind and water erosion. Due to their high macroporosity, they allow strong water infiltration but have a low water and nutrient retention capacity.

•**Clayey Texture:** A soil is classified as clayey when it contains at least 40-45% clay.

Clayey soils are characterized by:

- Low infiltration due to their microporosity.
- High cohesion, earning them the name heavy soils.
- High nutrient content.
- Poor aeration and unfavorable physical properties: they are difficult to work when wet due to their plasticity and become compact and hard when dry

Silty Texture: Soils with at least 30% silt and less than 20% clay fall into this category. These soils are rich in nutrients but are generally unfavorable for agriculture due to their low cohesion and poor porosity, as silt particles tend to clog soil pores.

Balanced Texture: This represents an optimal texture, containing a well-balanced proportion of the three soil fractions without significant disadvantages. A soil with a favorable granulometric composition for agriculture typically contains:

•20-35% clay,

•30-35% silt,

•40-45% sand

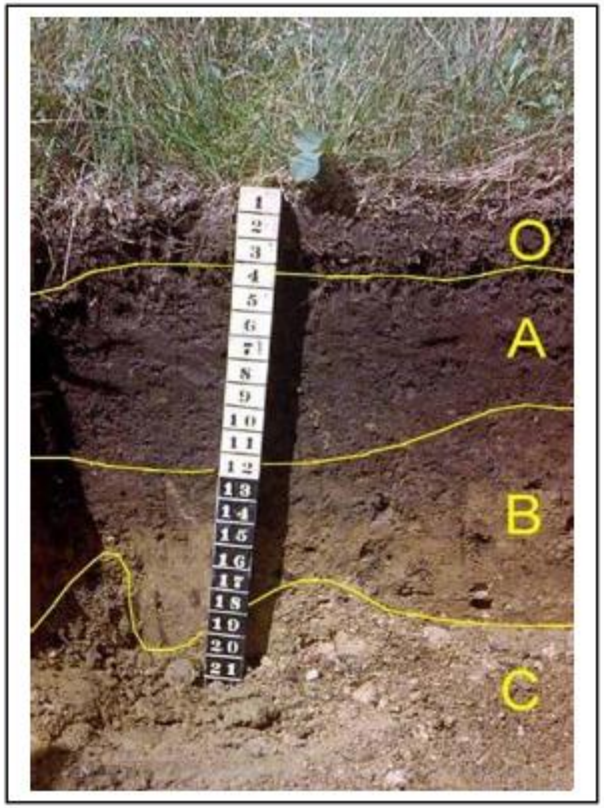
2. Soil Horizons and the Soil Profile:

When digging a trench to observe the soil in a vertical cross-section, it becomes evident that the soil is not homogeneous parallel to the surface. Instead, it is divided into layers or strata of varying thicknesses, called *horizons*, which are generally distinguished by their color and physical, chemical, and biological properties.

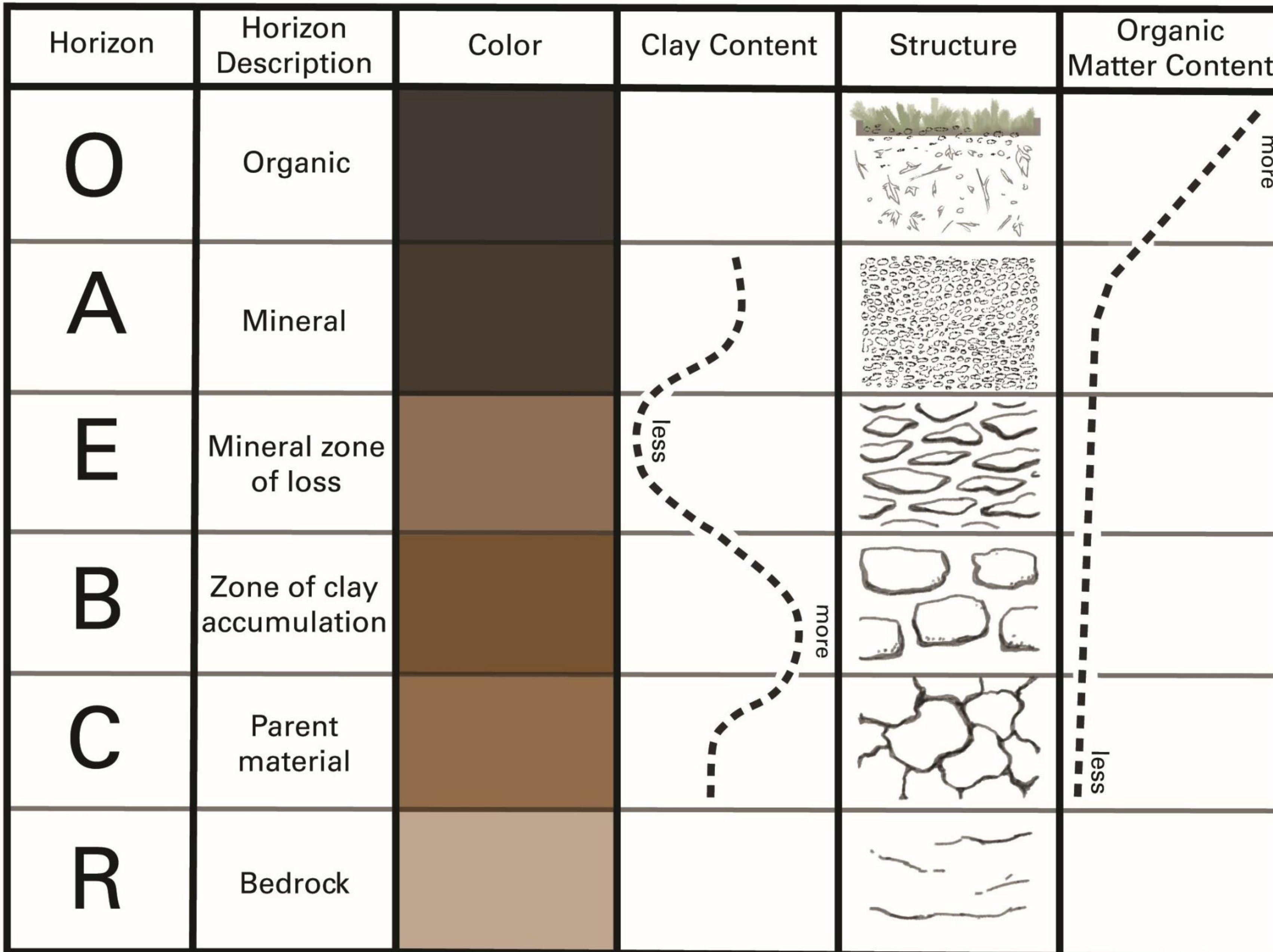
The set of layers or horizons observed in this vertical trench is referred to as the ***soil profile*** or ***solum***. Its depth can range from just a few centimeters (as in lithosols, which are weakly developed and very thin soils) to several meters (as seen in ancient pedological formations).

