Soil Spectroscopy: Principle and Applications

THE REMOTE SENSING LABORATORIES

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INVESTMENTS IN EDUCATION DEVELOPMENT

Course Outline

- Soil – definition, formation, terminology
- Spectroscopy – basic theory, quantitative usage
- Soil Spectroscopy - definition, problems, analysis
- Spectral Reflectance (SpeR) Analysis – definition, usage, prons and cons
- Exercises – Soil Measurement Protocol and Soil Sper-A

Course's Content :

Lectures

- Lesson 1: Soil and Soil Science: what is soil : definition, formation, interaction with environment, three phase composition , classification and exposure
- Lesson 2: Soil Spectroscopy 1: definition, evaluation and development, past present and future,
- Lesson3 : chromophores (physical and chemical), Hapke's theory and Hunt library , refractive and reflation, absorption , transmittance and reflectance, Soil Spectral Libraries and worldwide expert working group: The LUCAS and SWSG libraries
- Lesson 4: Near Infrared Analysis: definition, evaluation and current status in soil and other disciplines.
- Lesson 5: Soil analysis NIRS + all options . Basic statistics, pre- processing, analytical methods, QI

Exercise:

- Measurement with three ASDs with and with our protocol and normalization procedure
- Analysis of soil contaminated with TPH (unscrabmler, other methods)
- Working with Czech'S soils (measurements and analysis)

Soil

Lesson 1


Soil
definition, formation, terminology

Soil

Soil is the Erath's crust composed of loose material that acts as a bed for flora and fauna.

Soil is the most important natural resource enable life and environmental equilibrium.

Soil

From Wikipedia, the free encyclopedia

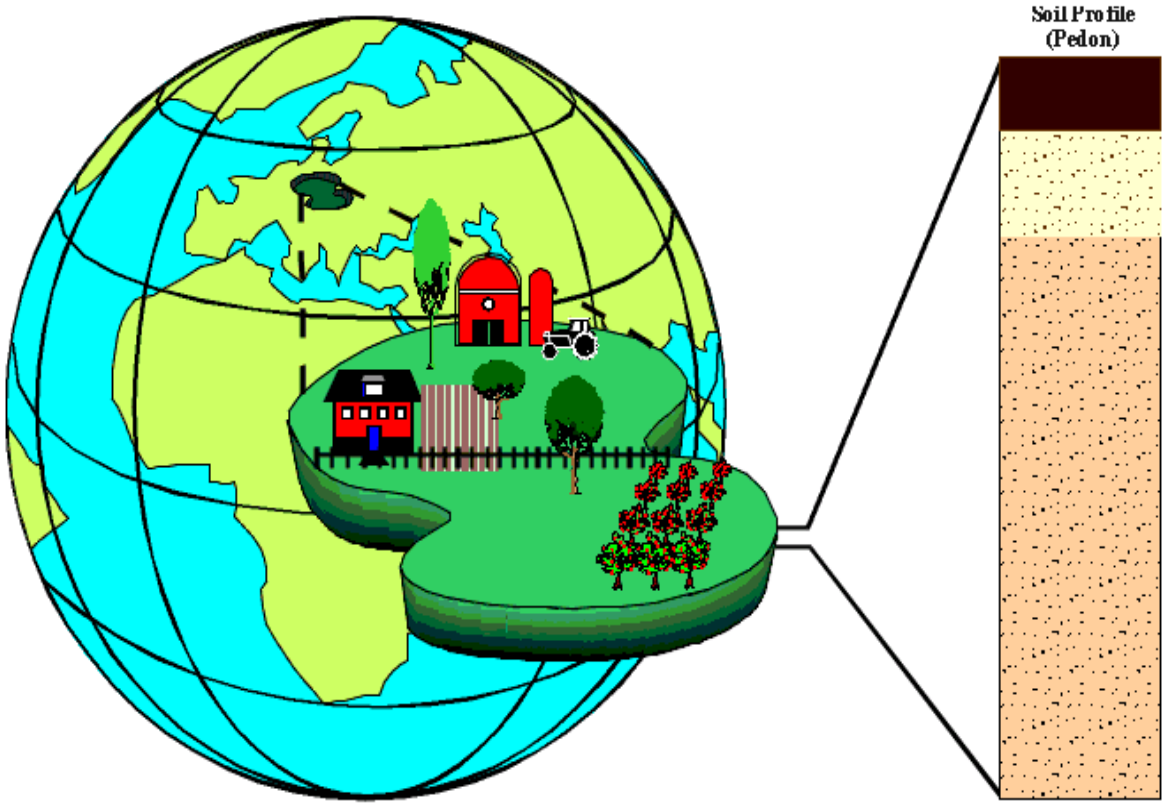
For other uses, see Soil (disambiguation).

