pedogenesis

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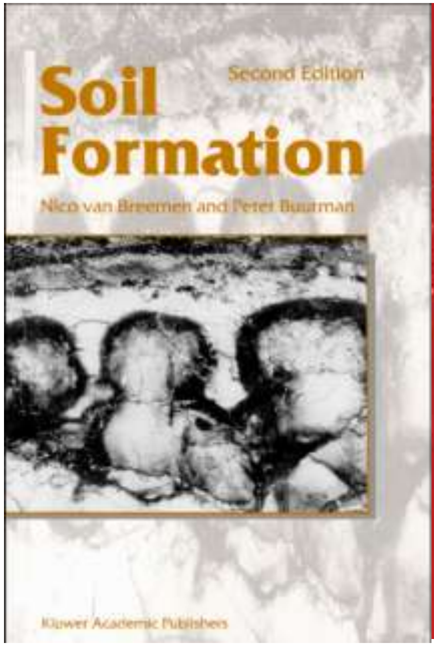
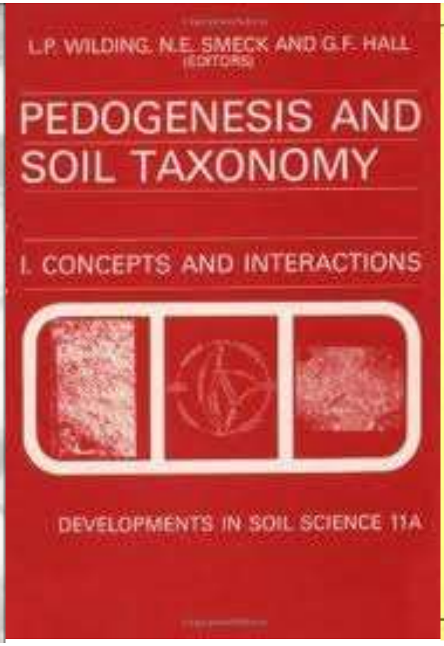
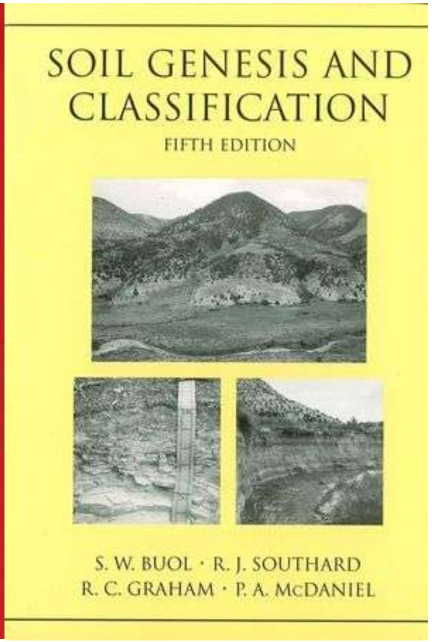
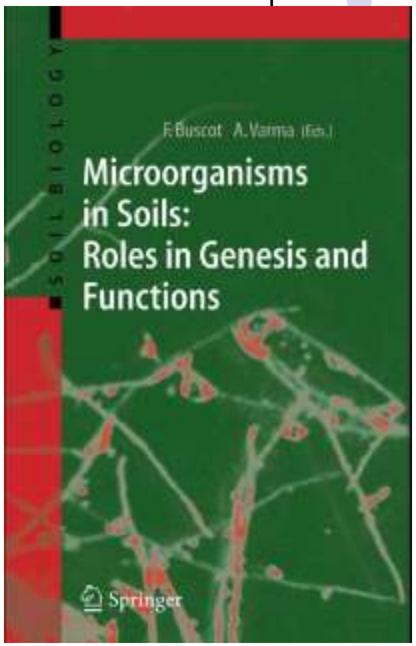
Bacaan:


Soil Formation
Second Edition
Nico van Breemen and Peter Buurman
Kluwer Academic Publishers


L.P. WILDING, N.E. SMECK AND G.F. HALL
(EDITORS)
PEDOGENESIS AND SOIL TAXONOMY
I. CONCEPTS AND INTERACTIONS
DEVELOPMENTS IN SOIL SCIENCE 11A

