

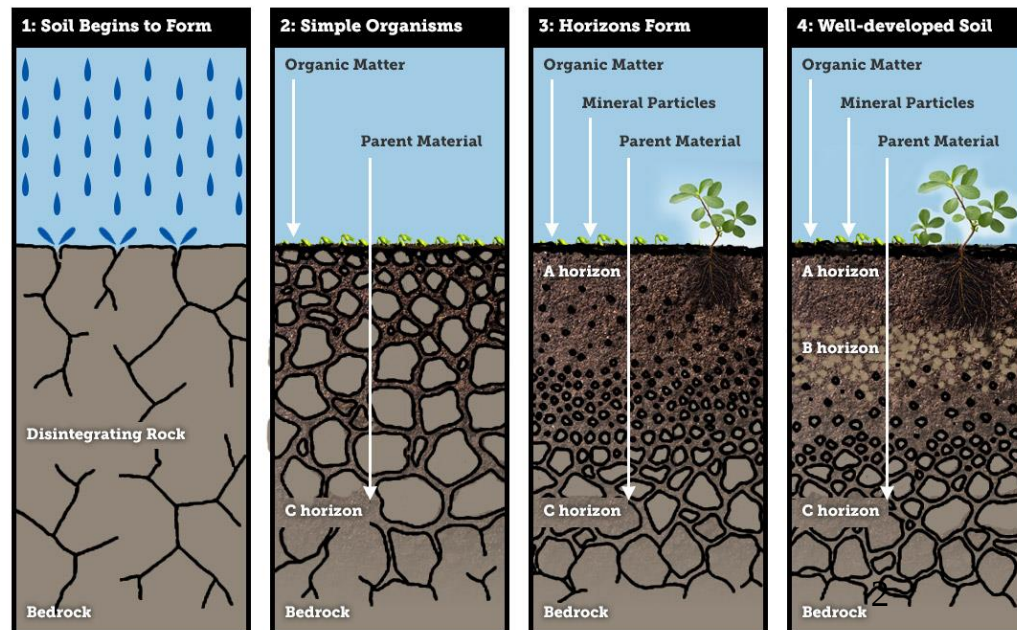
Introduction to soil chemistry

Part I: Introduction - What are soils?

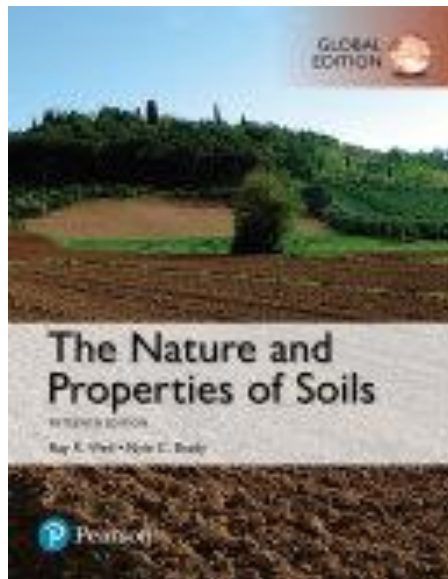
Dr. habil. Marie Spohn

Outline of the lecture

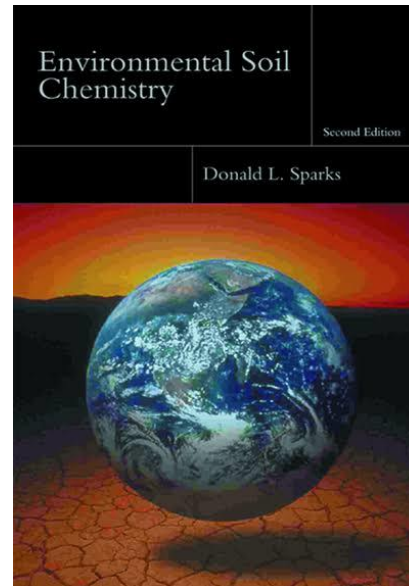
1. Introduction: What are soils?
2. Minerals and Rocks
3. Weathering
4. Biogenic weathering
5. Soil organic matter
6. Chemical reactions and chemical equilibrium
7. Soil enzymes
8. Ion exchange
9. Soil acidity and buffer agents
10. Redox reactions
11. Nitrogen
12. Phosphorus
13. Potassium
14. Magnesium
15. Calcium
16. Trace elements



Textbooks



**By R.R. Weil and
N.C. Brady**



By D. L. Sparks

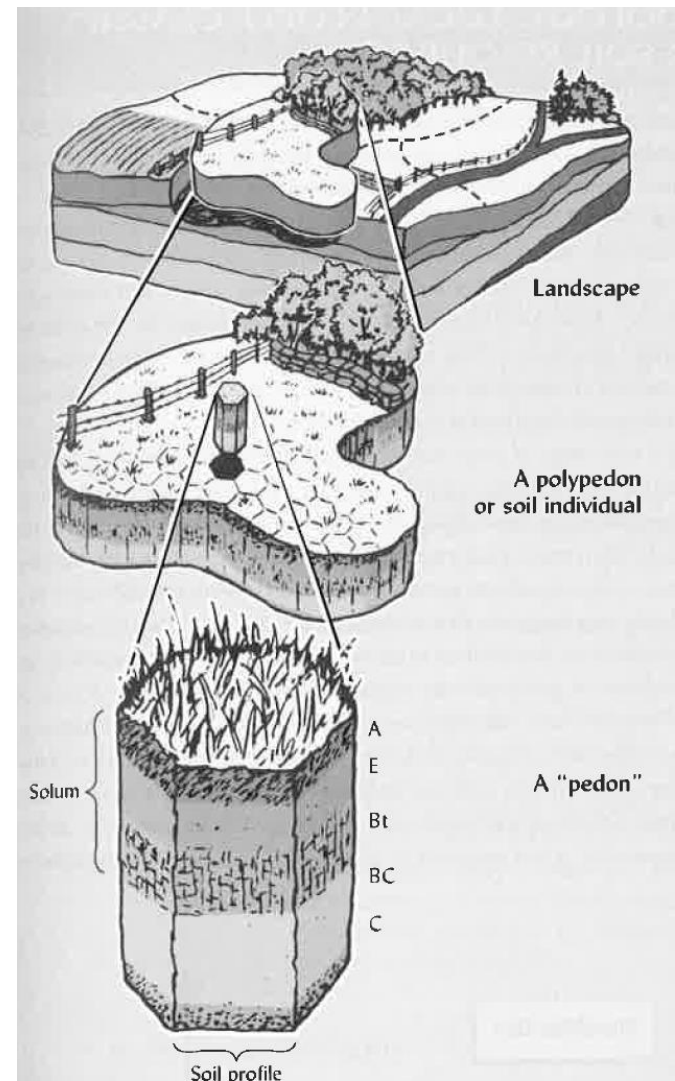
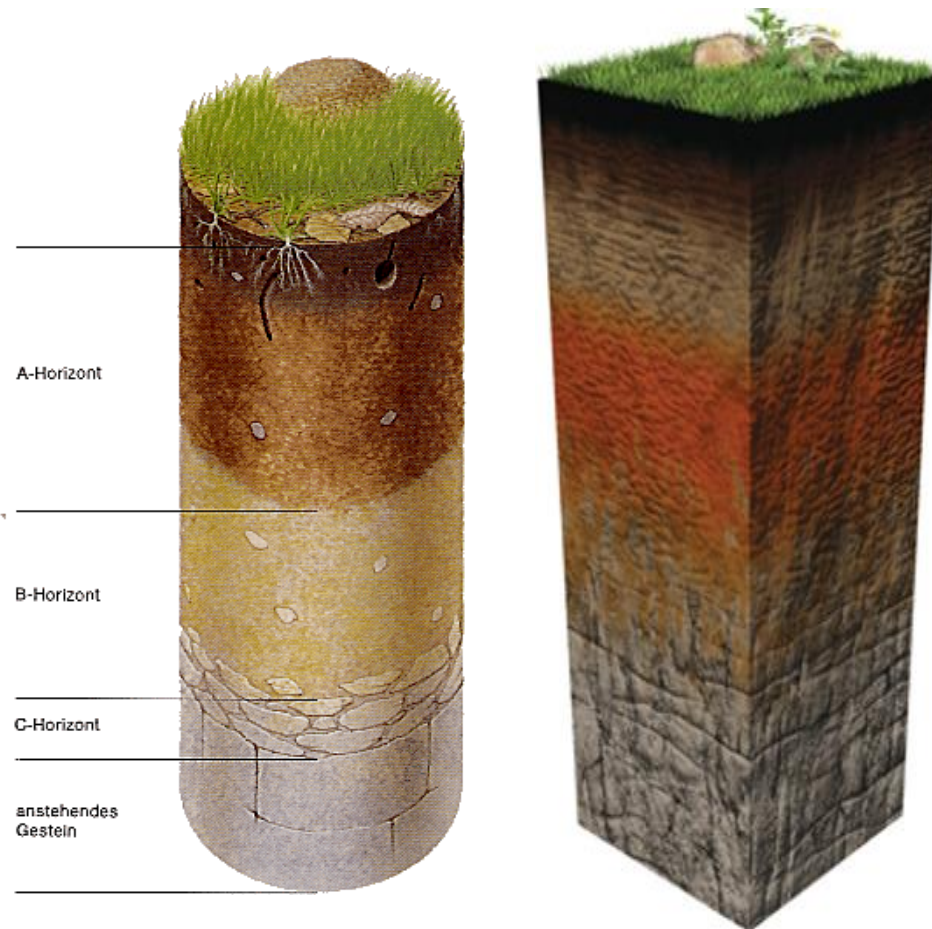


**By Scheffer and
Schachtschabel**

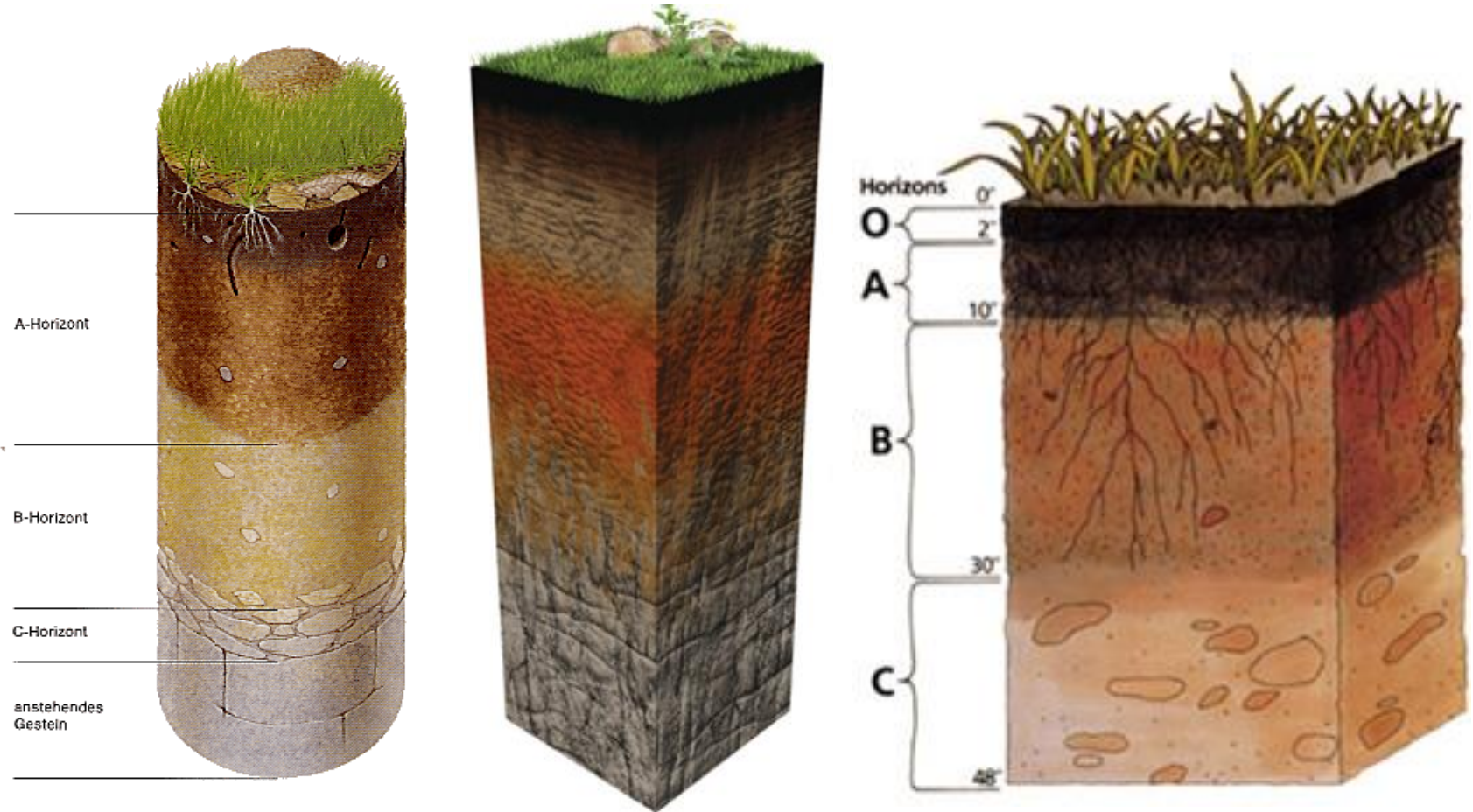
Overview – What are soils

- Definition
- Components
- Soil forming factors
- Soil forming processes
- The function of soils in landscape