Soil is a natural body consisting of layers (soil horizons) that are primarily composed of minerals, mixed with at least some organic matter, which differ from their parent materials in their texture, structure, consistency, color, chemical, biological and other characteristics. It is the unconsolidated or loose covering of fine rock particles that covers the surface of the earth.[1] Soil is the end product of the influence of the climate, relief (slope), organisms, parent materials (original minerals), and time.[2] In engineering terms, soil is referred to as regolith, or loose rock material that lies above the 'solid geology'.[*citation needed*] In horticulture, the terms 'soil' is defined as the layer that contains organic material that influences and has been influenced by plant roots and may range in depth from centimetres to many metres.

Soil is composed of particles of broken rock (parent materials) which have been altered by physical, chemical and biological processes that include weathering with associated erosion. Soil is created from the alteration of parent material by the interactions between the lithosphere, hydrosphere, atmosphere, and biosphere.[3] It can also be considered a mixture of mineral and organic materials in the form of solids, gases and liquids.[4][5] Soil is commonly referred to as "earth" or "dirt"; technically, the term "dirt" should be restricted to displaced soil.[6]

Soil forms a structure filled with pore spaces and can be thought of as a mixture of solids, water, and gases.[7] Accordingly, soils are often treated as a three-state system.[8] Most soils have a density between 1 and 2 g/cm³.[9] Little of the soil of planet Earth is older than the Pleistocene and none is older than the Cenozoic,[10] although fossilised soils are preserved from as far back as the Archean.[11]

Soil : ***"The upper layer of the earth which may be dug plowed specifically, the loose surface material of the earth in which plants grow."*** **(Thompson 1957)**



Soil is composed of

- **Clay**
- **silt**
- **sand**
- **organic matter**
- **carbonates**
- **iron oxides**
- **water**
- **air**

What is Soil Made of ?

It is a combination of:

- mineral material
- organic matter
- pore space (air and water)
- Organisms (fauna and micro fauna)

Soil is made of 5 main ingredients.

1. Mineral Matter (primaery and secondary)
2. Air (as in the atmosphere but with higher CO2)
3. Water (dry to flood)
4. Living Organisms
5. OM Litter and Humus

1. Minerals – Primary: properties not changed from the parent material, Secondary: properties are changed. The most pronounced minerals in the second category are: clay minerals.

2. Air– The air composition is similar to the atmosphere with higher CO2 value based on the root and fauna activities.

3. Water – Water contains dissolved salt, humus(OM) and minerals. Plants absorb these minerals through their roots, helping them to grow. These minerals are called nutrients.