Soil Horizon: A layer roughly parallel to the soil surface, whose existence is identified by an observer. This horizon is described in the field, analyzed in the laboratory if necessary, and then compared with reference horizons to classify it based on the best-matching criteria.

Reference Horizon or Diagnostic Horizon: An interpretative horizon characterized by a set of quantitatively defined properties. Each reference horizon typically reflects one or more fundamental soil formation processes



Vertical trenches in the soil



Madeline Schill. 2021 in Soils-Iowa's Nature Series.

SOIL LAYERS

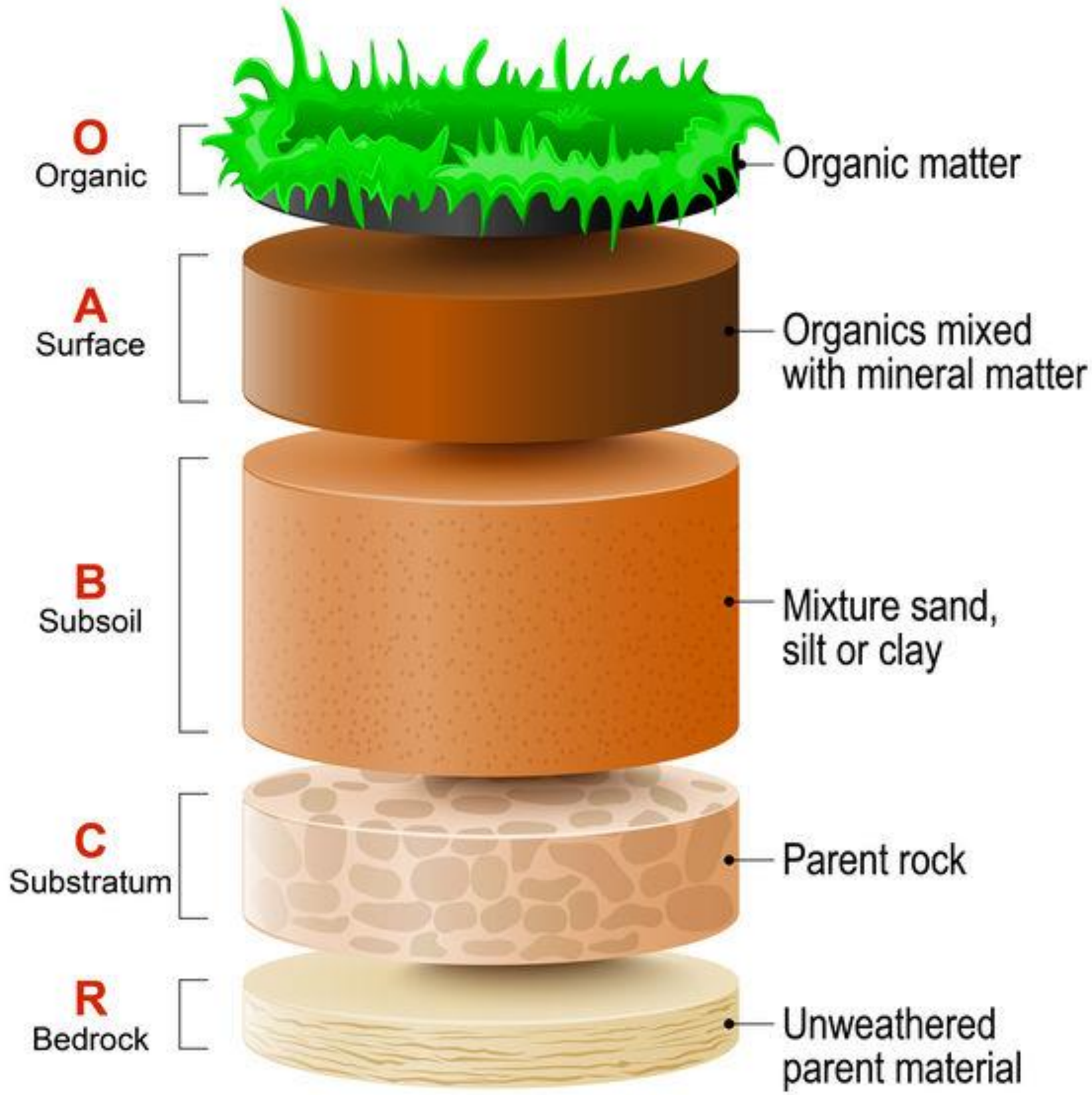

O
Organic
A
Surface
B
Subsoil
C
Substratum
R
Bedrock
Organic matter
Organics mixed
with mineral matter
Mixture sand,
silt or clay
Parent rock
Unweathered
parent material

Tableau Codification des horizons principaux dans le système traditionnel (TRAD) et celui du Référentiel Pédologique (RP).

TRAD	RP	Signification
L (ou A_{00}), F et H (ou A_0)	O_L, O_F, O_H	Horizons très organiques des milieux forestiers drainés (avec L pour Litière, F pour couche en Fermentation, H pour couche en voie d'Humification) ; pour les Américains, tout cela correspond à un horizon Folique (avec feuilles).
–	H	Horizons très organiques des milieux humides (Cf. horizons Histiques – voir Histosols).
A	A	Horizon organo-minéral de surface avec organismes vivants et/ou traces d'activité biologique.
A2	E	Horizon presque exclusivement minéral, appauvri en fer, matière organique, ou argile et souvent blanchi (E pour « éluvial »).
(B)	S	Horizon minéral représentant un stade d'altération limité par rapport à la roche mère dont certains caractères sont encore visibles (pendage, minéraux…) ; les marques d'évolution sont : une couleur spécifique (expression du fer) et/ou une structure d'origine pédologique et non pas géologique (prismes, polyèdres…).
B	B	Horizon où se concentrent certains éléments tels que fer, argile, humus, sels ou carbonates secondaires mais où les carbonates primaires ont disparu.
C	C	Horizon de la base du sol ; il est déjà soumis à l'influence des agents atmosphériques ; il présente une fissuration liée à des alternances de dessiccations – humectations et une oxydation partielle ou légère liée à la pénétration de l'oxygène. En revanche, sauf mention explicite contraire (ex : C_{ca}), il est dépourvu des accumulations observées typiquement en B.