The soil pedon – A section of a landscape

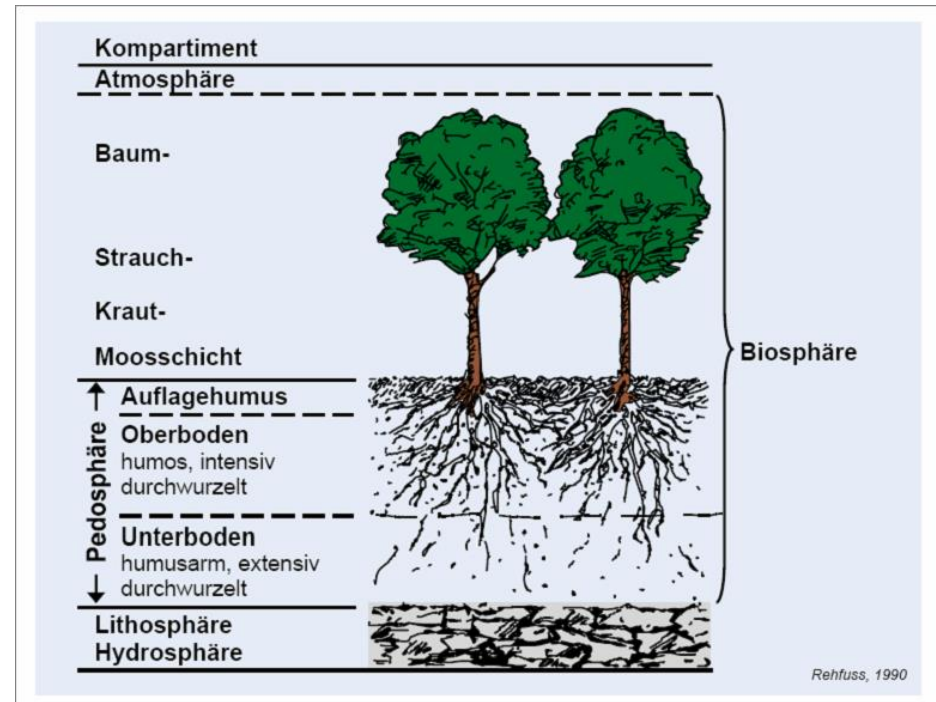
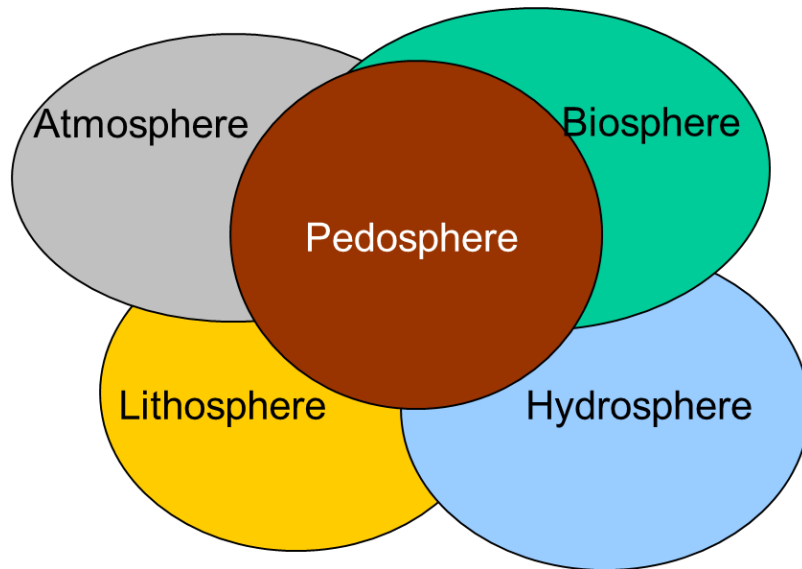


The soil pedon – A section of a landscape



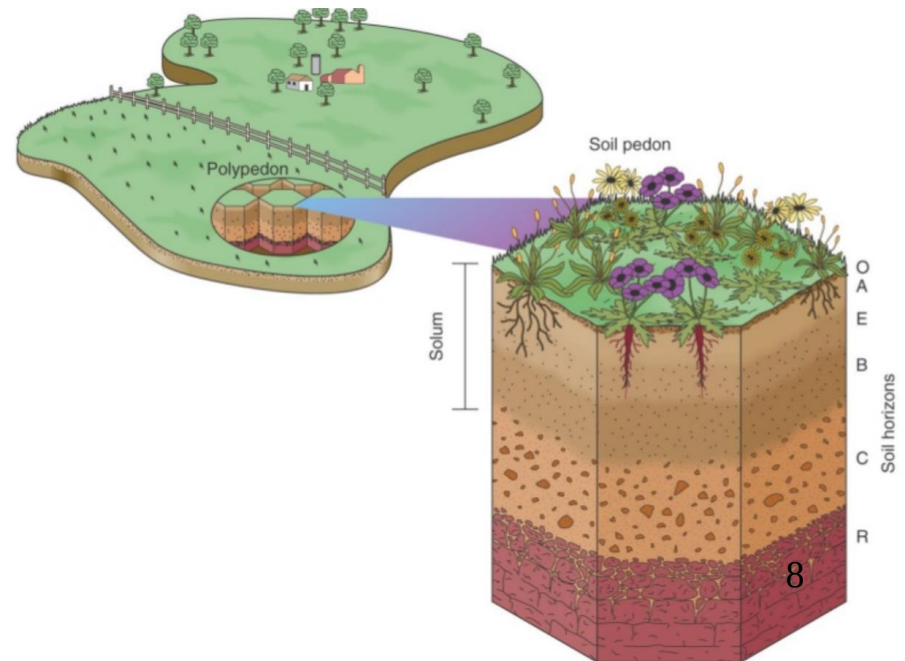
Definition

Soil constitutes the interphase at the Earth's surface, in which the lithosphere, the hydrosphere, the atmosphere and the biosphere overlap. Soil has formed during time under the influence of several environmental factors.

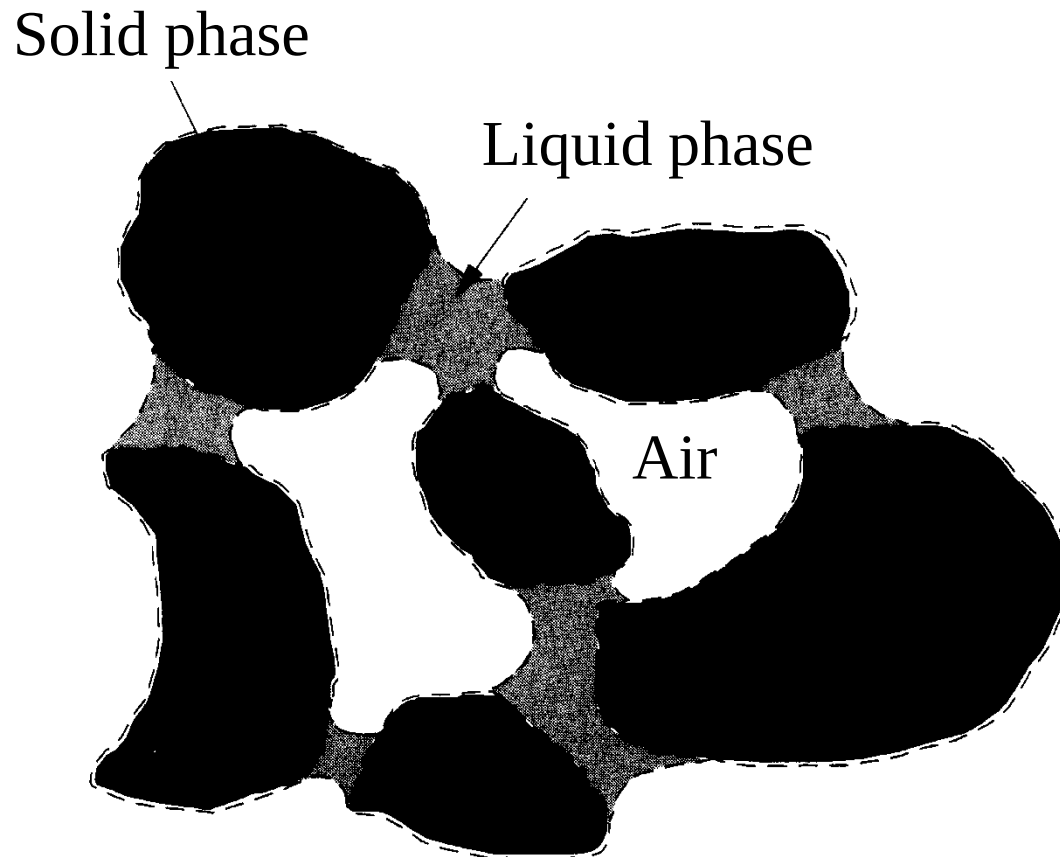


Some terms

	Explanation
Pedosphere	The total soil cover that forms a continuum
Pedon	Column of a soil
Horizon	More or less horizontal section of a soil that is formed through soil forming prozesses
Soil order/ Soil type	Soil with the same pedogenic properties that differ characteristically from other soils



Soil consists of three phases



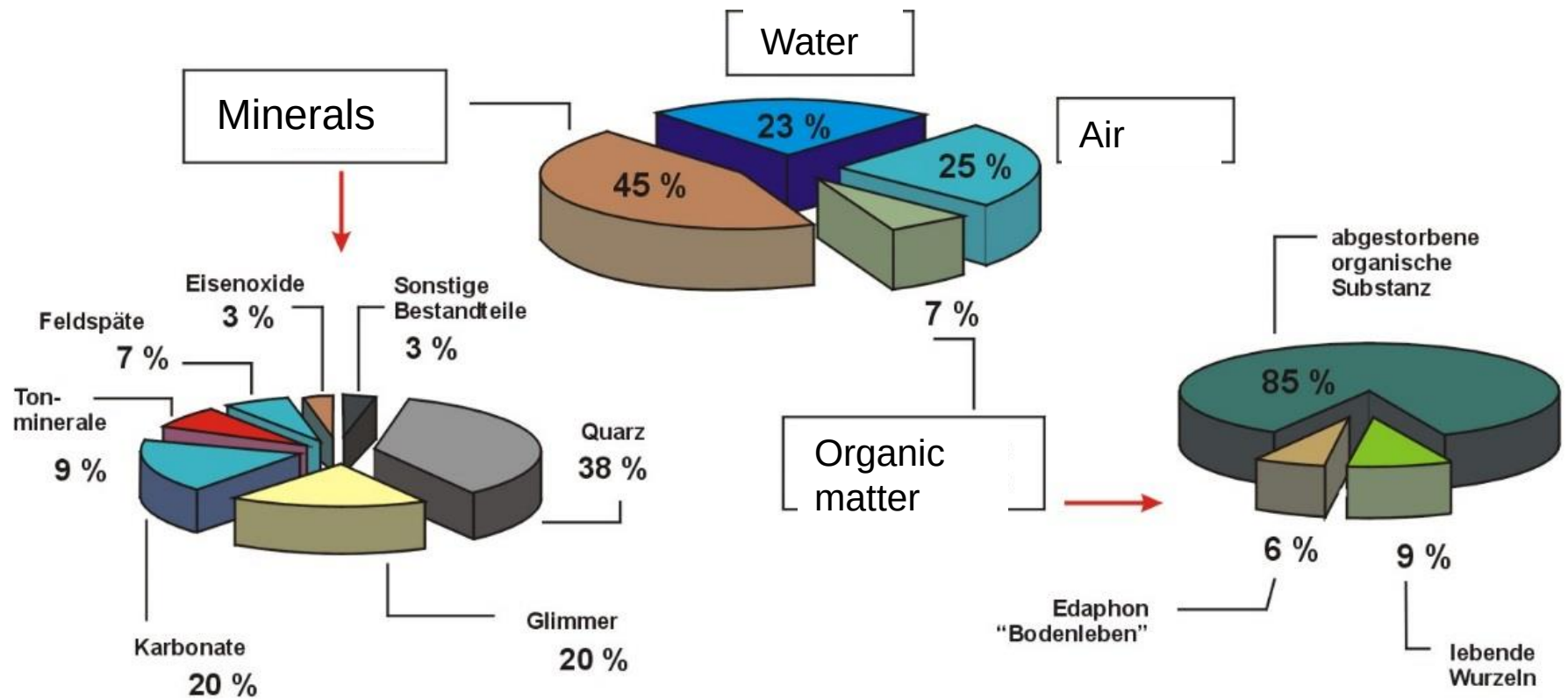
The solid phase of soils

- Mineral component (quantitatively dominating)
 - Stones, primary minerals, secondary minerals, amorphous substances
- Organic component
 - Soil organic matter, debris of animals and plants

Can be characterized:

- Physically (density, particle size distribution)
- Chemically
- Biologically (Archea, Bacteria, Protozoa, Animals)