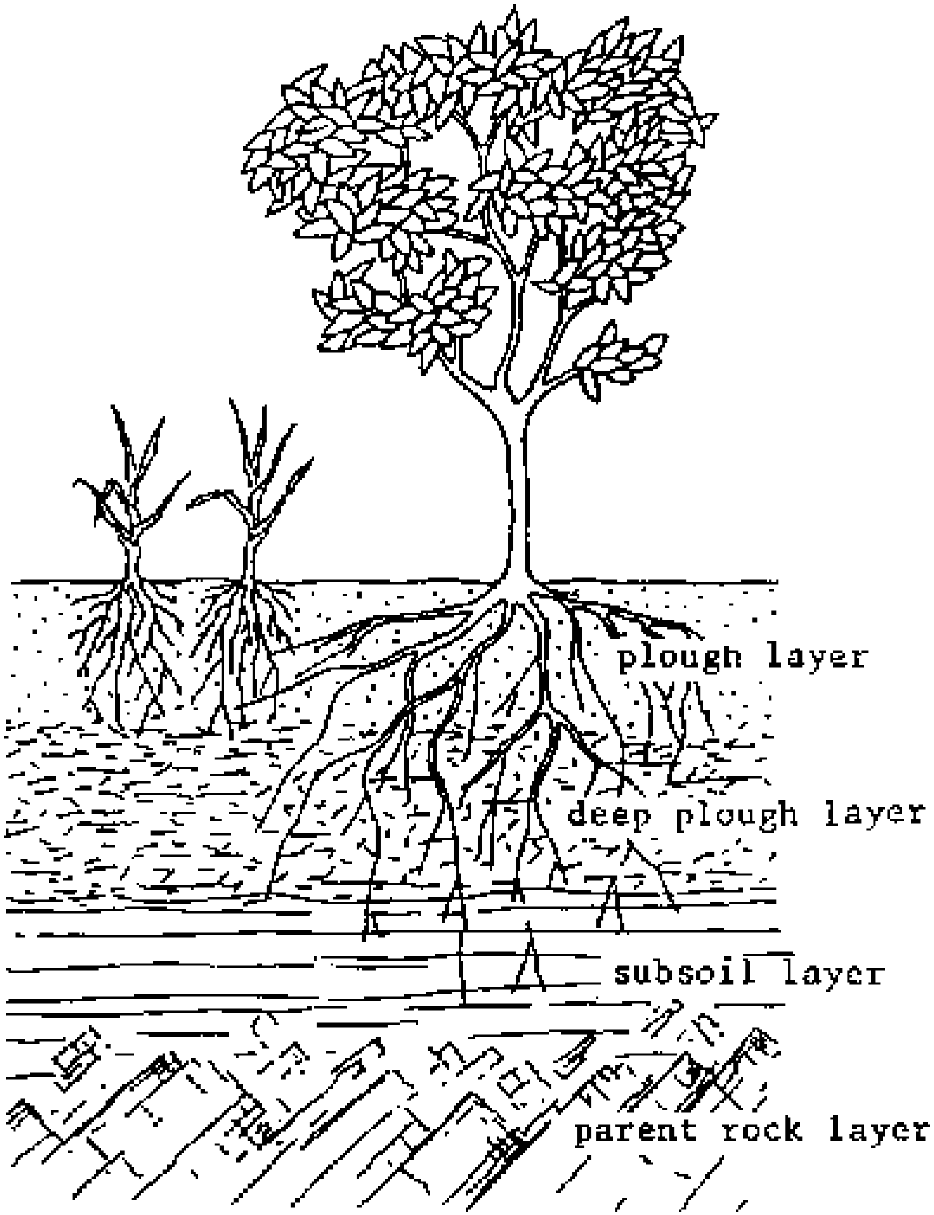

SOIL GENESIS AND CLASSIFICATION
FIFTH EDITION
S. W. BUOL · R. J. SOUTHARD
R. C. GRAHAM · P. A. McDANIEL

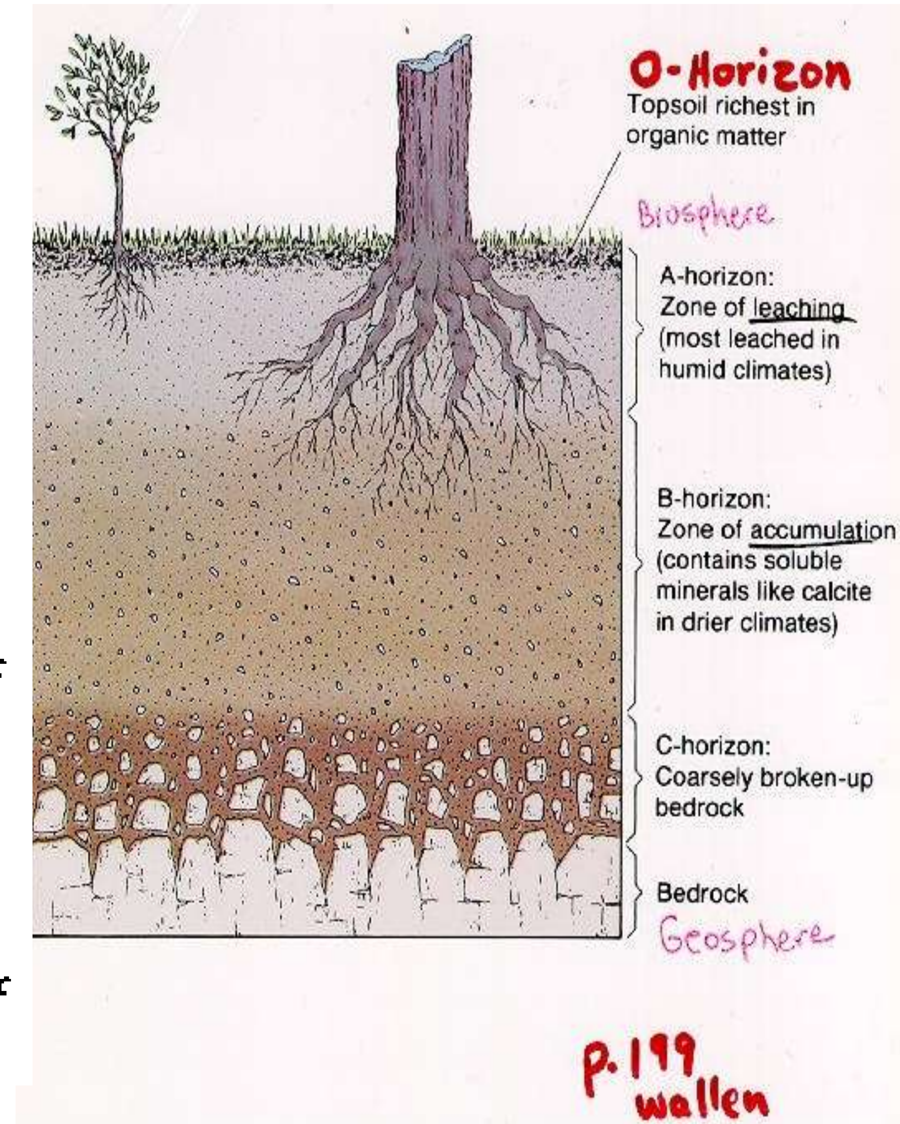

SOIL BIOLOGY
F. Buscot A. Varma (Eds.)
Microorganisms in Soils: Roles in Genesis and Functions
Springer