–	D	Matériel parental transformé mais qui ne présente pas les traces de météorisation intervenant dans le C ; par exemple : arène granitique, éboulis calcaire, moraine (voir altérites, chap. 2).
R	R	Correspond à la roche dure non altérée et non fragmentée ; elle est appelée « roche mère » quand elle est à l'origine du sol qui la surmonte.
(g)	Go	Présente des traces d'oxydation et de réduction du fer (hydromorphie) dans un contexte où les phénomènes de réduction ne sont pas dominants (Go = gley oxydé).
(G)	Gr	Phénomènes de réduction affirmés ; G = gley et Gr = Gley réduit ; taches grises, bleutées, blanchâtres voire verdâtres.

(g) et (G), mis entre parenthèses, sont bien équivalents à Go et Gr mais ils apparaissent en tant que suffixes et pas en temps qu'horizons majeurs ; cela matérialise le fait que l'on a parfois le choix entre considérer l'hydromorphie comme une caractéristique accessoire (ex : horizon Ag, Bg ou Cg) ou alors majeure donnant son appellation à l'horizon qui devient Go ou Gr, qu'il soit par ailleurs de type A, B ou C.

Main Reference Horizons:

Generally, horizons are symbolized by a capital letter, and in exceptional cases, this capital letter reflects their essential characteristics . They may be subdivided into sub-horizons using a second or even a third capital or lowercase letter, or a number indicating more subtle properties.

In a given soil, not all the horizons listed in the previous table are necessarily present. For example, profiles of the type AR or A (B) C may be encountered.

If multiple horizons of the same type follow one another, they are numbered sequentially.

For example, a profile may develop as A, B1, B2, C. If a horizon exhibits intermediate characteristics between two horizons, it is identified using both letters. For instance, an AB or BA horizon may be observed, with the order of the letters indicating whether it more closely resembles horizon B or horizon A.

Horizon O

The organic horizon (or humus) results from the transformation of plant debris accumulating on the soil surface into organic matter.

Horizon A

Horizon A contains both organic and mineral matter. It is the result of the activity of living organisms in the soil (worms, insects).

Horizon B

This horizon is enriched with various mineral or organic constituents: clay, iron, organic matter, calcium carbonate, etc. It forms through the transformation of primary minerals derived from the underlying rock.