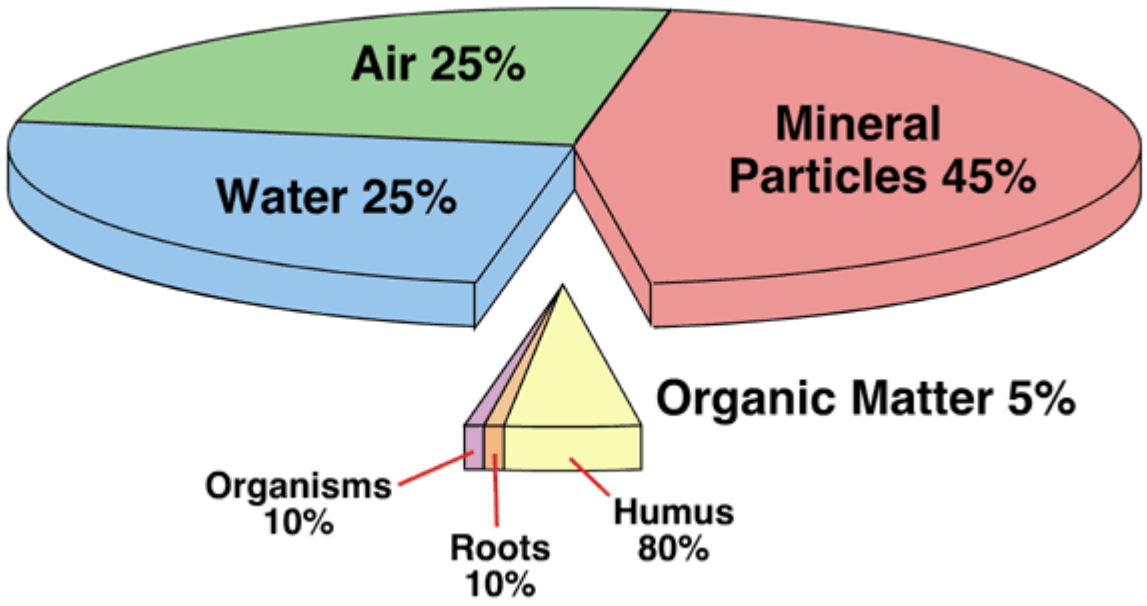
4. Living Organisms – Earthworms, slugs, woodlice and insects and millions of micro-organisms. They break down dead plants and help to create Humus.

5. OM – Litter and Humus – litter is closed to the original vegetation (less water and pigments). Humus – degraded litter by micro organisms. It is made from remains of dead creatures, plants, leaves, and grass. Humus provides nutrients to the soil as well as improve its physical structure.

Soil Phases

- Solid
- Water
- Gas

Distribution of Soil Elements in each phases



Pedosphere

- Upper part of regolith
- 1 to 2 meters
- Mix of minerals (primary and secondary), organic matter and air)
- Bulk Density 1.1-1.6 g/cm2

(opposed of the bed rock BD = 2.6g/cm2)