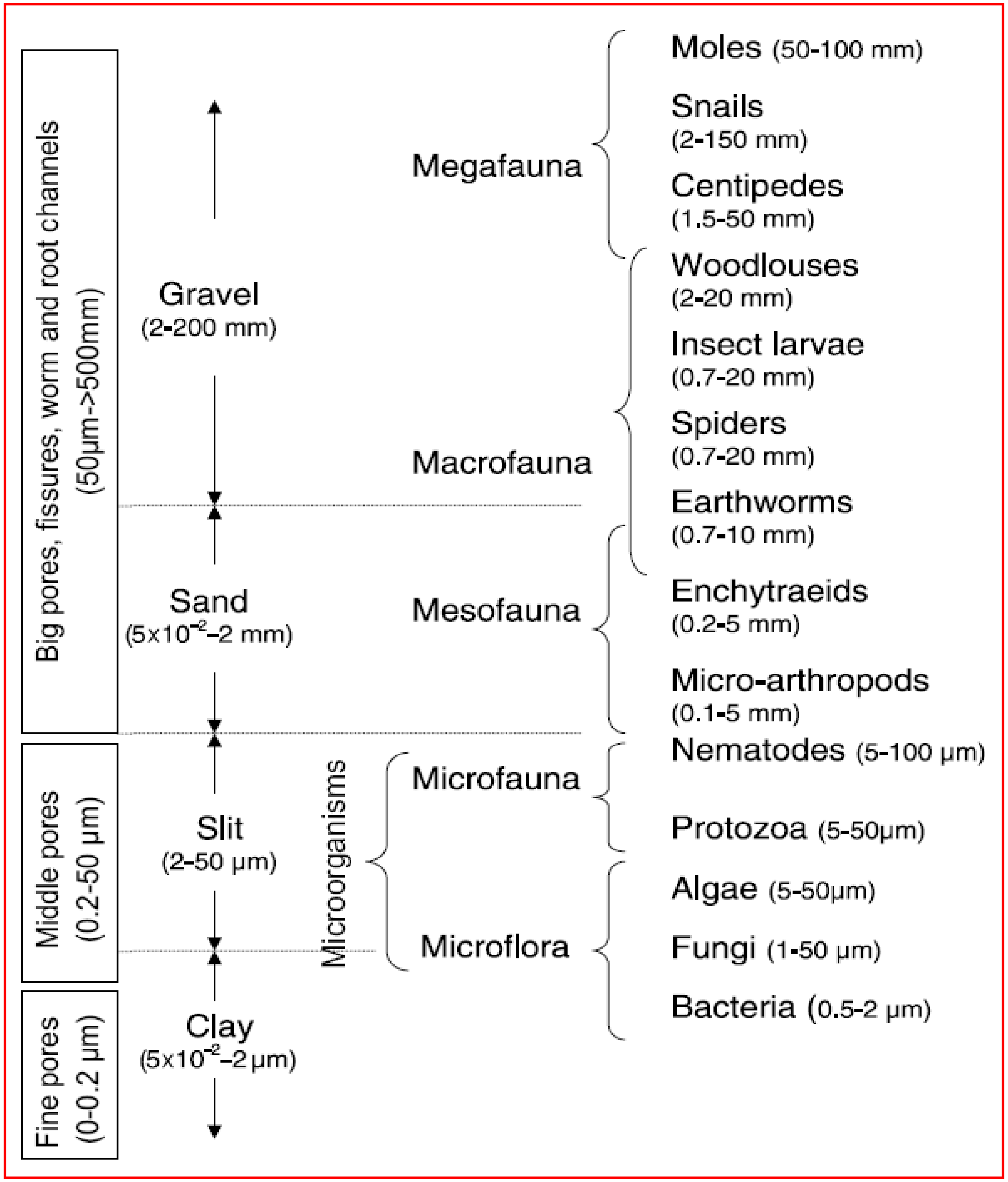
Pedologi terdiri atas:

- **Pedogenesis**
  : asal usul tanah
- Pedografi
  : penyidikan tanah
- Pedoklasifikasi
  : pengelompokan tanah

Profil Tanah







Classification of soil biota in relation to size of pores and particle in soils used in soil biology. (Adapted from Gisi et al. 1997)