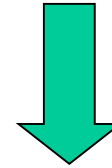
The components of soil



Pedogenesis = Soil formation



Soil forming factors



Soil forming processes

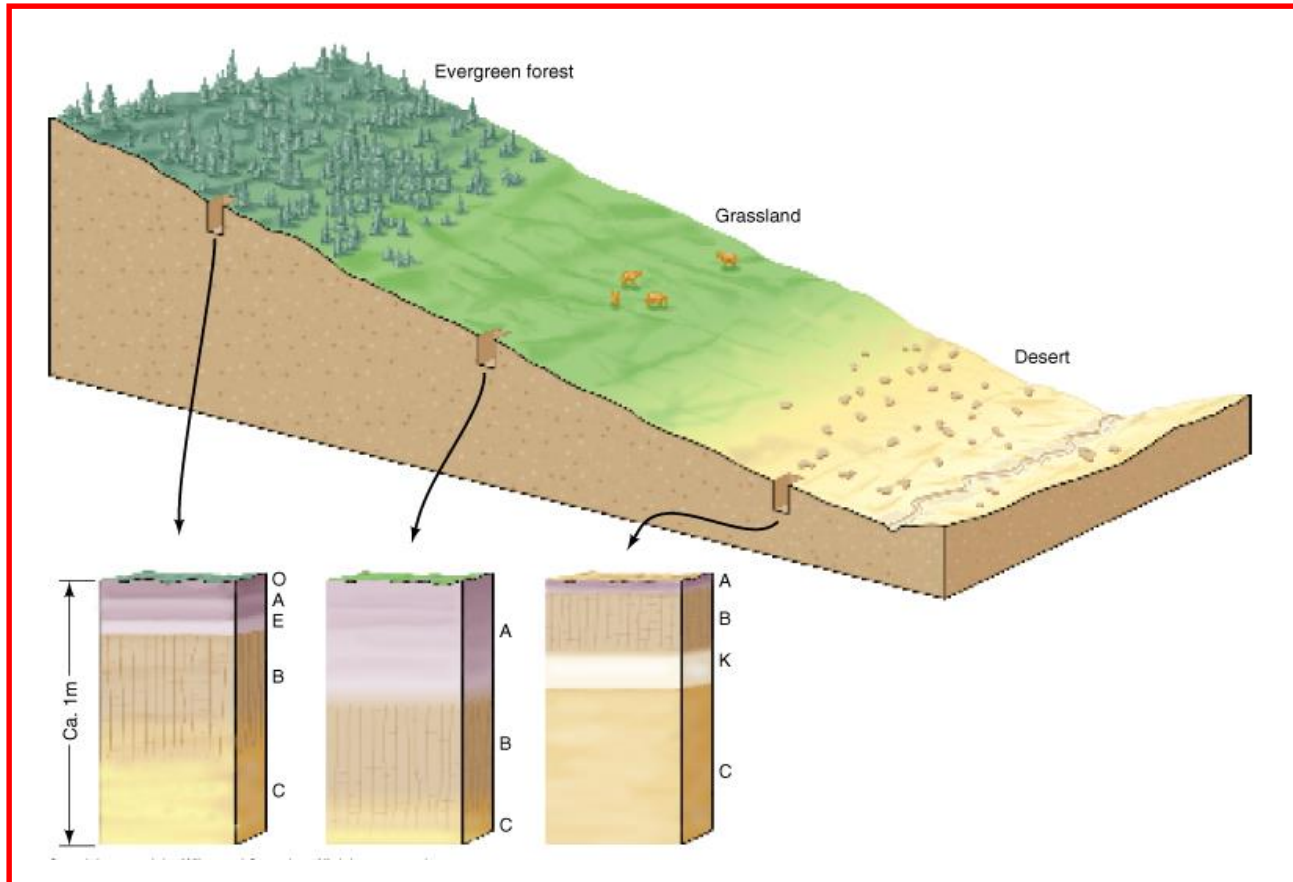


Soil horizons



Soil types/soil orders

Factors of soil formation



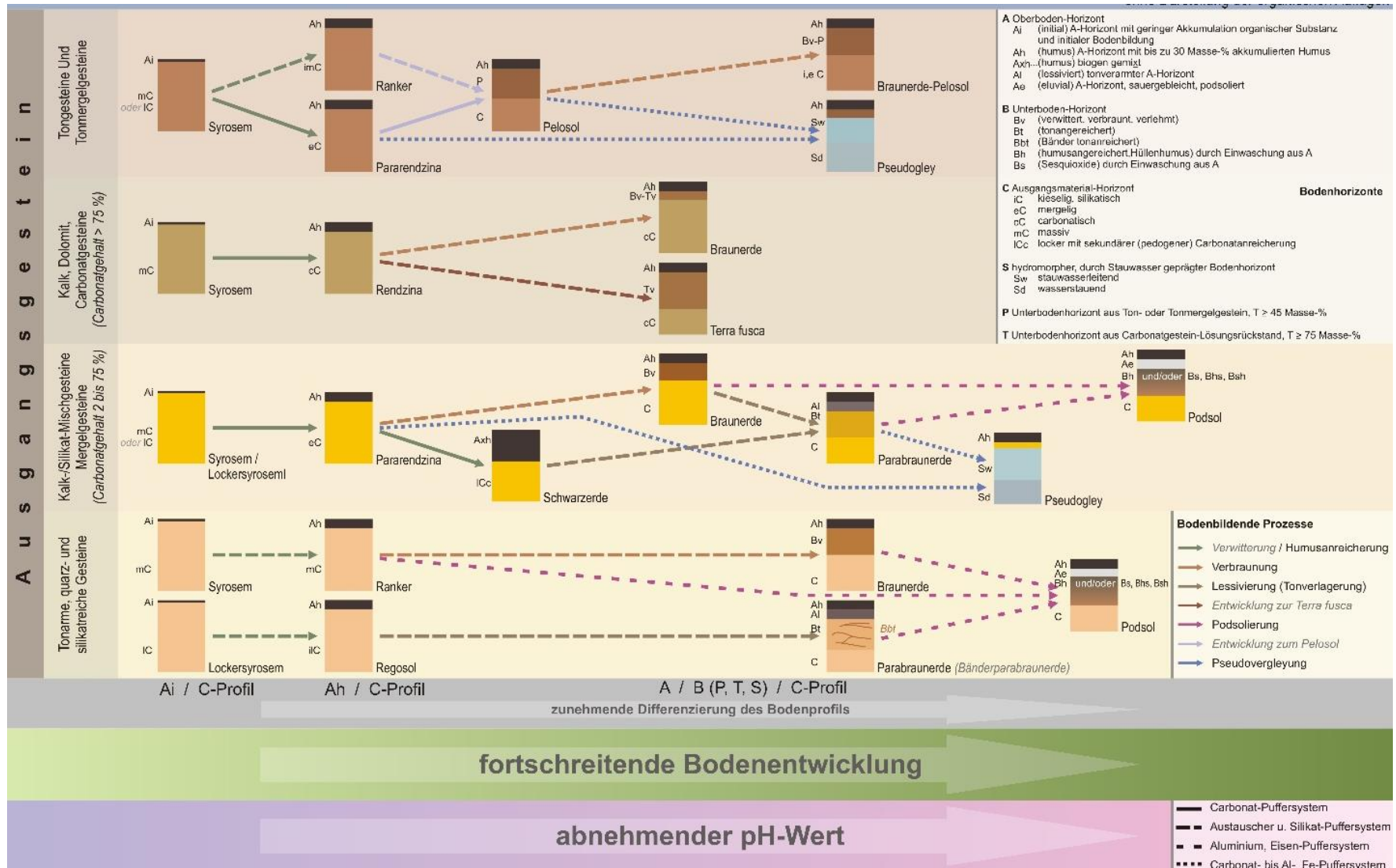
Factors of soil formation:

- Parent material/bedrock
- Relief
- Climate
- Water
- Soil organisms
- Time
- Humans

Soil forming factors I

- **Parent material/bedrock**
 - Different mineral composition and resistance to weathering, different element composition

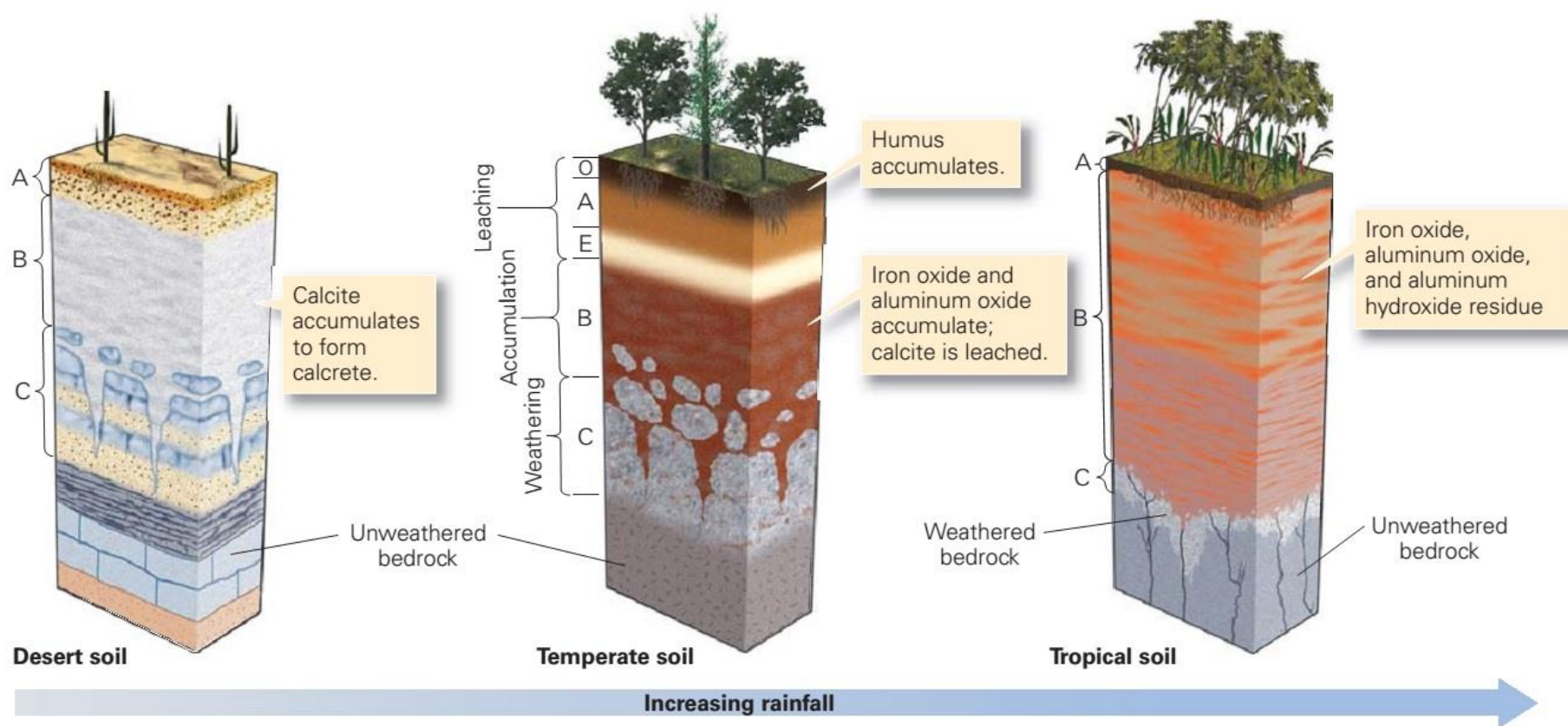
Soil forming factor parent material



Soil forming factors I

- **Parent material/bedrock**
 - Different mineral composition and resistance to weathering, different element composition
- **Climate**
 - Temperature affects the rates of (bio-) chemical reactions
 - Precipitation affect transport of matter, erosion, and weathering
 - Wind can cause erosion

The soil forming factor climate



(a) Aridisols form in deserts. Rainfall is so low that no O-horizon forms, and soluble minerals accumulate in the B-horizon.

(b) Alfisols form in temperate climates. An O-horizon forms, and less-soluble materials accumulate in the B-horizon.

(c) Oxisols form in tropical climates where percolating rainwater leaches all soluble minerals, leaving only iron- and aluminum-rich residues.

The soil forming factor climate

Precipitation	Clay	CEC	pH	Soil order
mm a ⁻¹	%	cmol _c kg ⁻¹		
370	15	12	7,8	Kastanozem
500	19	16	7,0	Chernozem
750	23	24	5,2	Phaeozem
900	26	27	5,2	Phaeozem

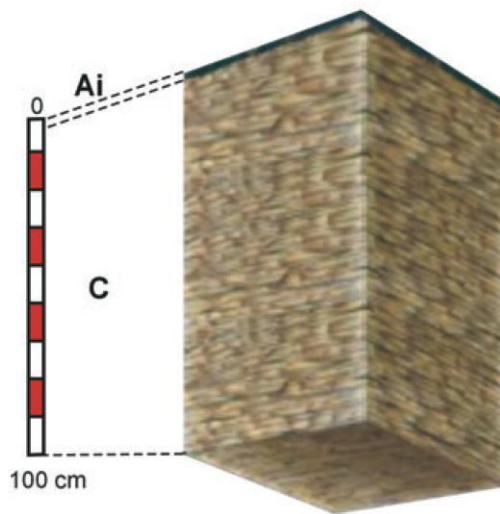
Soil forming factors II

- **Relief/Topography**
 - Affect water balance, transport of matter, erosion rates, soil temperature
- **Soil organisms**
 - Affect the accumulation and the transformation of organic matter
 - Vegetation affects the microclimate
 - Uptake of water and nutrients affect transport processes

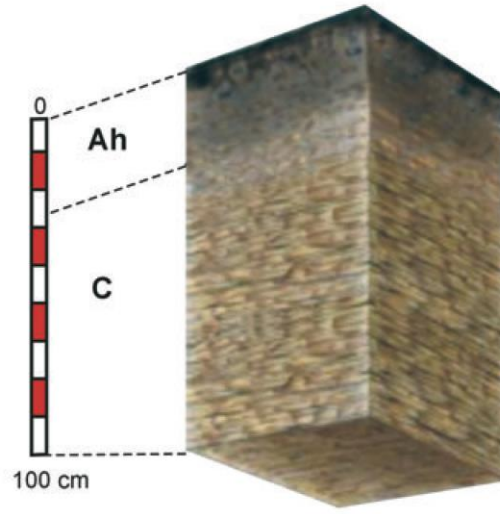
Soil forming factors III

- **Humans**
 - Affects soil formation through cultivation and tillage as well as constructions and element inputs
- **Time**
 - Controls the duration during which other factors exert their influence
 - Decades: Incepticols (initially developed soils)
 - Thousands of years – Many parts of the temperate zone that were galciated
 - Million of years - Tropics (that were not glaciated)

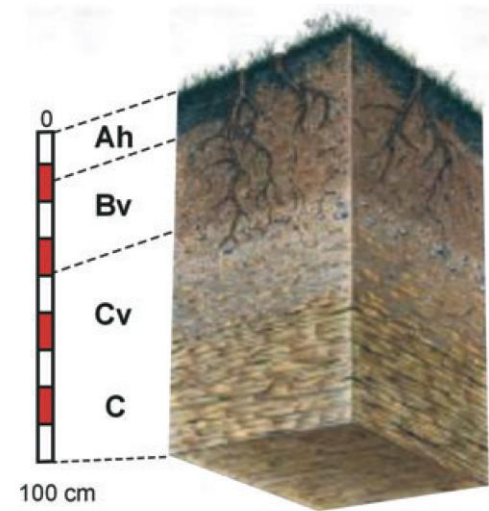
The soil forming factor time



After 100 years



After 500 years



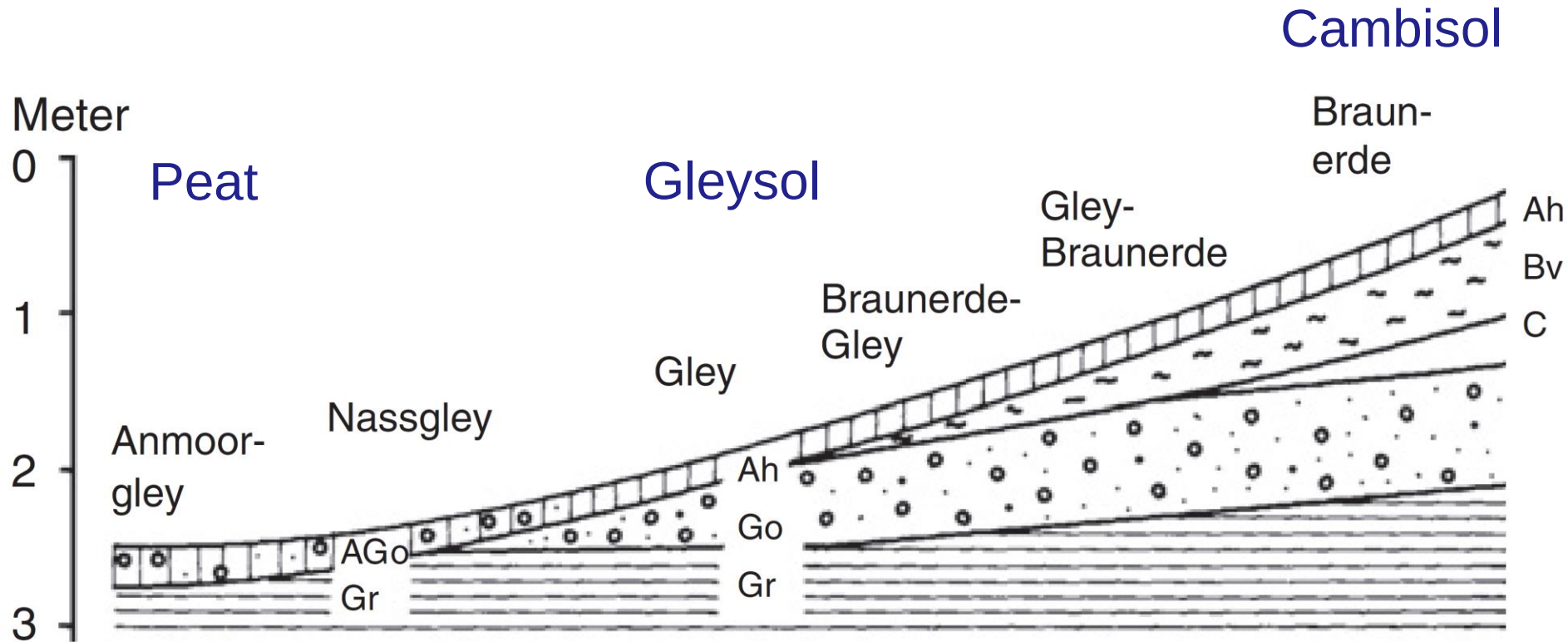
After 8000 years

Soil forming factors IV

- **Water**
 - Stagnant water
 - Groundwater

The soil forming factor water

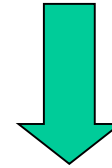
The effect of groundwater



Pedogenesis (Soil formation)