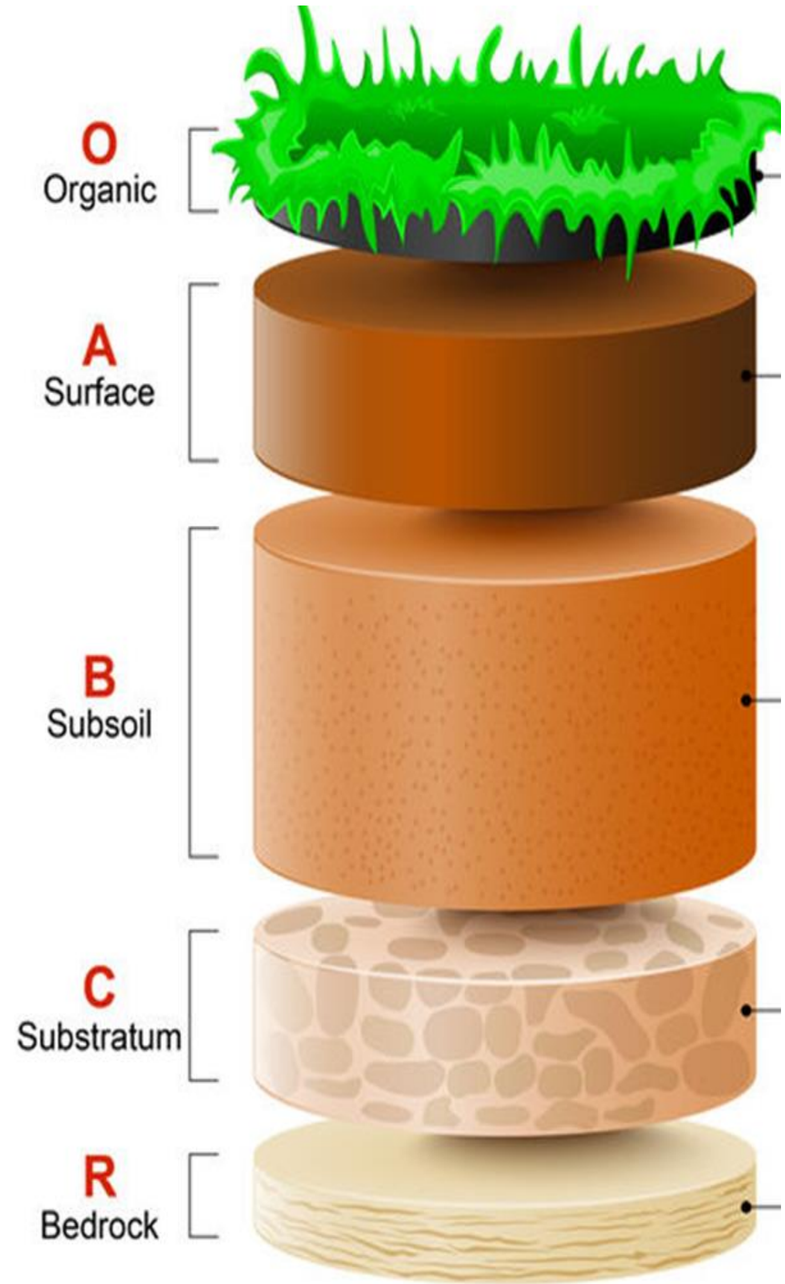
Horizon C

This is the horizon of weathering of the underlying parent rock.

Horizon R or M

This is the parent rock, classified based on its hardness.

- **R** for hard rocks (granite, sandstone, limestone).
- **M** for soft rocks (sand, marl, etc.).



Four mechanisms contribute to the formation of soil horizons.

These mechanisms work together, and due to variations in moisture, temperature, and biological activity, there is a continuous transformation of the physical, chemical, and mechanical properties of soil constituents. This leads to the transfer of mineral, liquid, gaseous, and organic materials.

1.Rock weathering and constituent alteration mechanism.

2.Biological mechanisms and organic matter accumulation.

3.Release, migration, and accumulation mechanism of constituents resulting from rock weathering and organic matter transformation.