Soil Layers

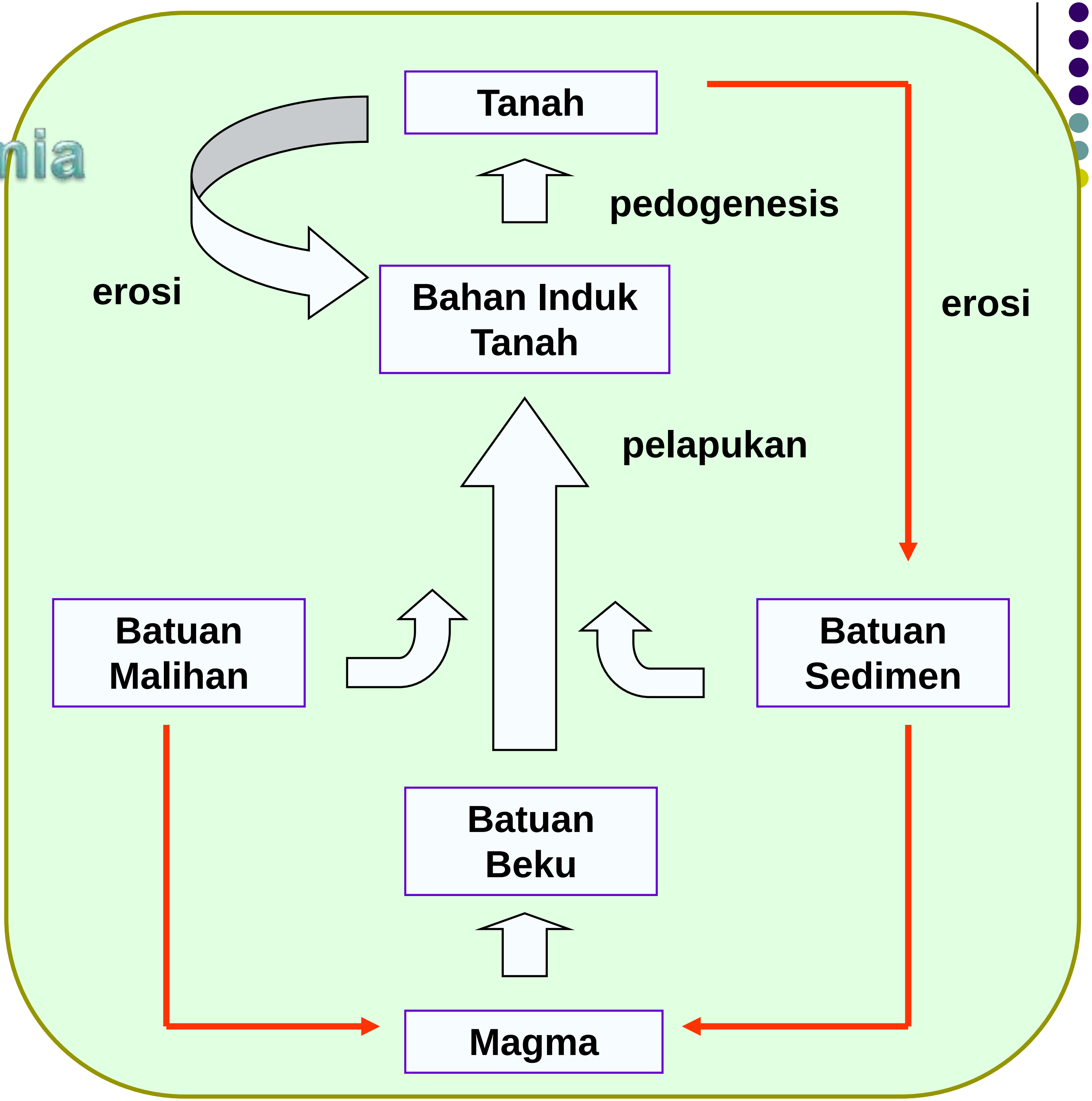
Regolith, Weathered Material	O Horizon Organic Plant Residues		O1	Undecomposed litter
			O2	Partly decomposed debris
	Solum, True Soil	A Horizon Zone of eluviation (leaching)	A1	Zone of humus accumulation
			A2	Zone of strongest leaching
			A3	Transition to B horizon
		B Horizon Zone of illuviation (deposition)	B1	Transition to A horizon
			B2	Zone of strongest deposition
			B3	Transition to C horizon
	C Horizon Parent Material		C	Unconsolidated rock
R Layer - Bedrock			R	Consolidated rock

See "Fundamentals of Soil Physics", D. Hillel, 1980, Academic Press.

Proses pembentukan tanah:

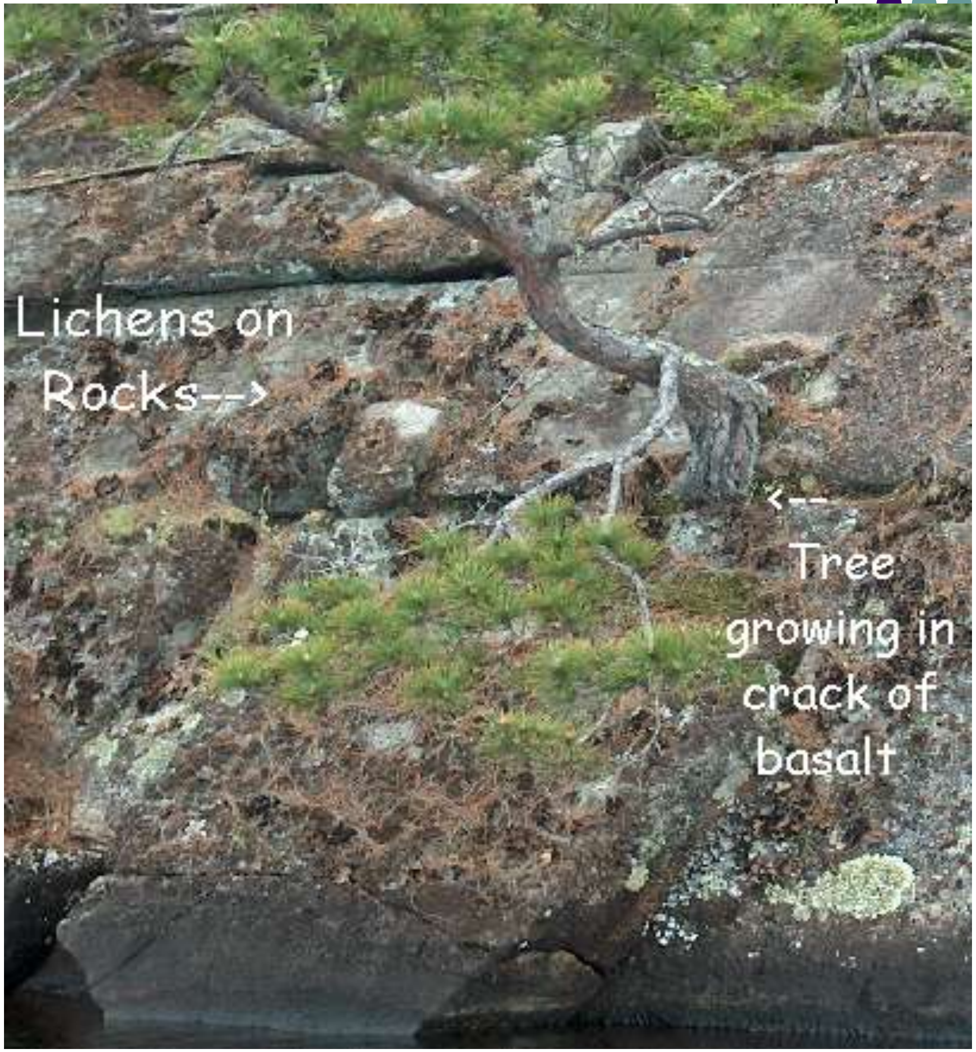
1. BATUAN BEKU --pelapukan--> BAHAN INDUK TANAH --**pedogenesis**--> TANAH
2. BATUAN BEKU --pelapukan/diagenesis--> BATUAN SEDIMEN --pelapukan--> BAHAN INDUK TANAH --**pedogenesis**--> TANAH
3. BATUAN BEKU --metamorfisme--> BATUAN MALIAN --pelapukan--> BAHAN INDUK TANAH --**pedogenesis**--> TANAH
4. TANAH --erosi/pengendapan--> BAHAN INDUK TANAH --**pedogenesis**--> TANAH