Soil forming factors



Soil forming processes

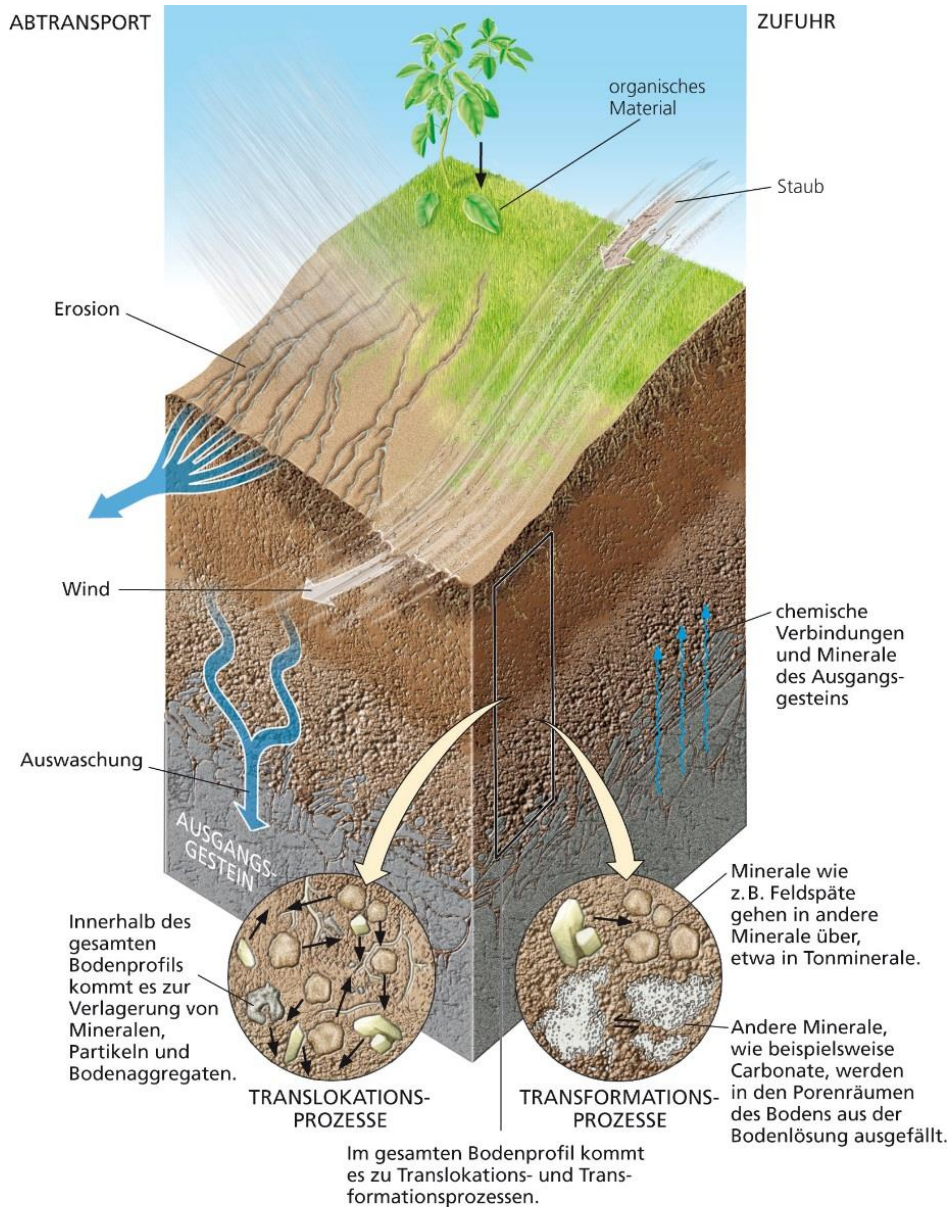


Soil horizons



Soil types/soil orders

Soil forming processes



Processes of translocation and transformation

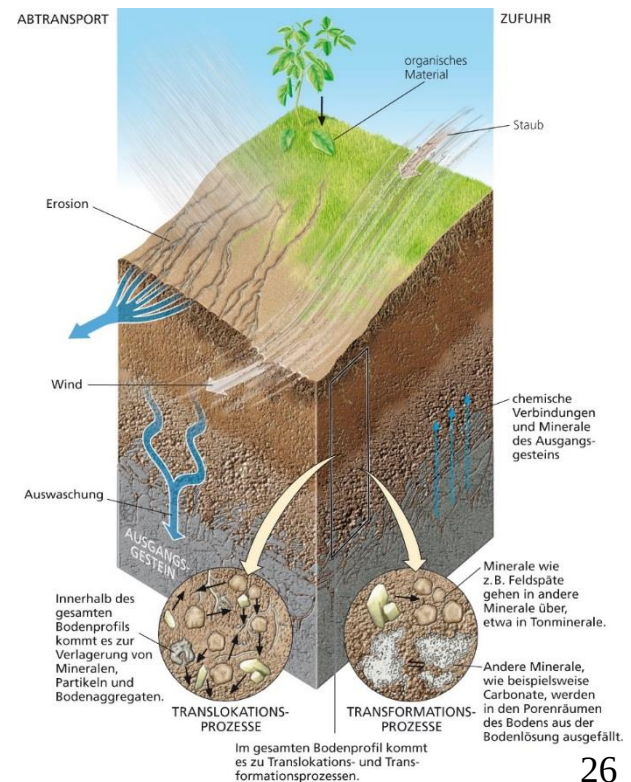
Soil forming processes

A) Transformation

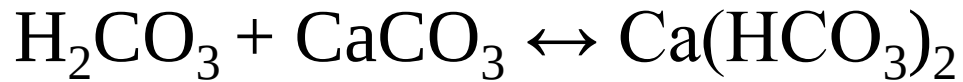
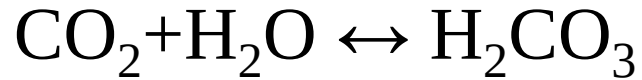
- Decarbonatization
- Formation of soil organic matter
- Formation of clay minerals and iron oxides/hydroxides
- Formation of soil aggregates

B) Translocation

- Clay migration
- Podzolization
- Salinization
- Turbation



Soil forming processes I: Decarbonatization



CO ₂ partial pressure (kPa)	Solubility of CaCO ₃ at 25 °C (mg l ⁻¹)
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0.031	49
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0.33	117
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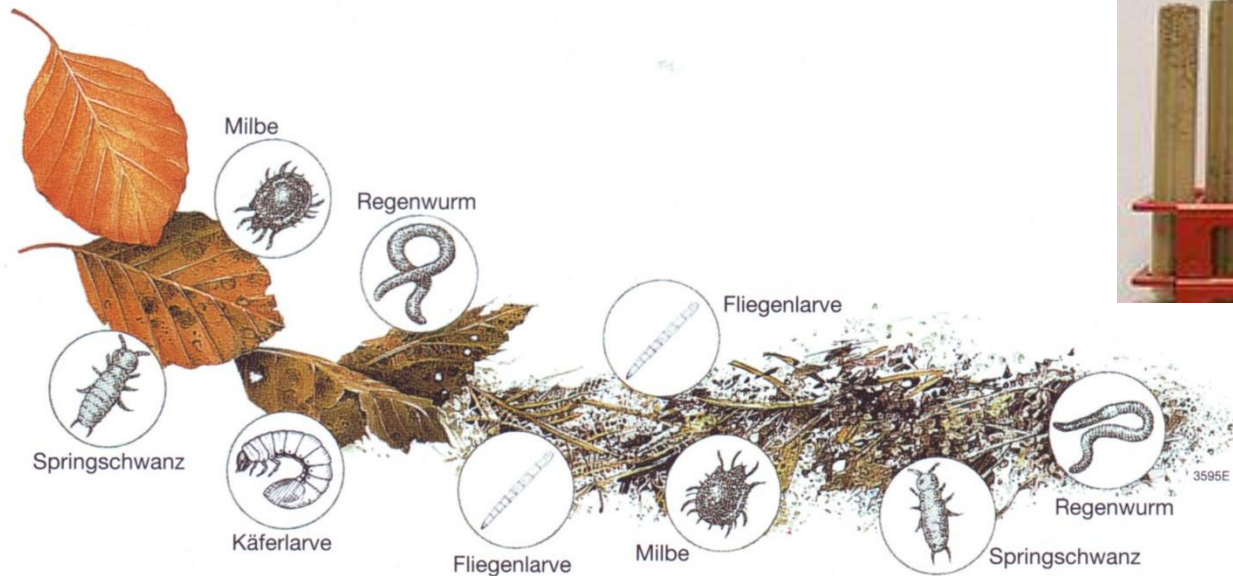
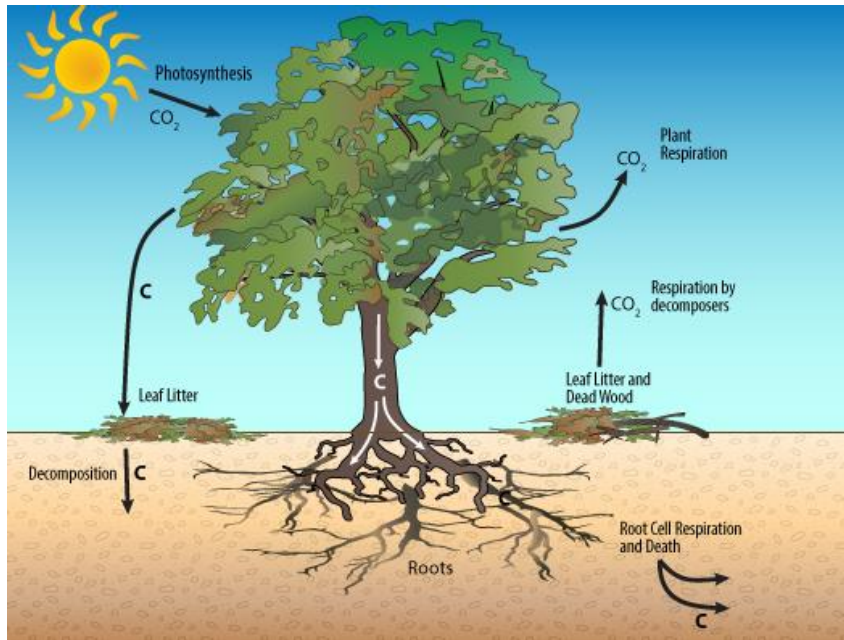
1.6	201
-----	-----

4.3	287
-----	-----

10	390
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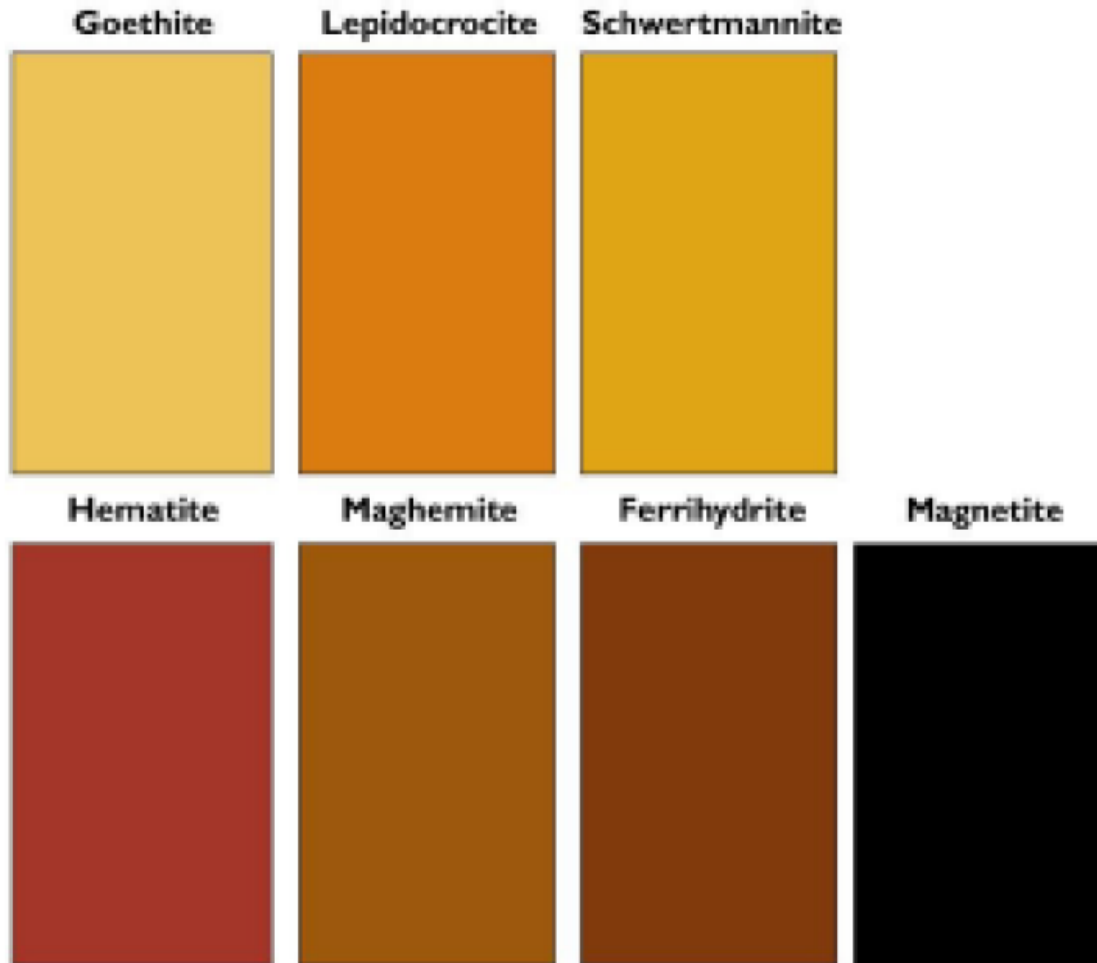