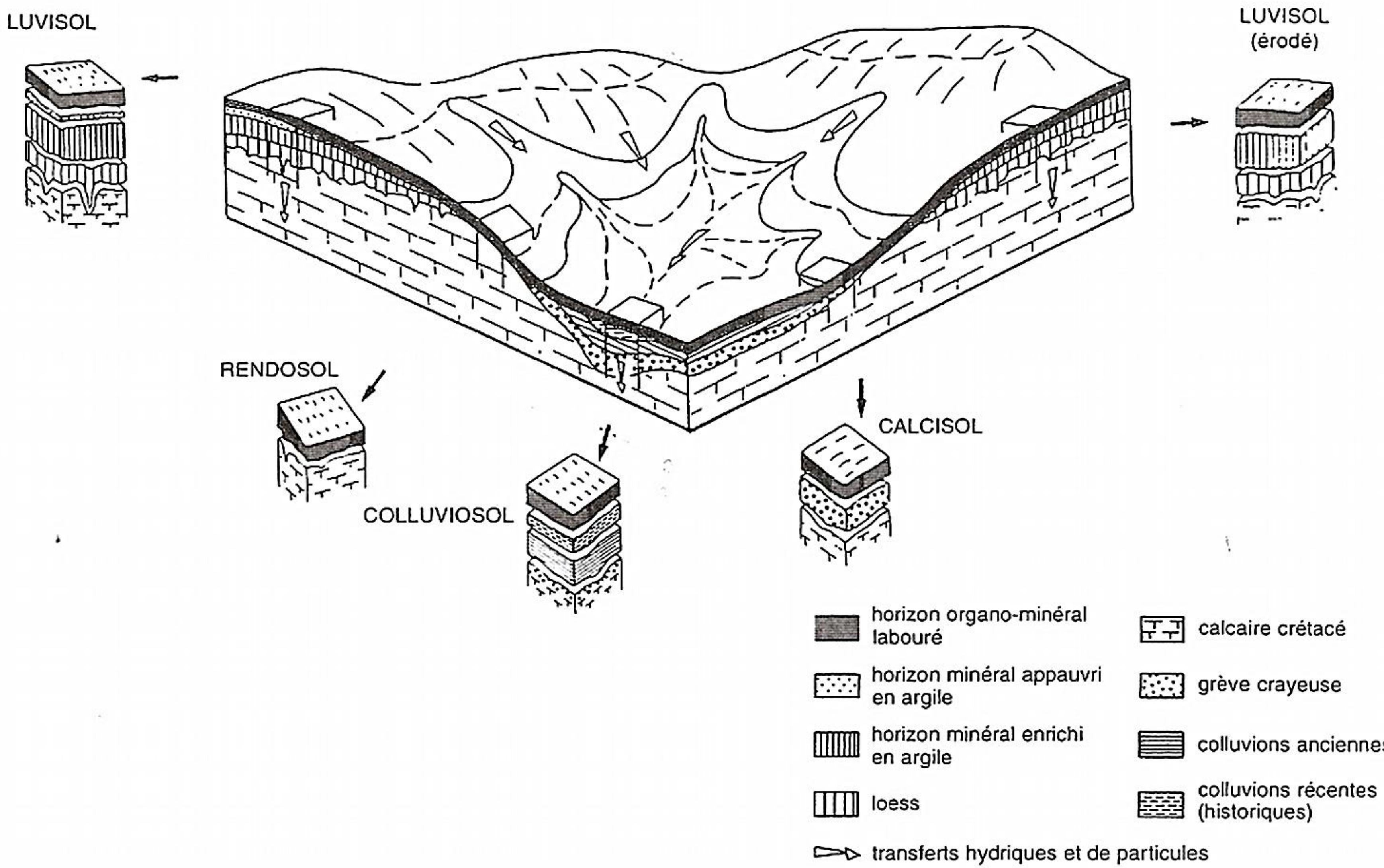
4.Arrangement and aggregation mechanisms of altered constituents, which are then repositioned through migration.

Soil Cover (pedological cover)

The term **soil cover** (used in the singular or plural) refers to the soil or soils that more or less continuously cover the Earth's surface.

- Located between the Earth's crust (the upper part of the lithosphere) and the atmosphere, the soil cover is constantly evolving.
- The soils that compose it are heterogeneous pedological volumes that continuously transform in different ways, depending on geographical location, slope position (upstream or downstream), forested or plain environments, the nature of the parent rock (shale, limestone, granite, etc.), climate, or human activities.
- Whether continuous, reduced, or discontinuous, the soil cover can thicken, be submerged, covered by vegetation, or undergo erosion.

PAYSAGE LIMONO-CRAYEUX DE PICARDIE



Soil and Water

Soil water plays a crucial role in plant nutrition. It is involved both directly and indirectly, serving as a medium for dissolving and transporting nutrients and facilitating various metabolic reactions. Additionally, it is a key factor in **pedogenesis**, influencing most soil formation processes.

The main sources of soil water include:

•**Precipitation water** (including irrigation water)

•**Groundwater** (a permanent water table replenished through underground flow)

States of Water in Soil

Soil water can exist in three different states, classified based on how strongly the soil retains it and its availability to plants:

1.**Gravitational water** – Drains freely through large pores under the influence of gravity.

2.**Available water** – Held in the soil and accessible for plant uptake.

3.**Unavailable water** – Strongly bound to soil particles, making it inaccessible to plants

Soil Atmosphere (Soil Air)

Soil air is a **variable gas mixture** whose composition changes over time and space.

These variations depend on:

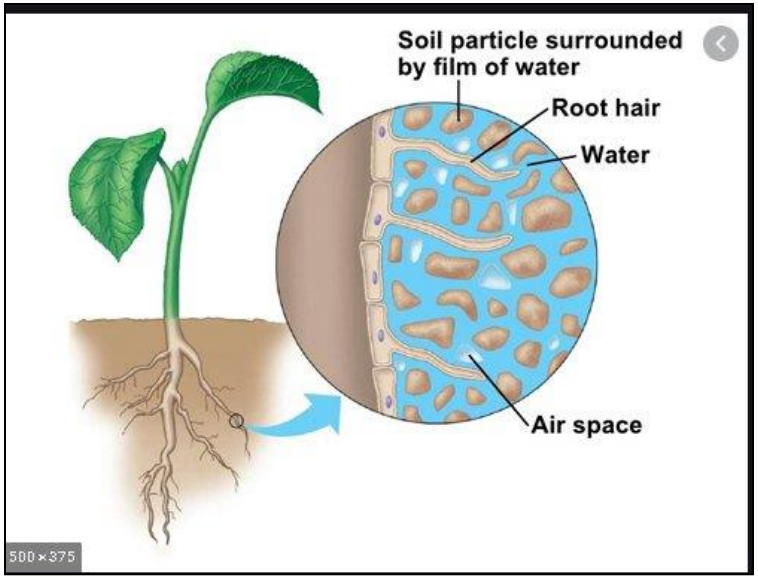
•The intensity of **biological activity** from various soil organisms.