Daur Geokimia



Rocks Weather to Soil

- Weathering is the process by which all rocks at the earth's surface get broken down.
- Weathering occurs by both chemical (decomposition) and mechanical processes (disintegration).



S = f(Cl,R,O,P,T)

Karts Formation – Gunung Kidul

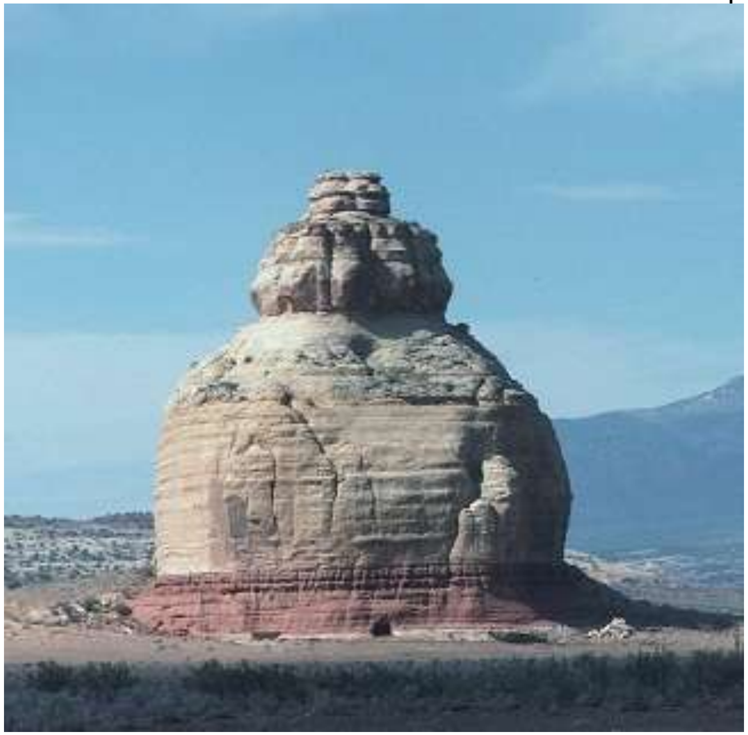
PELAPUKAN

- Secara umum yang disebut pelapukan adalah sejumlah proses batuan pecah menjadi butiran yang lebih kecil atau larut ke dalam air, sebagai dampak kegiatan **atmosfer** dan **hidrosfer**.
- Pelapukan umumnya berjalan sangat lambat, yaitu ratusan sampai ribuan tahun. Tempo batuan dan mineral terpapar pada permukaan bumi sangat mempengaruhi tingkat pelapukan tersebut.
- Mineral primer dan batuan terpecah menjadi potongan atau remukan yang lebih kecil disebabkan **pelapukan fisik**.
- Dengan bertambahnya luas permukan akan mendorong proses **pelapukan kimia** lebih intensif.

FISIKA (Physical Weathering)

- **Abrasion**: Water carrying suspended rock fragments has a scouring action on surfaces.

- **Wetting and drying**: Water penetrates into rocks and reacts with their constituent minerals.



- **Freezing and Thawing**: When water is trapped in the rock (or in cracks) repeatedly freezing and thawing results in forces of expansion and contraction (when water freezes, the increase in its volume is about 9 %).

- **<u>Thermal expansion and contraction of minerals</u>**:
  - Rocks are composed of different kind of minerals. When heated up by solar radiation each different mineral will expand and contract a different amount at a different rate with surface-temperature fluctuations. With time, the stresses produced are sufficient to weaken the bonds along grain boundaries, and thus flaking of fragments.