Soil forming processes II: Formation of soil organic matter



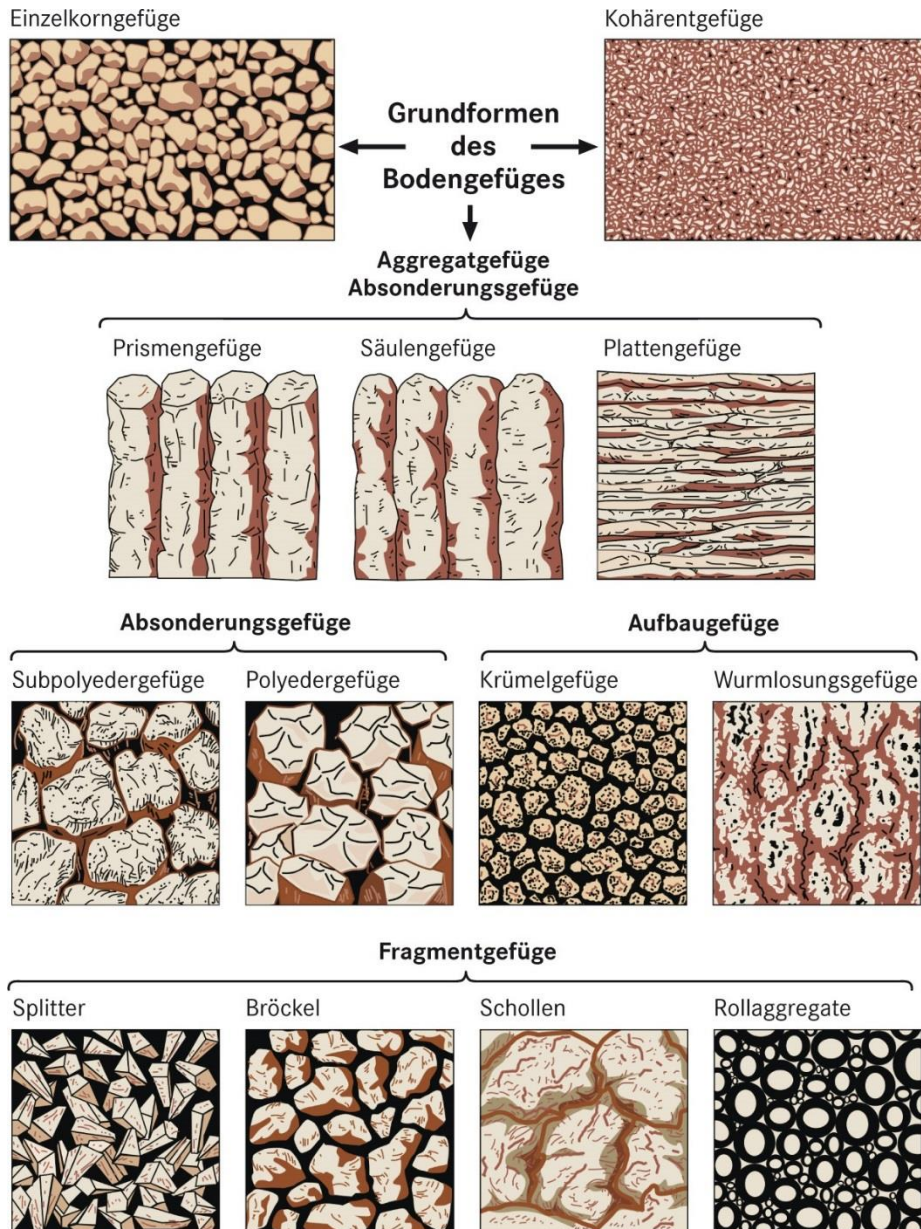
Soil forming processes III

Formation of clay minerals and iron oxides



German:
„browning“

Soil forming processes IV: Formation of soil aggregates



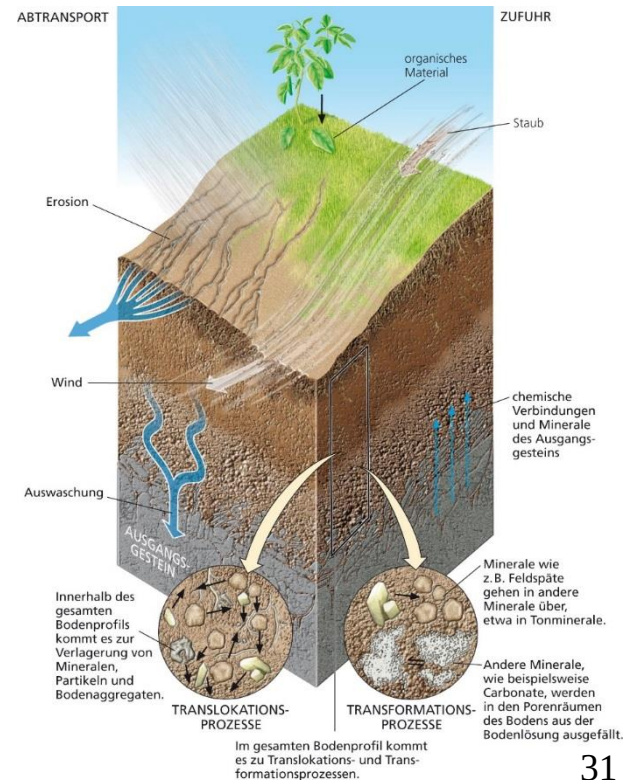
Soil forming processes

A) Transformation

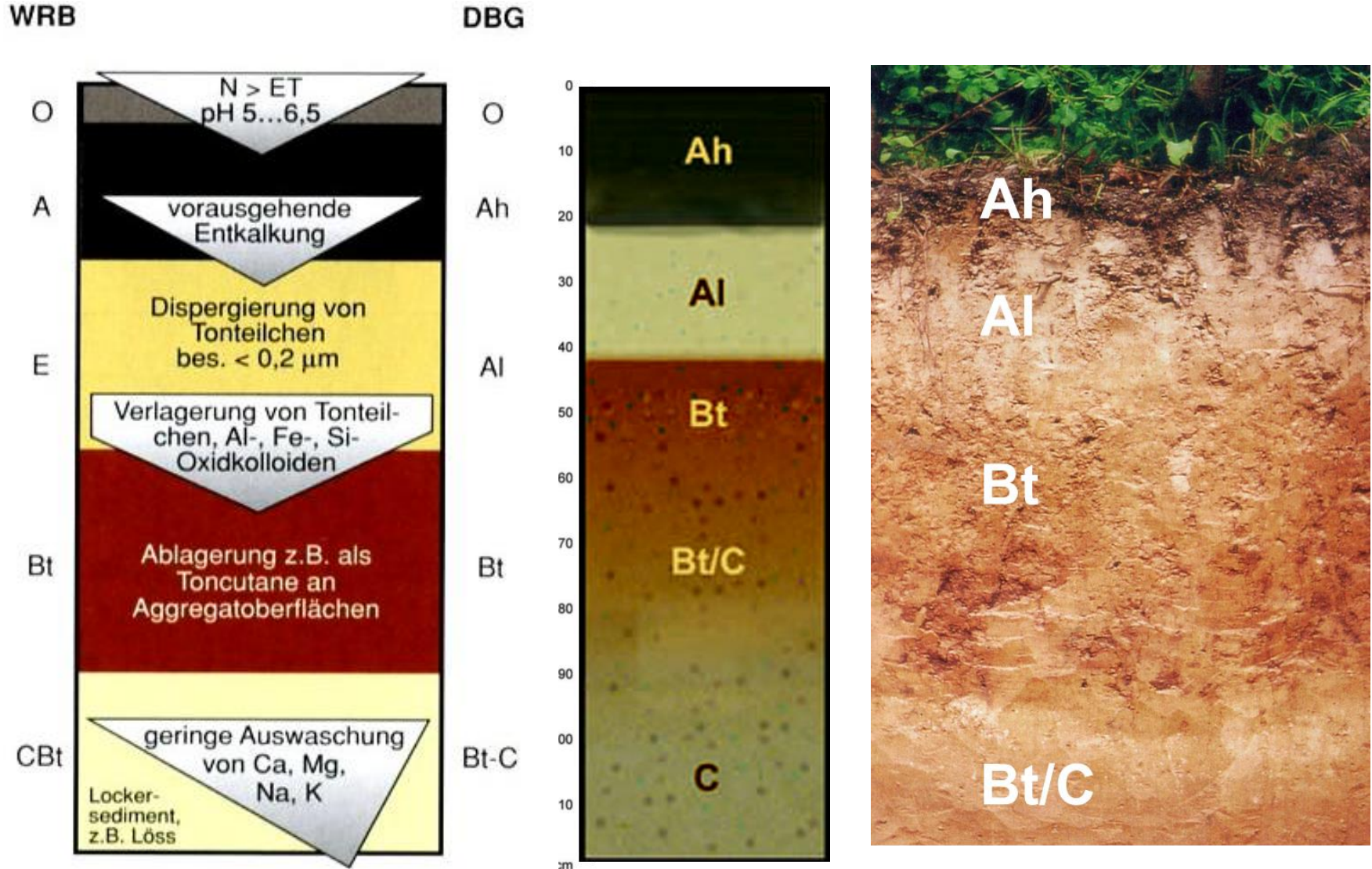
- Decarbonatization
- Formation of soil organic matter
- Formation of clay minerals and iron oxides
- Formation of soil aggregates

B) Translocation

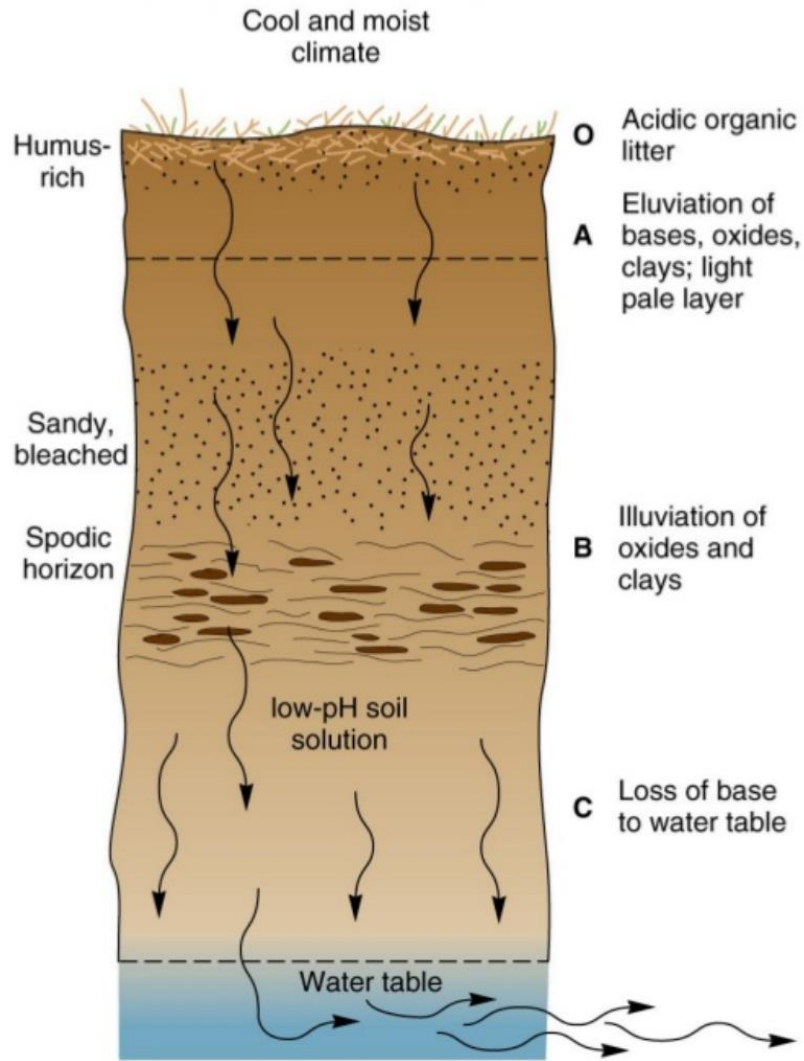
- Clay migration
- Podzolization
- Salinization
- Turbation



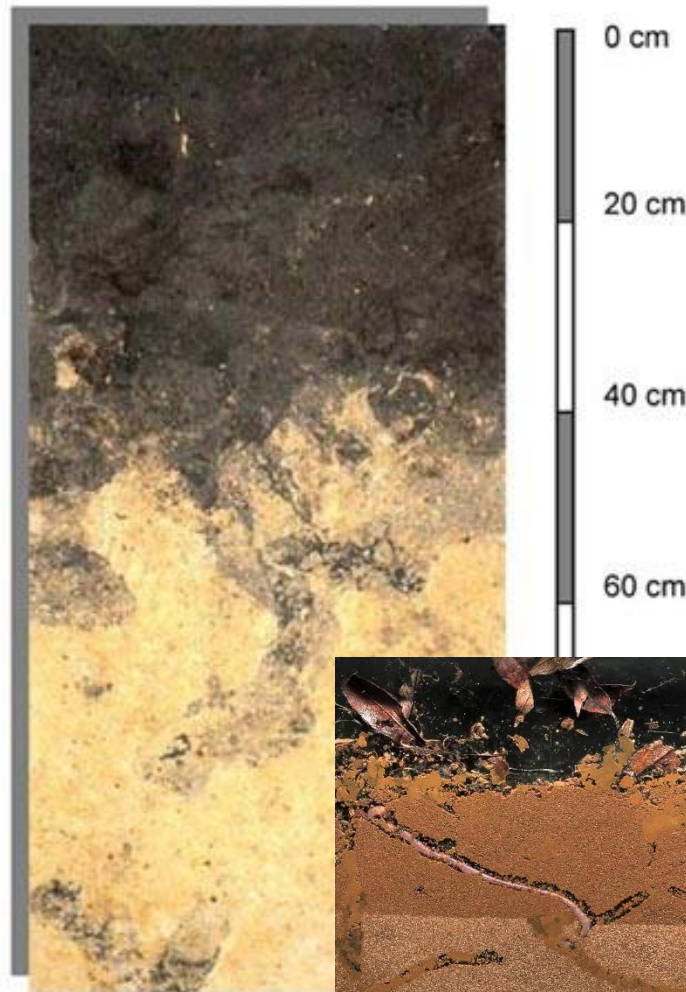
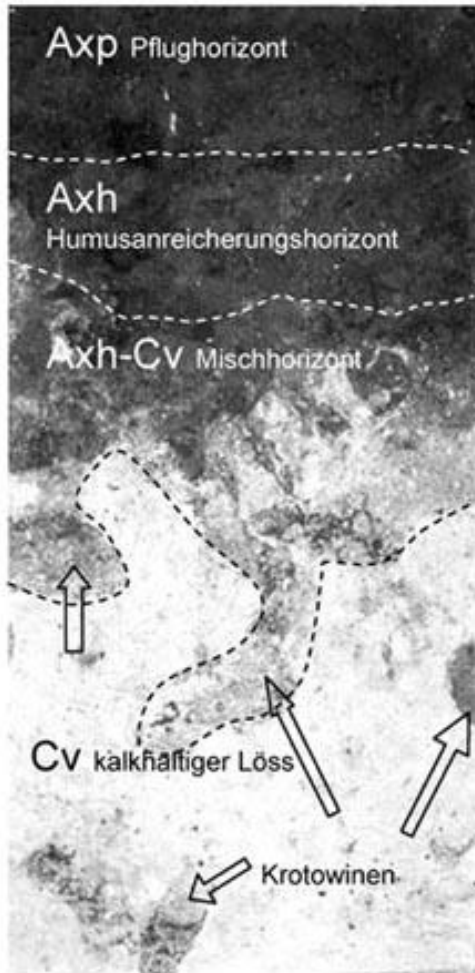
Soil forming processes V: Clay migration