•The **quality of gas exchange**, which regulates oxygen supply and the removal of carbon dioxide produced by respiration.

Efficient gas exchange is essential for maintaining soil health, supporting root respiration, and sustaining microbial activity.

1. Soil Air Occupies All Pores Not Filled by Water

When a water-saturated soil **drains**, air fills the spaces left by **gravitational water**. At **field capacity**, air primarily occupies the **macropores**. As soil moisture continues to decrease, air gradually infiltrates the **micropores**.



Factors Affecting Soil Air Content:

•**Texture** → Influences **microporosity** (small pores).

•**Structure** → Determines **macroporosity** (large pores).

•**Soil Moisture** → Regulated by both **texture and structure**.

Soil aeration is **critical** for root respiration and microbial activity, ensuring adequate **oxygen supply** and **carbon dioxide removal**.

2. Composition of Soil Air

Soil air has a **less stable composition** than atmospheric air. A comparative analysis shows:

•**Nitrogen (N_2)** → Similar levels in both soil air and atmospheric air.

•**Oxygen (O_2)** → Lower in soil air due to **root respiration and microbial activity**.

•**Carbon dioxide (CO_2)** → Higher in soil air because of **biological decomposition and respiration**.

These variations depend on **soil moisture, aeration, and biological activity**, influencing **plant growth and microbial processes**.

一、Composition of soil air

Compare soil air with atmosphere（Volume %）

Atmosphere	O_2	CO_2	N_2	Other gases
Atmosphere near soil surface	20.94	0.03	78.05	0.95
Soil air	18.0-20.03	0.15-0.65	78.8-80.24	—

30 cm		90 cm		150 cm	
CO_2	O_2	CO_2	O_2	CO_2	O_2
1,2	19,4	6,6	3,5	10,4	2,4
1,9	18,65	7,85	0,25	—	—
1,7	19,25	5,35	16,4	10,95	2,1
2,4	19,0	5,0	16,7	11,85	12,95

Causes of Variations in Soil Oxygen (O_2) Levels

1. Oxygen Supply in the Soil

Oxygen enters the soil through:

- **Diffusion from the atmosphere** → Main source of oxygen.
- **Dissolved oxygen in rainwater** → Contributes to soil aeration.
- **Aerenchyma tissues in certain plants (e.g., rice)** → Transport oxygen from leaves to roots.
- **Oxygen release by photosynthetic algae** → Occurs in waterlogged soils.

2. Oxygen Consumption in the Soil

Oxygen is depleted due to:

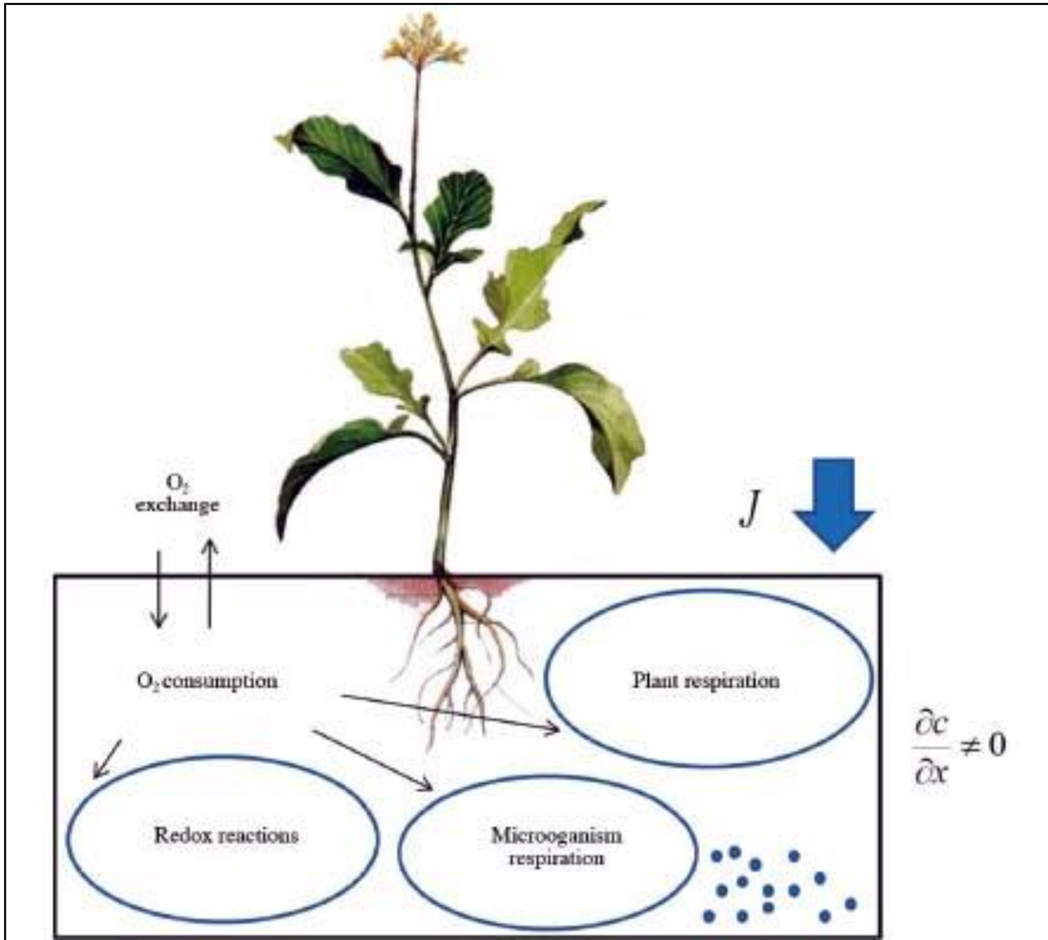
- **Soil microorganisms and fauna respiration** → Accounts for nearly **⅔ of total consumption**.
- **Root respiration** → Consumes about **⅓ of total oxygen**.
- **Oxidation of rocks and minerals** → Minimal contributio