The difference in temperature in desert environments or mountain regions may range from 30 - 50 degrees C between day and night.
Rocks are heated and cooled from the outside by change in solar radiation, which results in high temperature gradients inside and outside of the rocks (the heat conductivity of rocks is very low)

- **Pressure unloading or pressure-release jointing**: There is a reduction in pressure on a rock due to removal of overlying material. This allows rocks to split along planes of weakness, called joints.

Crystallization:
In arid environments, water evaporates at the surface of rocks and crystals form from dissolved minerals. Over time, the crystals grow (They expand their volume) and exert a force great enough to separate mineral grains and break up rocks.

- **Action of organisms**:
  They aid in the physical disintegration of rocks.
- **Plant roots**:
  They aid in the physical disintegration of rocks. Pressures exerted by roots during growth are able to rupture rocks.

KIMIA
(Chemical Weathering)
dekomposisi

- The larger the surface area, i.e, the smaller the fragments, the better for chemical weathering.
- Water is the dominant agent because it initiates chemical weathering.

The difference between physical and chemical weathering is that with the latter one the mineral composition of the mineral or rock is changed.

- **<u>Hydration</u>**:
  Ions have the tendency to hydrate when H_2O is present and dissociate. This kind of weathering happens in arid environments where salts are present. For example, chlorides and sulfates weather due to hydration. In general, ions with the same charge but smaller ion radius have a larger layer of H_2O ions and therefore do not tend to adsorb tight.
- The small Li^+ ion tends to remain hydrated at the surface, whereas the large Al^{3+} ion tends to dehydrate and become tightly adsorbed. The strength of adsorption increases in the following sequence:
  $Li^+ < Na^+ < K^+ < Mg^{2+} < Ca^{2+} < Al^{3+}$

- **Hydrolysis**:
Water molecules at the mineral surface dissociate into H+ and OH- and the mobile H+ ions (actually H3O+) penetrate the crystal lattice, creating a charge imbalance, which causes cations such as Ca2+, Mg2+, K+ and Na+ to diffuse out.
- For example, the **feldspar orthoclase** hydrolyses to produce a weak acid (silicic acid), a strong base (KOH), and leaves a residue of clay mineral **illite**, which is a secondary mineral:

  3KAl4 + Si3O8 + 14H2O <- ->
  K(AlSi3)4Al24O10(OH)2 + 6Si(OH)4 + 2KOH

- In hydrolysis reactions it has to be taken into account the important role played by dissolved CO_2. This is shown in the hydrolysis of Mg-olivine:

  $$Mg_2SiO_4 + 4CO_2 + 4H_2O \leftrightarrow 2Mg^{2+} + 4HCO_3^- + H_4SiO_4$$

- This reaction uses an acid (carbonic acid - H_2CO_3)and therefore the solution becomes increasingly alkaline during completion of hydrolysis reactions.

- **<u>Oxidation-Reduction</u>**:
  Several primary minerals contain Fe^{2+} and Mn^{2+}.
  If there are oxidizing environmental conditions the Fe^{2+} is oxidized to Fe^{3+} (precipitates as an insoluble oxyhydroxide, usually either ferrihydrite or the stable mineral goethite)
  and Mn^{2+} to Mn^{3+} or Mn^{4+} partly inside the minerals,
  which results in a positive charge and the mineral becomes unstable.
- This charge imbalance is neutralized by a loss of some oxidized iron and manganese ions and/or some cations dissociate from the mineral.

- The precipitate may form a coating over the mineral surface, which slows down the subsequent rate of hydrolysis. Note that the oxidation of Fe^{2+} to Fe^{3+} according to:

  $Fe^{2+} + 2H_2O + 1/2O_2 <-> Fe(OH)_3 + H^+$

  is an acidifying reaction (acid solution weathering). The H^+ ions produced by this reaction will generally accelerate the rate of hydrolysis.

- **Complexation**:
  Metals released from primary minerals such as Fe, Mn, and Al, build complexes with organic components, such as fulvic acids and humic acids, which are very stable.
  Important referring to chemical weathering is the loss of the cations out of the active system, therefore causing an imbalance between cations and anions.

BIOLOGI (Biological Weathering)

Lichens play an important part in weathering, because they are rich in chelating agents, which trap the elements of the decomposing rock in organo-metallic complexes.

- Some of the lichens being epilithic (i.e. living on the rock surface), some endolithic (actively boring into the rock surface), and some chasmolithic (living in hollows or fissures within the rock).
- Evidence for the operation of these processes comes mainly from detailed microscopic and microchemical analyses of the lichen : rock interface.

Mechanisms	**Results of weathering**
Chemical mechanisms ➢Chelation of extracellular, soluble compounds ➢Attack by oxalic acid ➢Attack by water acidified by respired carbon dioxide	**Results of chemical action** ➢Grooves at endolithic thalli interfaces ➢Etching minerals ➢Precipitation of alteration products, e.g. calcium oxalate, which may or may not play a further role in weathering
Physical mechanisms ➢Rhizine penetration ➢Thallus expansion and contraction on wetting and drying	**Results of physical action** ➢Exfoliation of rock surface layer ➢Cracking of rock ➢Increase in pore volume

Weathering Resistance

The resistance to weathering, i.e. the mineral stability of parent material depends on:

- Types of mineral present
- Surface area of rock exposed
- Porosity of rocks

- Weathering is not only dependent on the mineral composition but also on the porosity of the rock.
  Rocks consisting of coarse fragments (e.g. granite) easily weather physically but do not weather chemically fast.
- In contrast, rocks consisting of fine fragments (e.g. basalt) chemical weathering is higher than physical weathering.
  The weathering of stratified sedimentary rocks is dependent on the orientation of the stratification and the cementation.