Soil forming processes VI: Podzolization



Soil forming processes VII: Turbation



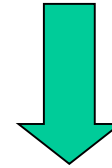
Example:
Bioturbation



Pedogenesis (Soil formation)



Soil forming factors



Soil forming processes



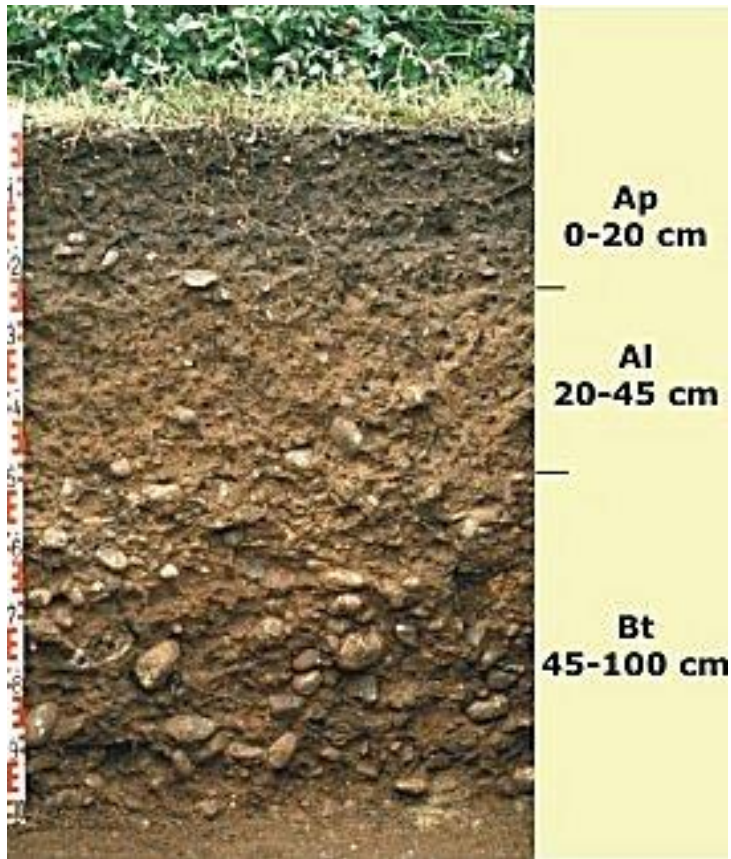
Soil horizons



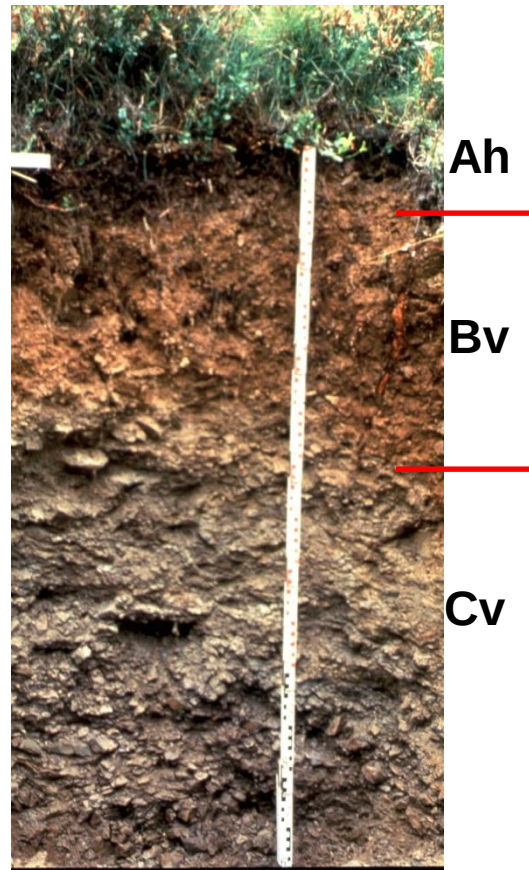
Soil types/soil orders

Some soil types

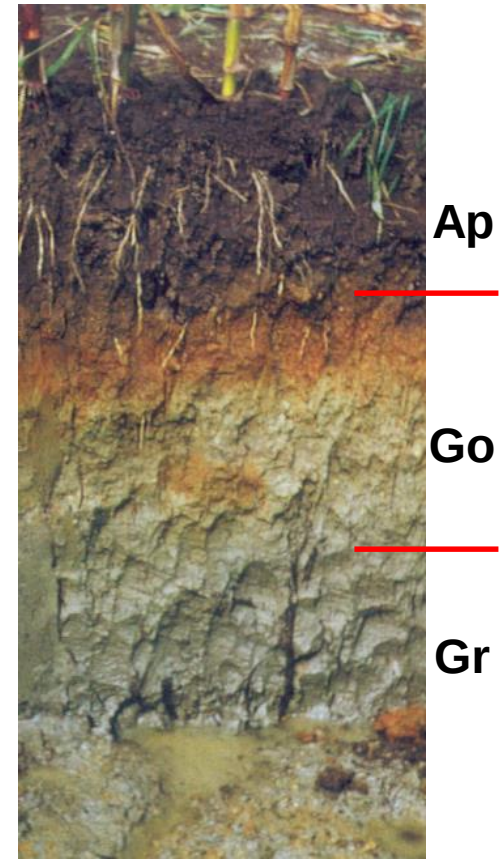
Luvisol



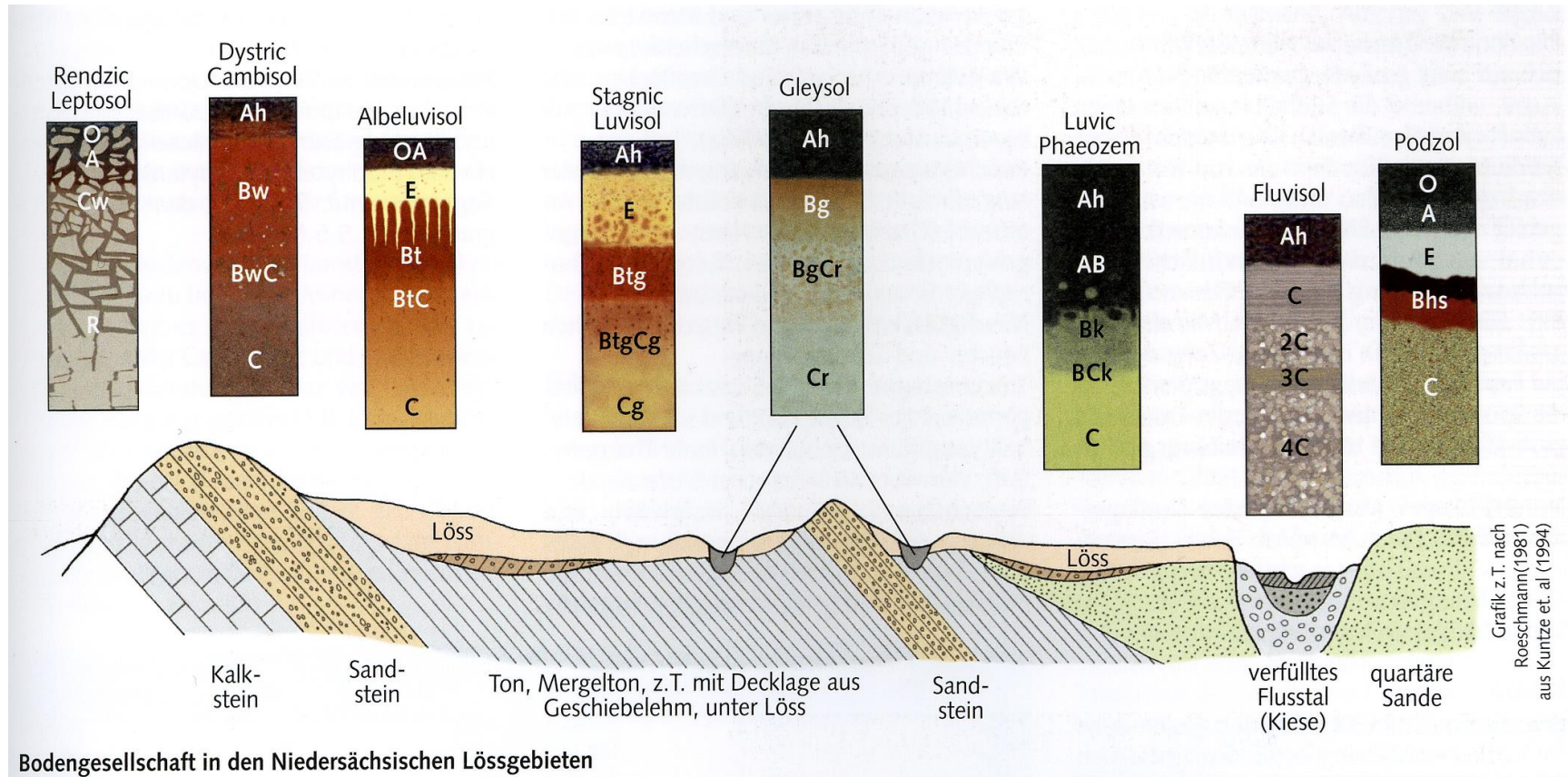
Cambisol

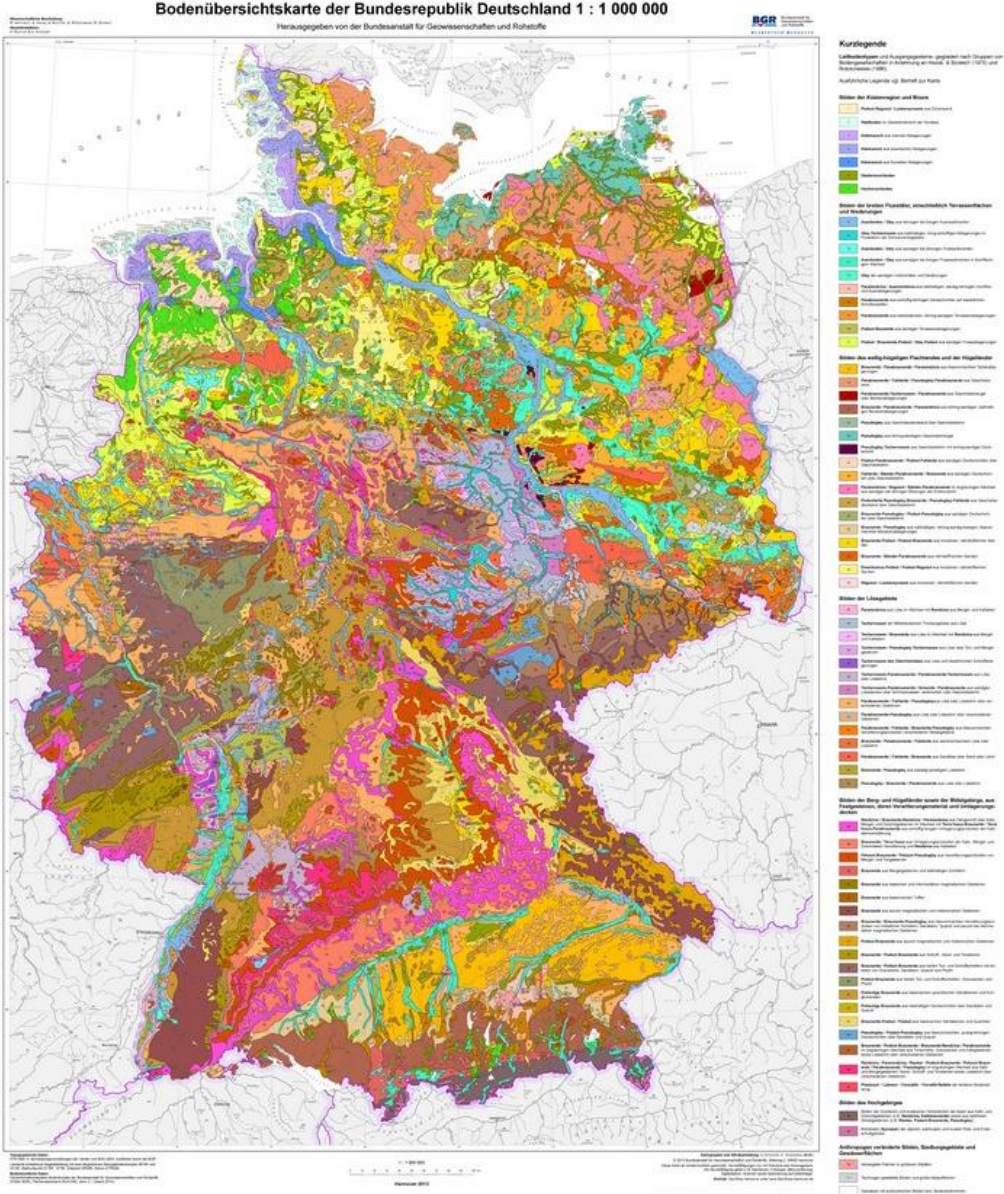


Gleysol

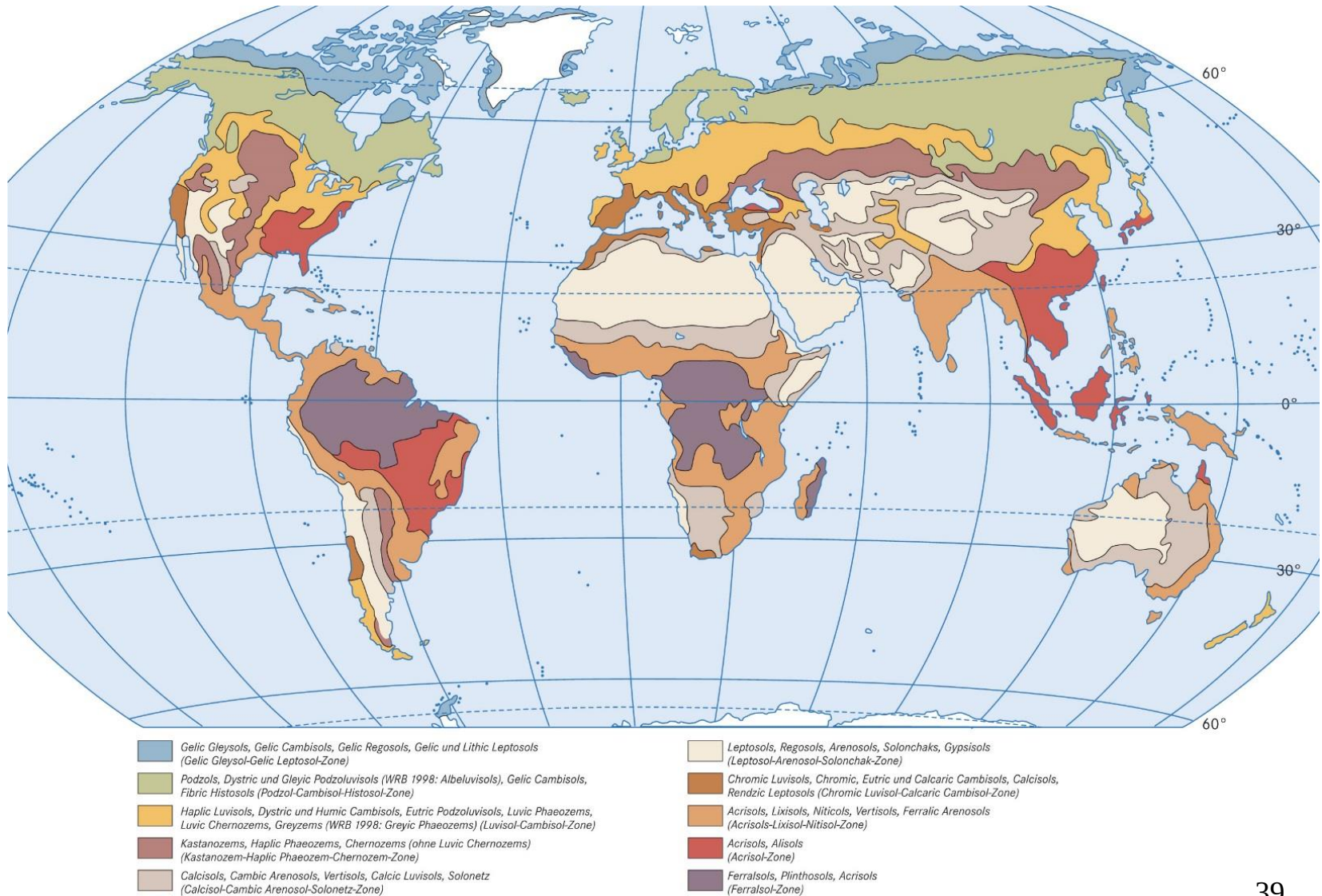


Diversity of soils – At the local scale

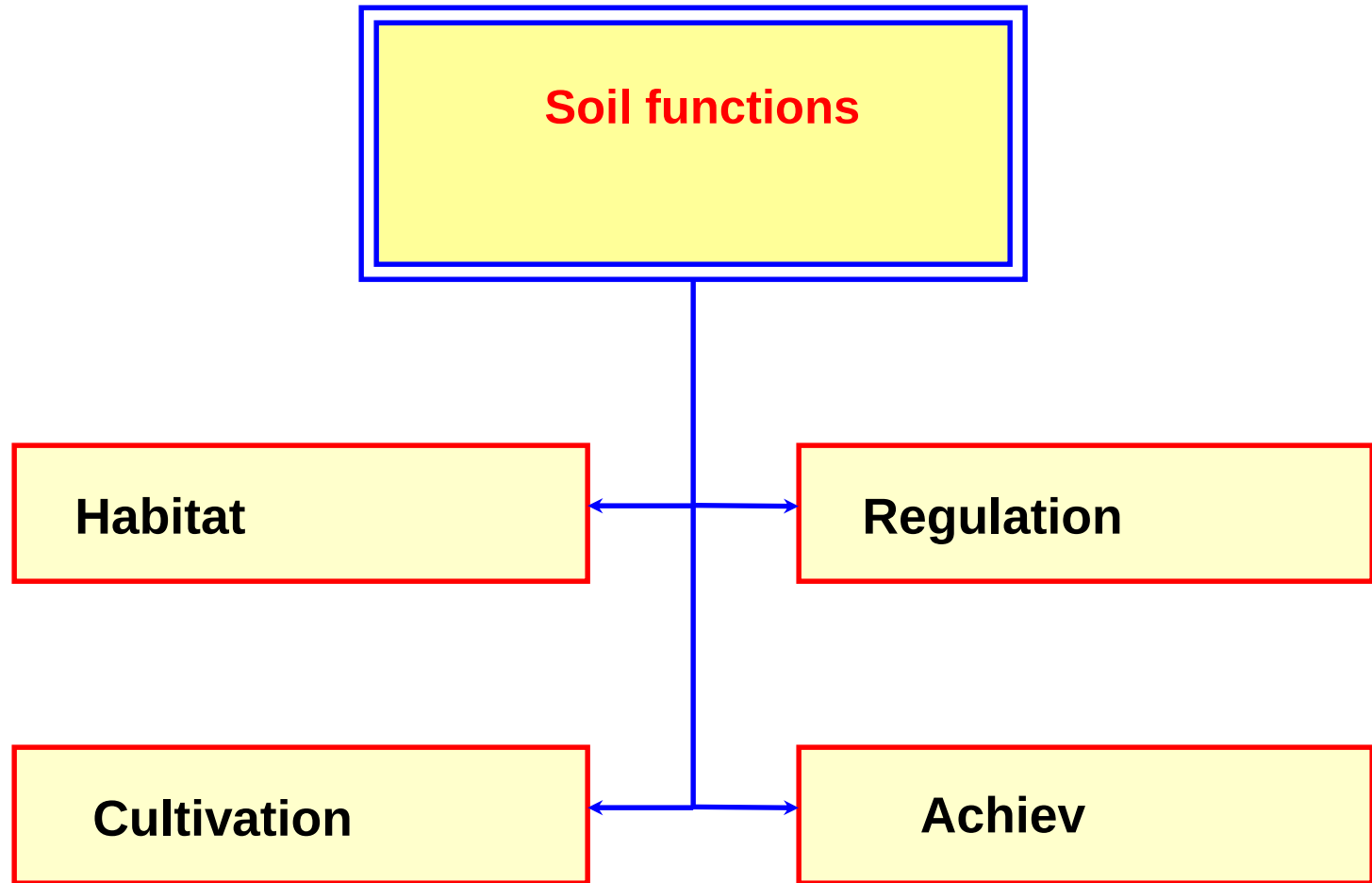




Diversity of soils – At the global scale



Soil functions



Soil functions – Federal law for the protection of soils

Bundes-Bodenschutzgesetz (BBodSchG § 2, Abs. 2)

Der Boden erfüllt im Sinne dieses Gesetzes

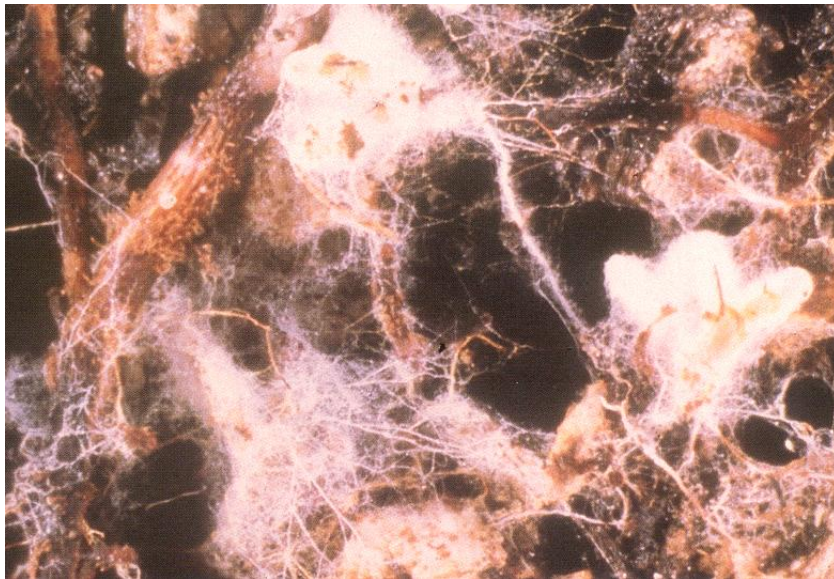
- 1. natürliche **Funktionen** als
 - a) **Lebensgrundlage und Lebensraum** für Menschen, Tiere, Pflanzen und Bodenorganismen,
 - b) Bestandteil des Naturhaushalts, insbesondere mit seinen Wasser- und Nährstoffkreisläufen,