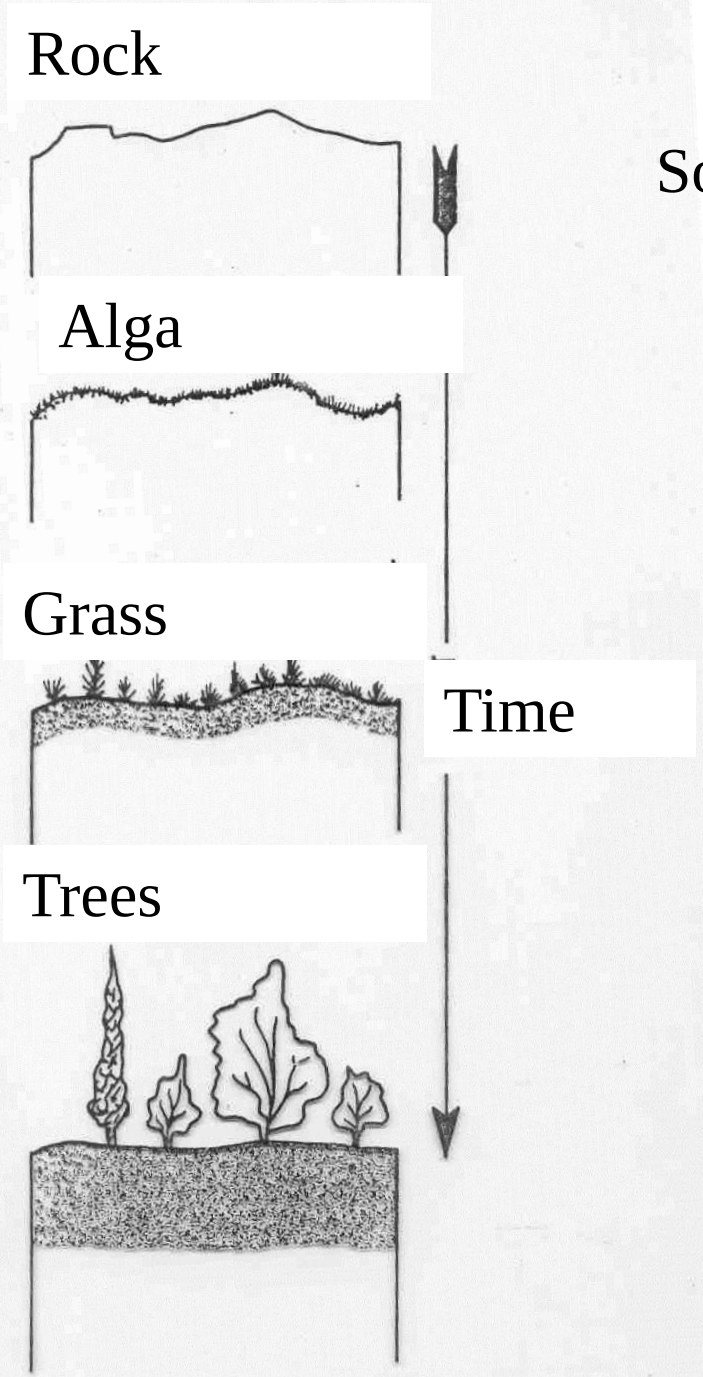
sol

The Pedosphere

affected by

- atmosphere
- hydrosphere
- biosphere
- Lithosphere

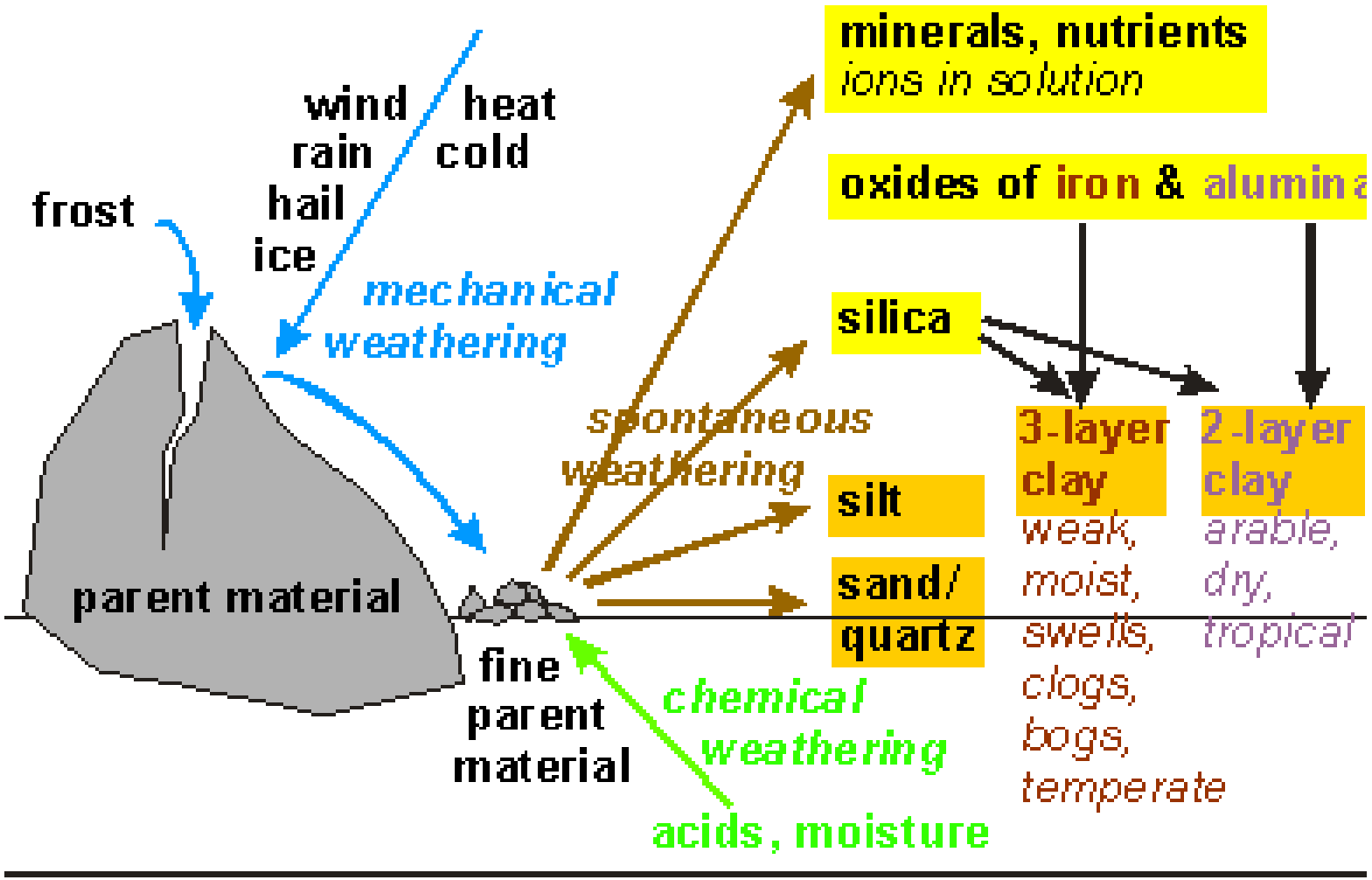