3. Importance of Gas Exchange in the Soil

Two key gases influence soil gas exchange:

- **Oxygen (O_2)** → Essential for **root respiration, microbial activity, and oxidation reactions**.
- **Carbon dioxide (CO_2)** → Produced by **respiration** and used by **certain bacteria** for organic synthesis.

These gas exchanges **directly affect soil aeration, plant growth, and microbial ecosystems**



Soil Temperature:

The majority of the heat energy that the soil receives comes from **solar energy** (estimated at an average of **144 calories/day/cm^2** in temperate climate regions). It varies significantly depending on **latitude, season, exposure, and vegetation cover**. During the day, the heat energy received **raises the soil temperature and evaporates retained water**, whereas at night, the soil **cools down through radiation.**

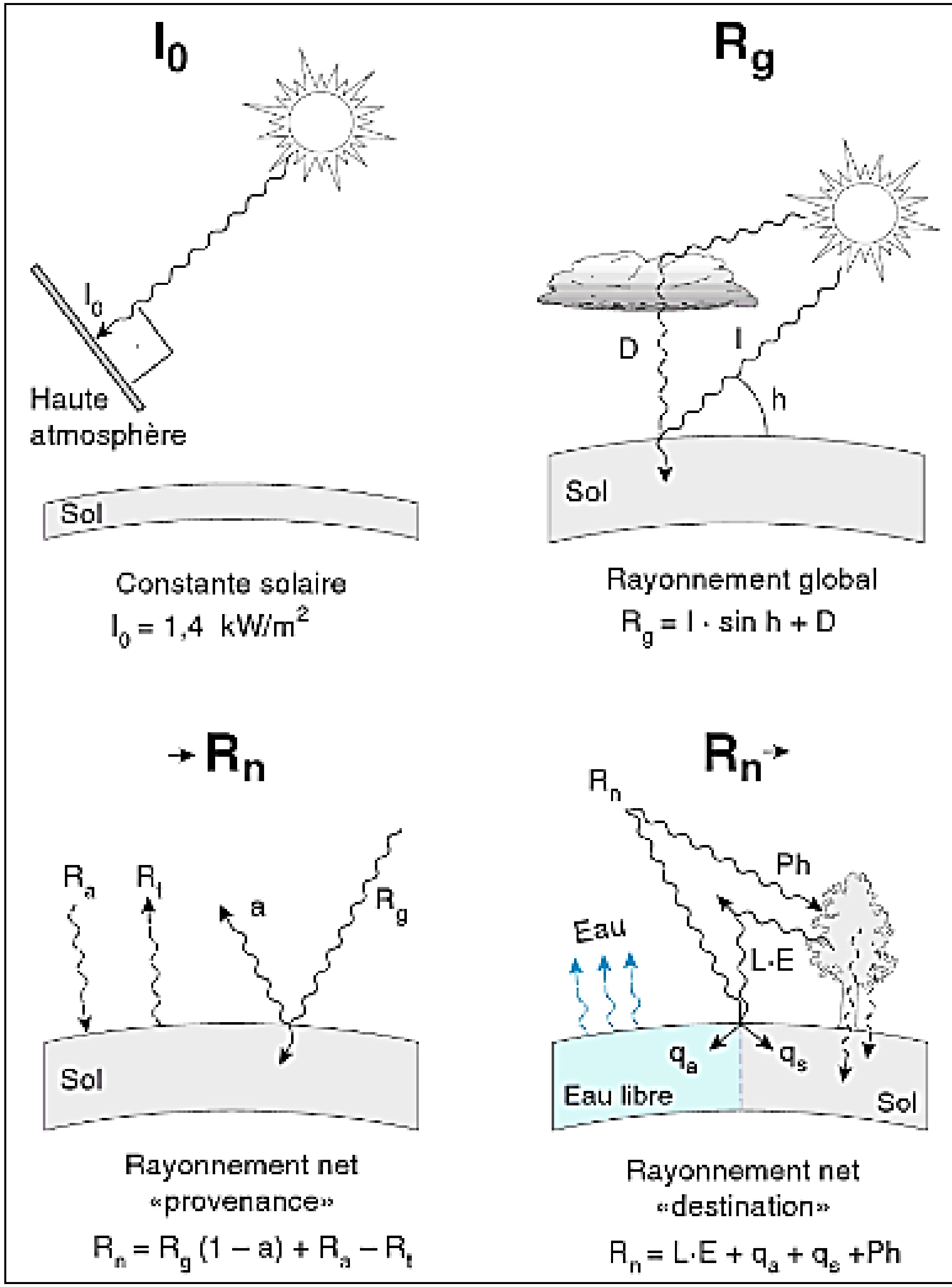
Solar Energy:

The initial flux of solar energy is the **solar constant**, which includes all wavelengths between **200 and 4000 nm**. **Thermal infrared** radiation between **700 and 1000 nm** primarily affects the soil, while **visible light** between **400 and 700 nm** is essential for living organisms.