 - c) Abbau-, Ausgleichs- und Aufbaumedium für stoffliche Einwirkungen auf Grund der **Filter-, Puffer- und Stoffumwandlungseigenschaften**, insbesondere auch zum Schutz des Grundwassers,
- 2. Funktionen als **Archiv der Natur- und Kulturgeschichte** sowie
- 3. **Nutzungsfunktionen** als
 - a) Rohstofflagerstätte,
 - b) Fläche für Siedlung und Erholung,
 - c) Standort für die land- und forstwirtschaftliche Nutzung,
 - d) Standort für sonstige wirtschaftliche und öffentliche Nutzungen, Verkehr, Ver- und Entsorgung.

Soil functions

1. Soils as habitat

➤ In one kg of fertile soil:

- 1 - 100 Billion Bacteria and fungi
- 10 Million - 1 Billion Geißeltiere, Amöben, Wimpertiere
- 10000 - 10 Million Rädertiere, Fadenwürmer, Milben, Springschwänze
- 10 - 50 Insects and worms



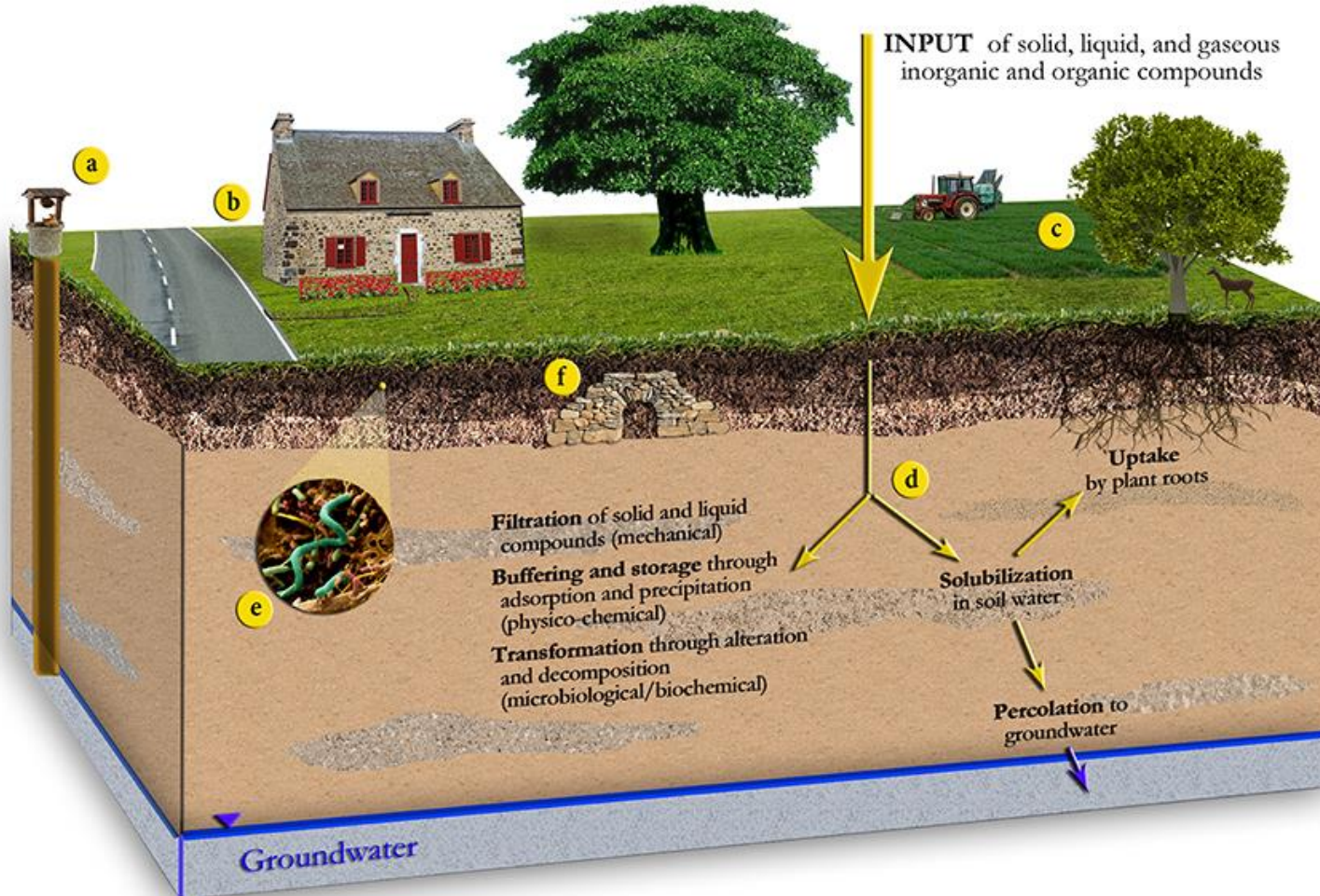
Root with fungal hyphae



Earthworm

Soil functions

2. Regulation in ecosystems

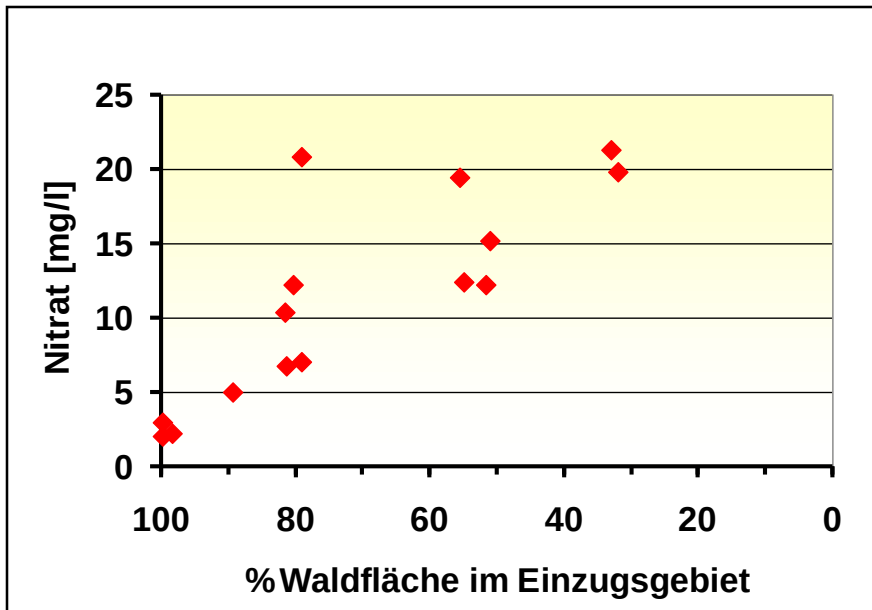


Soil functions

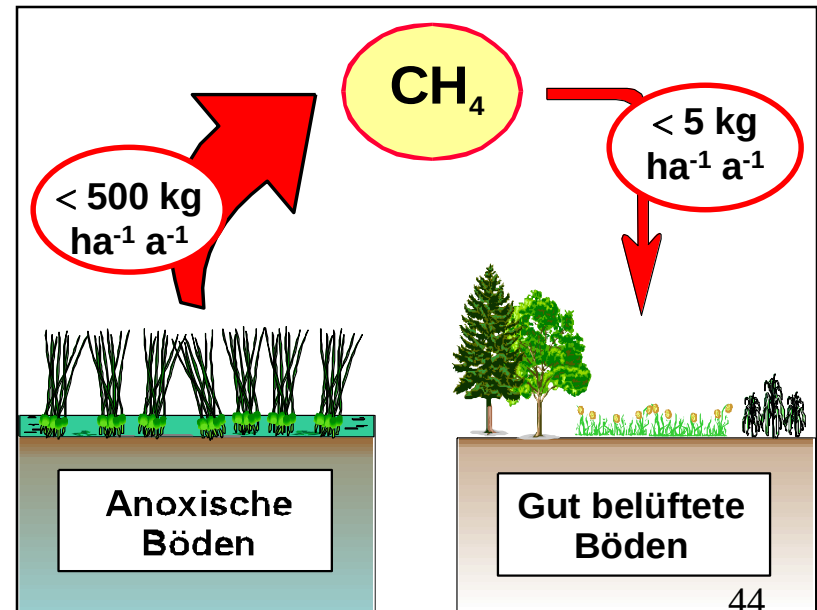
2. Regulation in ecosystems: Soils work as