- In general, the resistance of a primary mineral to weathering increases with the degree of sharing of oxygens between adjacent Si tetrahedra in the crystal lattice.
  The SI-O bond has the highest energy of formation, followed by the Al-O bond, and the even weaker bonds formed between O and the metal cations (e.g. Na^+, Ca^{2+}).

- Olivine weathers rapidly because the silicon tetrahedra are only held together by O-metal cations. In contrast quartz is very resistant because it consits entirely of linked silicon tetrahedra. In the chain (amphiboles and pyroxenes) and sheet (phyllosilicates) structures, the weakest points are the O-metal cation structures.
- Isomorphous substitution of Al3+ for Si4+ also contributes to instability because the proportion of Al-O to Si-O bonds increases and more O-metal cations bonds are necessary. This accounts for the decrease in stability of the calcium feldspars when compared with the sodium and potassium feldspars.

The rate of weathering is influenced by:

- Temperature
- Rate of water percolation
- Oxidation status of the weathering zone

- The oxidation status influences the degree of chemical weathering processes. An oxidizing environment favors the oxidation of ions such as Fe^{2+} and Mn^{2+}.
- Water is the agent forcing the processes of hydration and hydrolysis. High water contents mean also reducing (anaerobic) environmental conditions, which decrease the rate of oxidation.

Clay formation

- In many soils, the ingredients are present for the formation of new clay minerals in the soil, especially due to the process of hydrolysis.
- Occasionally, recent alluvial sediments may contain clay minerals formed elsewhere and transported in.
- Clay minerals and their formation predominate around alluvial areas as hydrolysis is a major chemical reaction here.

- Clay formation usually forms what is known as a **cambic B horizon**, which is a B horizon that has undergone changes in color and structure (**Bw**).
- In humid tropical areas, clays form a group known as **low activity clays**, which contain a low cation exchange capacity, sometimes known as **low base status** in the U.S. Clays with a high base status mean base ions are abundant, the soil contains many nutrients, and the area is highly fertile.

Leaching

- *Describes the removal of soluble constituents from the soil* ***in solution****.* Predominates wherever rainfall exceeds evapotranspiration.
- Water percolating downward dissolves soluble salts containing Ca2+, Mg2+, Na+, and K+. Notice that these are also cations (nutrients) and therefore are removed in more humid environments.
- However, some of these are held in the exchange complex, and are therefore readily available for plant uptake. Remember that the clay-humus complex helps retain cations for plant uptake!

- Leaching also helps the formation of the **cambic B horizon** by bringing inminerals to help clay development, and contributing to the creation of the **Bw** subhorizon.
- Leaching is a very important managerial process that can lower the salt concentration of an area through drip irrigation, but the root zone can again become saturated with salts if allowed to dry.
- Furthermore, removal of those important bases causes acidification of the B horizon, contributing to the formation of the Bw subhorizon.

Clay eluviation

- Related to leaching, but this process specifically describes the removal of soil constituents in suspension, and is considered a purely mechanical washing of fine particles suspended in the soil solution.
- Finely dispersed clays, humus, and other mineral particles can move as colloidal suspensions from upper eluvial horizons to lower illuvial horizons lower in the soil profile where they are redeposited.

- Occurs in areas where alternating periods of wetting and drying of soils takes place. After wetting, the suspended material removed from the A horizon is deposited on the sides or peds along pores in the lower horizon.
- Eluviation is responsible for the formation of the **argic (or argillic) B horizon**, which is a B horizon enriched with clays redeposited from suspension (= **Bt**). Noticeable by the coating of clay on peds.
- To qualify as an argic: if overlying horizon has < 15% clay, argic = clay percent + 3 percent. If overlying horizon has 15-40% clay, argic lower horizon = clay percent + 20 percent. If overlying horizon has > 40%, argic = clay percent + 8 percent.

Proses	Arti
Eluviasi	Pemindahan bahan-bahan tanah dari suatu horizon ke horizon lain
Iluviasi	Penimbunan bahan-bahan tanah dalam suatu horizon
Leaching	Pencucian basa-basa (unsur hara) dari tanah
Enrichment	Penambahan basa-basa (hara) dari tempat lain
Dekalsifikasi	Pemindahan $CaCO_3$ dari tanah atau horizon tanah
Kalsifikasi	Penimbunan $CaCO_3$ dari tanah atau horizon tanah
Desalinisasi	Pemindahan garam-garam mudah larut dari tanah atau suatu horizon tanah
Salinisasi	Penimbunan garam-garam mudah larut dari tanah atau suatu horizon tanah

Dealkalinisasi (solodisasi)	Pencucian ion-ion Na dari tanah atau horizon tanah
Alkalinisasi	Penimbunan ion-ion Na dari tanah atau horizon tanah
Lessivage	Pencucian (pemindahan) liat dari suatu horizon ke horizon lain dalam bentuk suspensi (secara mekanik). Dapat terbentuk tanah Ultisol (Podzolik) atau Alfisol
Pedoturbasi	Pencampuran secara fisik atau biologik beberapa horizon tanah sehingga horizon-horizon tanah yang telah terbentuk menjadi hilang. Terjadi pada tanah Vertisol (Grumusol)

Podzolisasi (Silikasi)	Pemindahan Al dan Fe dan atau bahan organik dari suatu horizon ke horizon lain secara kimia. Si tidak ikut tercuci sehingga pada horizon yang tercuci meningkat konsentrasinya. Spodosol (Podzol)
Desilikasi (ferralisasi, laterisasi, latosolisasi)	Pemindahan silika secara kimia keluar dari solum tanah sehingga konsentrasi Fe dan Al meningkat secara relatif. Terjadi di daerah tropika dimana curah hujan dan suhu tinggi sehingga Si mudah larut. Oksisol (Laterit, Latosol)
Melanisasi	Pembentukan warna hitam (gelap) pada tanah karena pencampuran bahan organik dengan bahan mineral. Mollisol
Leusinisasi	Pembentukan horison pucat karena pencucian bahan organik