The Earth “rusted” crust



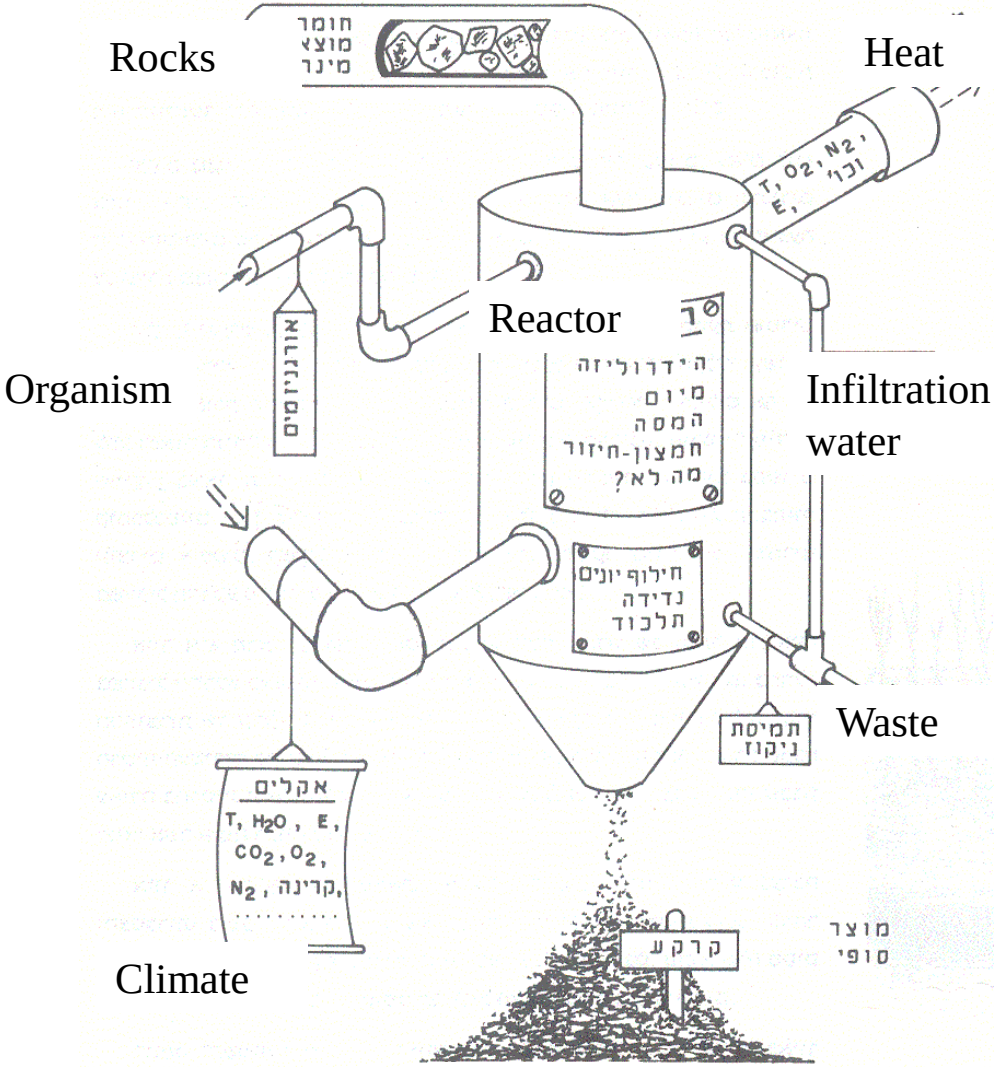
Soil Profile and organic matter Development
(Flora and Fauna)