- Filter and Buffer
- Regulator of water fluxes
- Sinks and sources of nutrients, gases, toxins

Soils affect the water quality



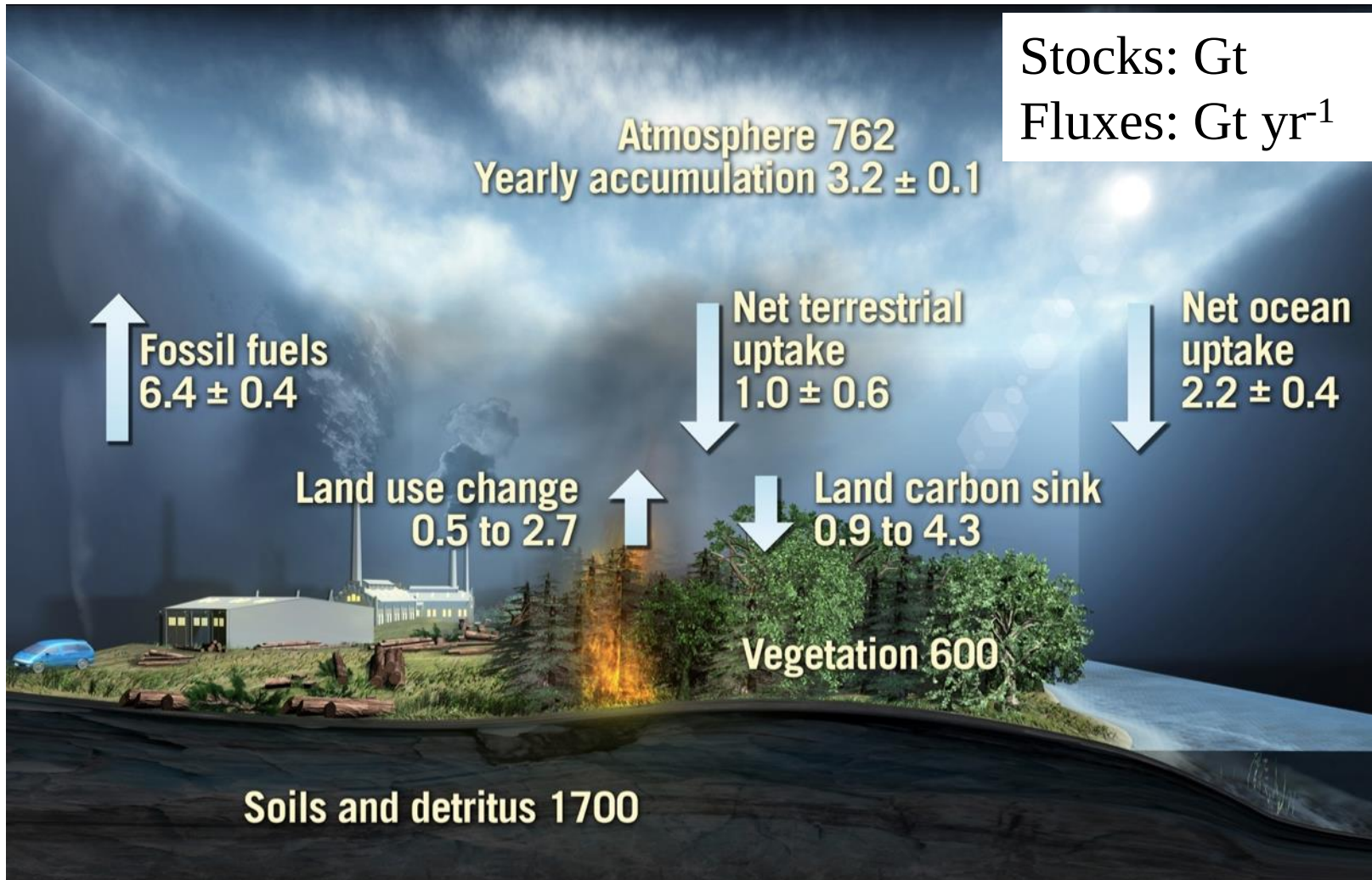
Soils form sinks and sources of CH₄



Soil functions

2. Regulation in ecosystems: Soils work as

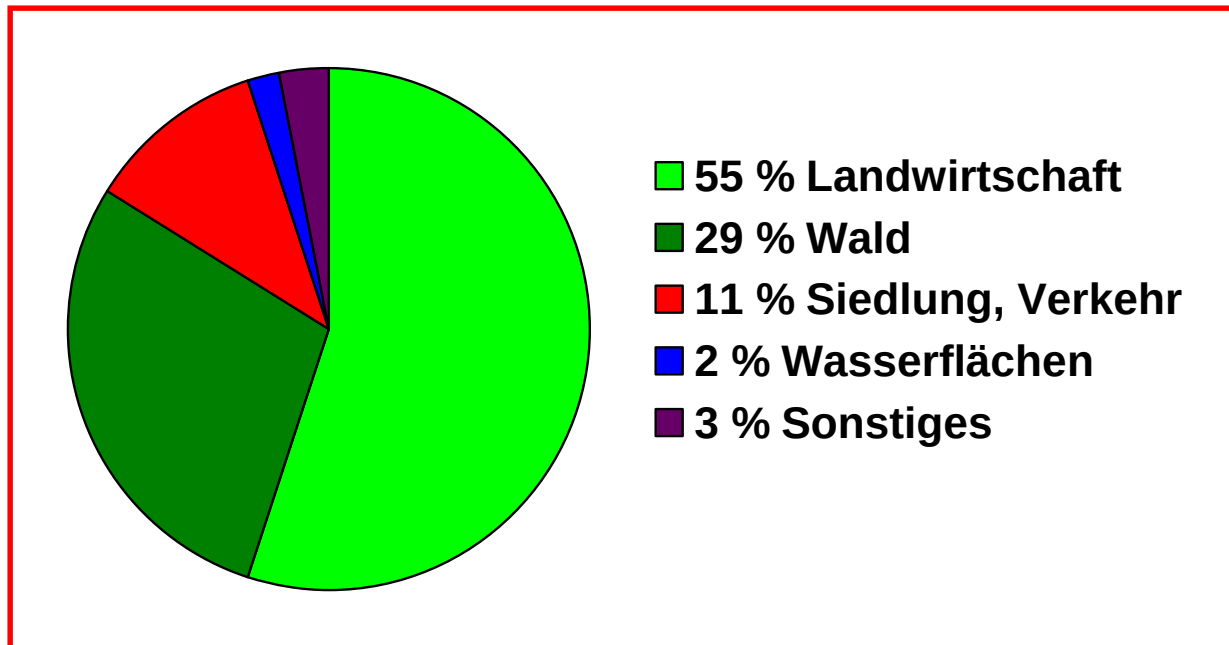
- Important sinks for CO₂



Soil functions

3. Cultivation and production

- Production of biomass (Food and fiber)
- Repository (Clay, sand, peat)
- Basis for settlements



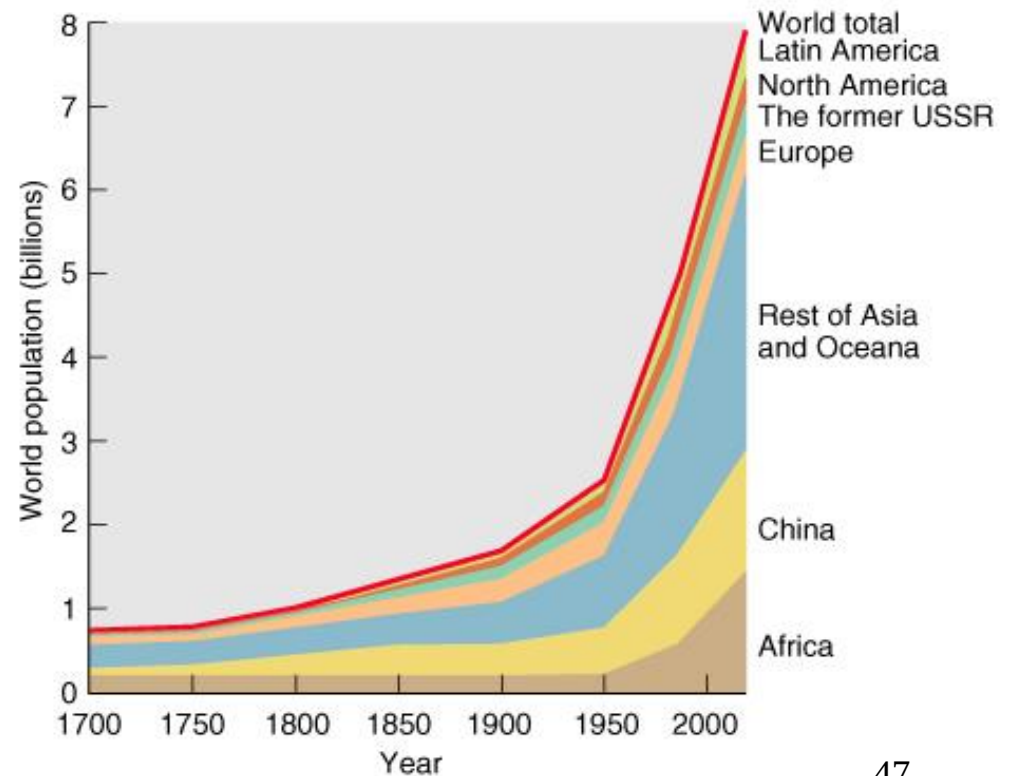
Land use in Germany

Soil functions

➤ Fertile soils are a limited resource



- Worldwide about 1475 Mio. ha cropland (about 0.25 ha per person)

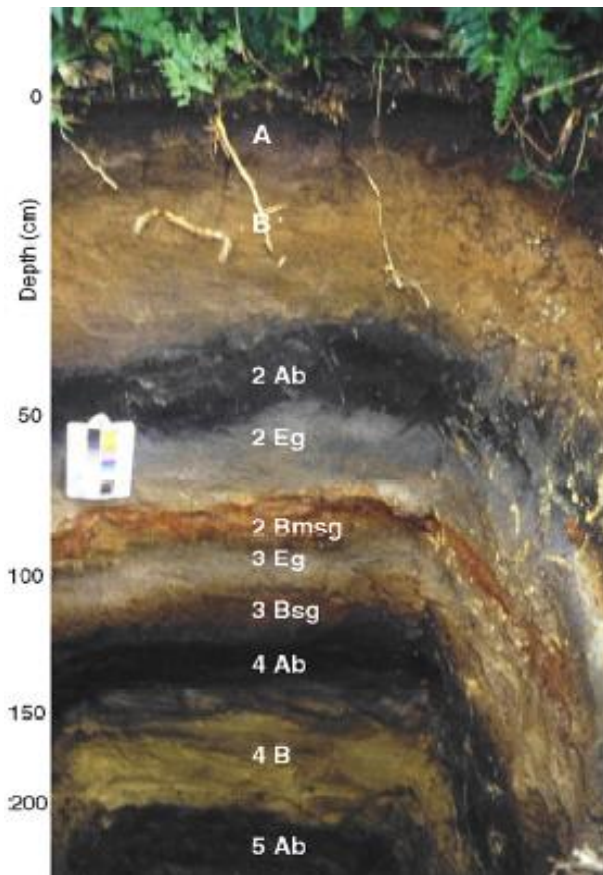


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Soil functions

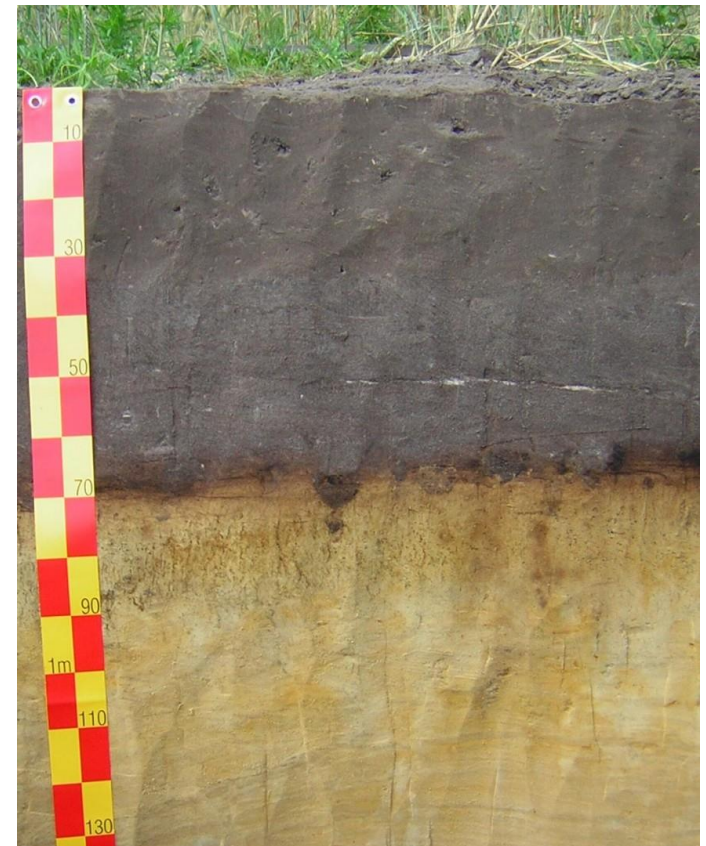
4. Soils as an archive of natural and human history:

- Soils are the basis for human life and culture
- Soils are testimony of archive of natural and human history



Soil at the
Kilimanjaro that
documents the
vegetations and
climate history

Soil Northwest
German that
documents
history of human
land use



Take home message

Factors of soil formation:

- Parent material/bedrock
- Relief
- Climate
- Water
- Soil organisms
- Time
- Humans

Process of soil formation:

- Translocation
- Transformation

Soil functions:

- Habitat
- Regulation
- Cultivation
- Archiv

Soil forming factors



Soil forming processes



Soil horizons



Soil types/soil orders