Braunifikasi, Rubifikasi, Feruginasi	Pelepasan besi dari mineral primer dan dispersi partikel-partikel besi oksida yang makin meningkat. Berdasar besarnya oksidasi dan hidrasi dari besi oksida tersebut maka dapat menjadi berwarna coklat (braunifikasi), coklat kemerahan (rubifikasi) atau merah (feruginasi)
Gleisasi	Reduksi besi karena keadaan anaerob (tergenang air) sehingga terbentuk warna kebiruan atau kelabu kehijauan
Littering	Akumulasi bahan organik setebal kurang dari 30 cm di permukaan tanah mineral
Humifikasi	Perubahan bahan organik kasar menjasi humus

Podzolization

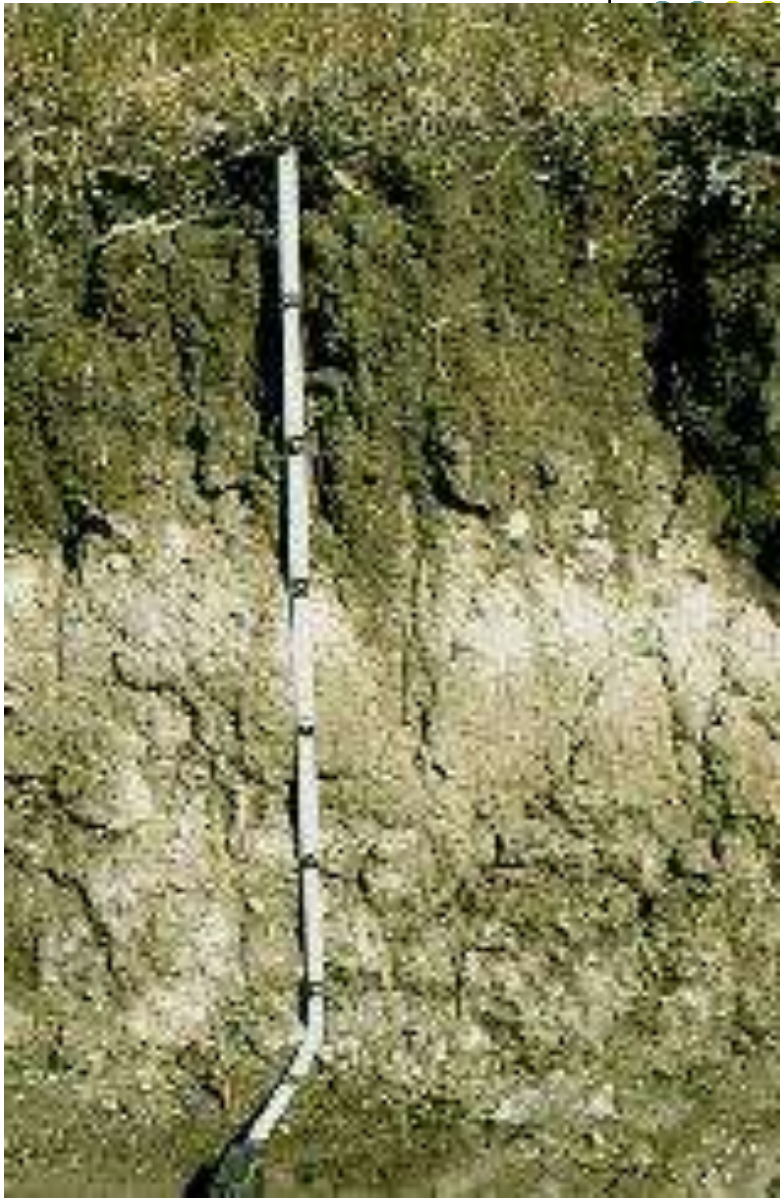
- The upper portion of the B horizon is stained reddish color from the accumulation of sesquioxides. The profile gets lighter in color as depth increases.
- Podzolization of sandy soils in the southern United States has been the result of planting pine plantations.

Laterization

- The deep red to bright orange-red soils of the tropics are a product of laterization.
- Laterization occurs in the hot, rainy tropics where chemical weathering proceeds at a rapid rate. Soils subject to laterization tend toward the acidic and lack much organic matter as decomposition and leaching is extreme.
- Exposure of the soil to the hot tropic sun by deforestation bakes the soil dry, reducing infiltration, increasing runoff, and reducing fertility.

Calcification

- Calcification occurs in warm, semi-arid environments, usually under grassland vegetation.
- Soil tends to be rich in organic matter and high in soluble bases. The B horizon of the soil is enriched with calcium carbonate precipitated from water moving downward through the soil, or upward by capillary action of water from below.



Salinization

- Salinization occurs in warm and dry locations where soluble salts precipitate from water and accumulate in the soil. Saline soils are common in desert and steppe climates. Salt may also accumulate in soils from sea spray. The rapid evaporation of salt-rich irrigation water has devastated thousands of acres of land world-wide.

Gleization

- Gleization occurs in regions of high rainfall and low-lying areas that may be naturally waterlogged.
- Bacterial activity is slowed in the constantly wet environment thus inhibiting the decomposition of dead vegetation allowing it to accumulate in thick layers.
- Peat is found in the upper portion of the soil. Decaying plant matter releases organic acids that react with iron in the soil. The iron is reduced rather than oxidized giving the soil a black to bluish - gray color.