The fraction of the solar constant that actually reaches the soil, either directly (**I**) or diffusely (**D**), is called **global radiation (Rg)**. This radiation depends on the **angle (h) of the solar rays with the soil**, which is influenced by **latitude and time of day**.

It is one of the components of **net radiation (Rn)**, which is distributed in four forms within the ecosystem (Fig):

- •**LE**: Energy used for evaporation or released through water condensation.
- •**Qa**: Heat transfer by convection and diffusion in a liquid medium.
- •**Qs**: Heat transfer by conduction and diffusion in a solid medium.
- •**ph**: Energy absorbed for photosynthesis



Factors Affecting Superficial Soil Heating:

When measuring the temperature of different soils within the same region and at the same time, significant variations can be observed. Three key factors influence these variations:

Soil Color – Dark-colored soils heat up faster than light-colored soils.

Water Content – This plays a crucial role. The heat capacity of water is four to five times higher than that of air or solid soil particles. As a result, a much greater amount of heat is required to raise the temperature of a water-saturated soil compared to a dry soil. Sandy or calcareous soils, which dry out quickly, are considered "warm" soils, whereas poorly drained or peat soils are classified as "cold" soils

Vegetative Cover – This factor significantly affects soil temperature. Forests provide greater thermal regulation than grasslands. A dense forest floor can be 8 to 10°C cooler than bare soil during summer. On hot, sunny days, the temperature of bare soil can exceed 50°C in temperate climates and reach 60 to 70°C in tropical climates.

Soil color

is a property that is indicative of iron oxide presence or absence, which varies according to the mineral type or proportions between them.

Soil colors are used to infer pedogenic processes in soils. The main pigmenting (coloring) agents in soils are organic matter, iron, and, to a lesser extent, manganese. When these agents are not covering the mineral grains, the natural color of the grains is visible.

Most mineral grains are naturally gray. The contrast of color is shown in Figures A and B, where two soils have similar texture and structure yet differ in color scheme. When a soil horizon has more than one color, the dominant color by volume is the matrix color.

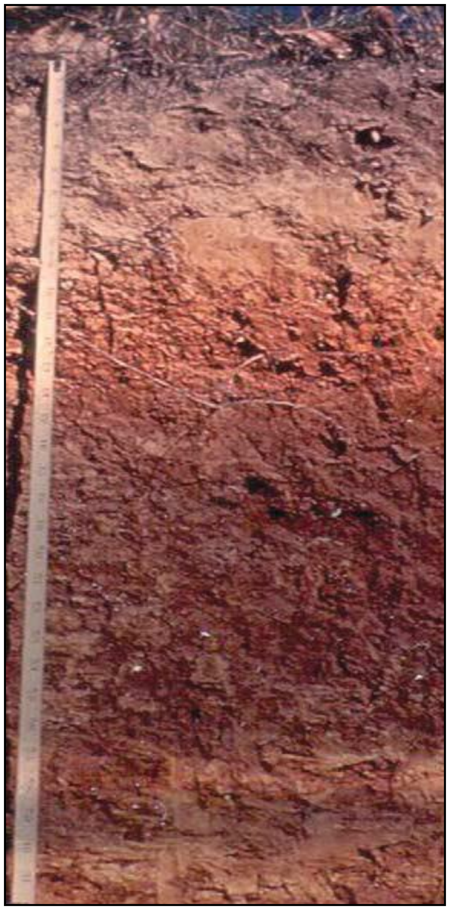


Fig A. Highly developed soil in a well-drained convex position.

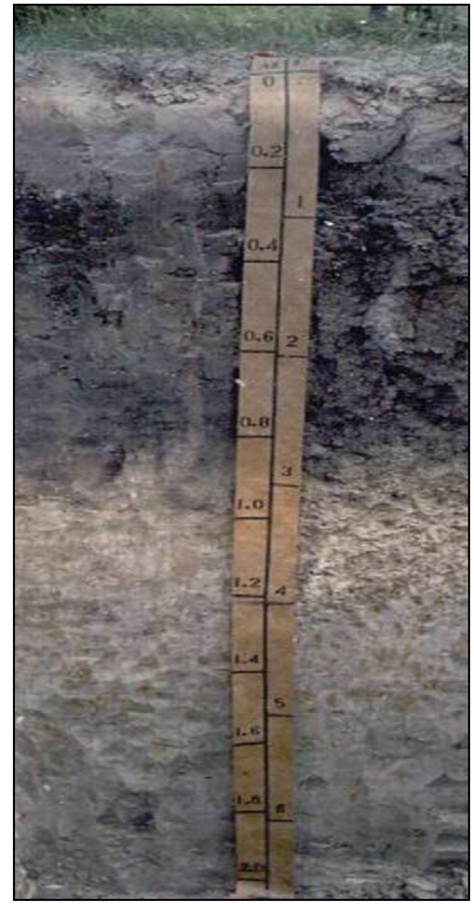


Fig B. Highly developed soil In a poorly-drained concave position.