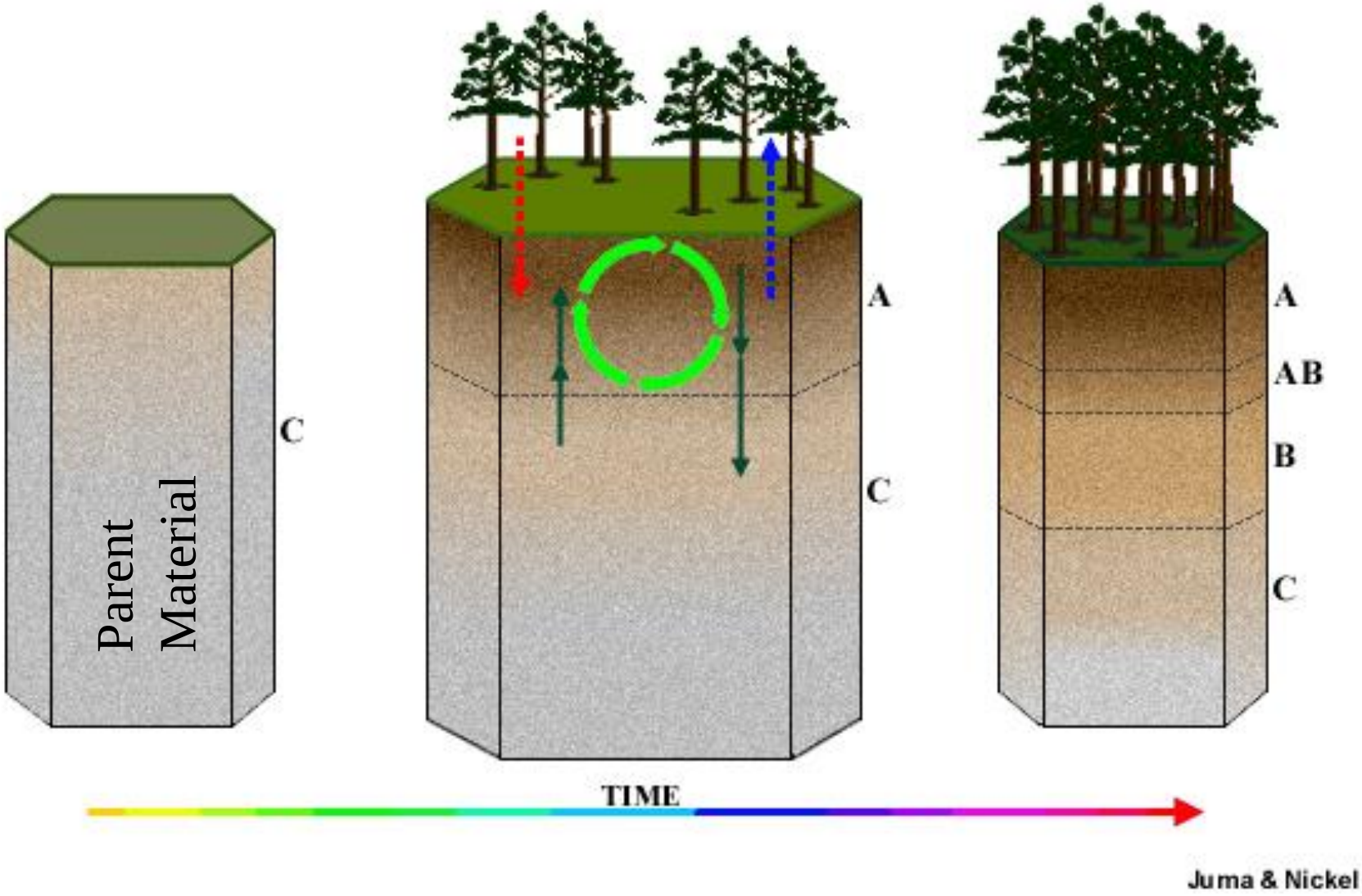
A soil (profile) formation

How is soil made? - weathering

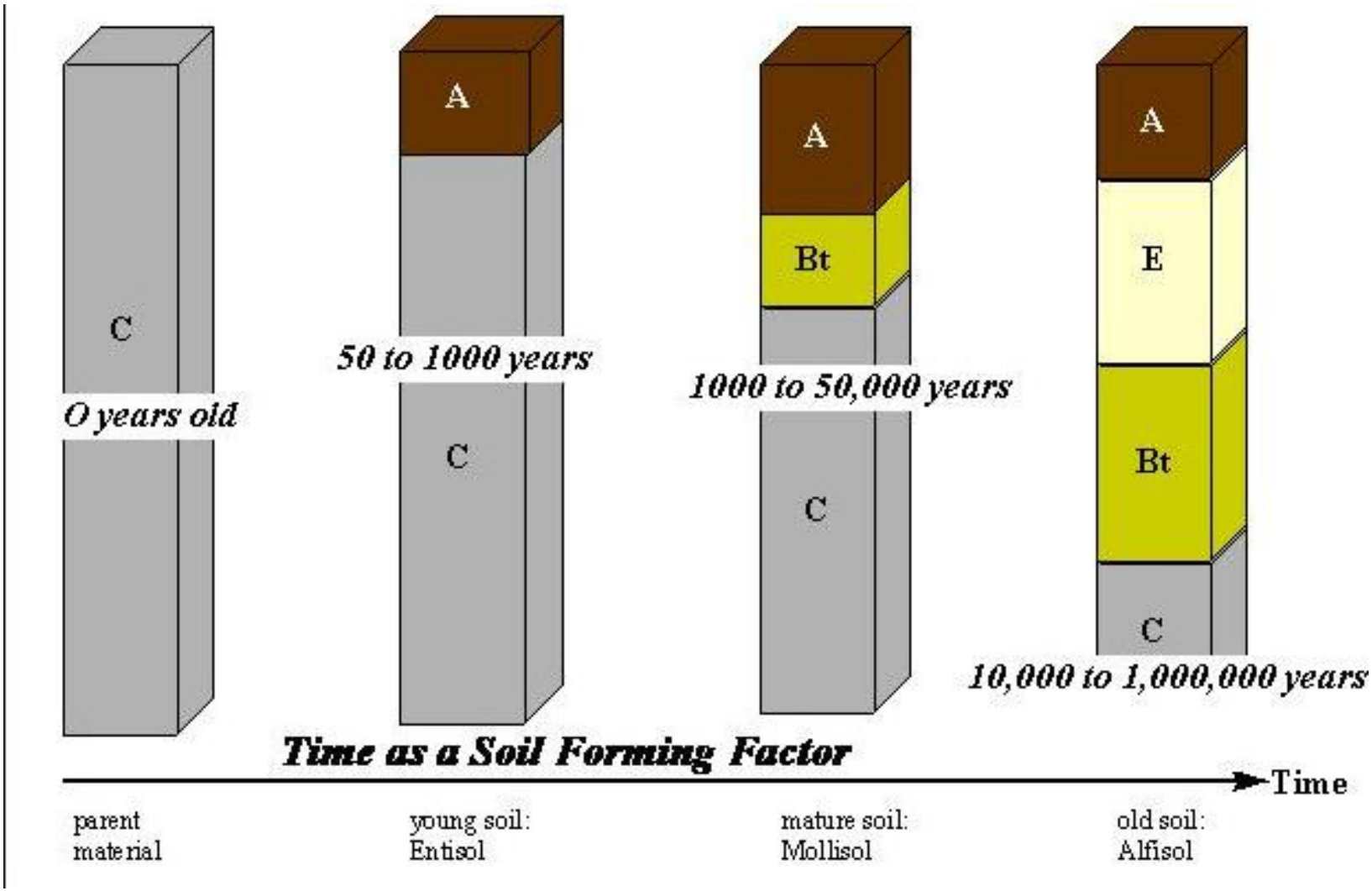


Soil Formation





Soil Profile evaluation with Time

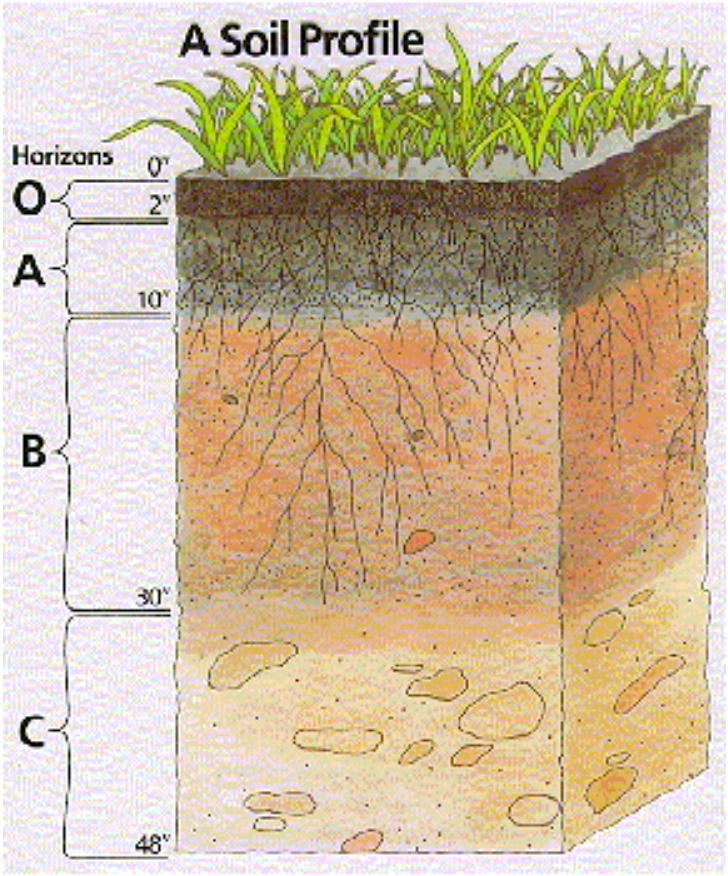

C
O years old
A
C
50 to 1000 years
A
Bt
C
1000 to 50,000 years
A
E
Bt
C
10,000 to 1,000,000 years
Time as a Soil Forming Factor
Time
parent material
young soil: Entisol
mature soil: Mollisol
old soil: Alfisol

Soil Profile (1)

If you dig down into the ground you will reach the bedrock.
You will be able to see a number of different layers of soil.
Each layer is called a horizon.

There are 3 horizons, called the A,B, and C horizons. These 3 layers make up the soil profile.

Horizon: A unique horizontal structure of the soil profile that can be recognized by naked eyes.



Soil Profile (2)

A Horizon – The upper layer of soil (topsoil). It is dark in colour because it contains lots of humus. Most of the organisms live here.

B Horizon – This is beneath the topsoil. It is called the subsoil. It is lighter in colour because it has less humus. It contains more rocks than the A horizon.

C Horizon – This is the parent rock. It is made from The bedrock and pieces of rock.

Soil Horizons: A real world

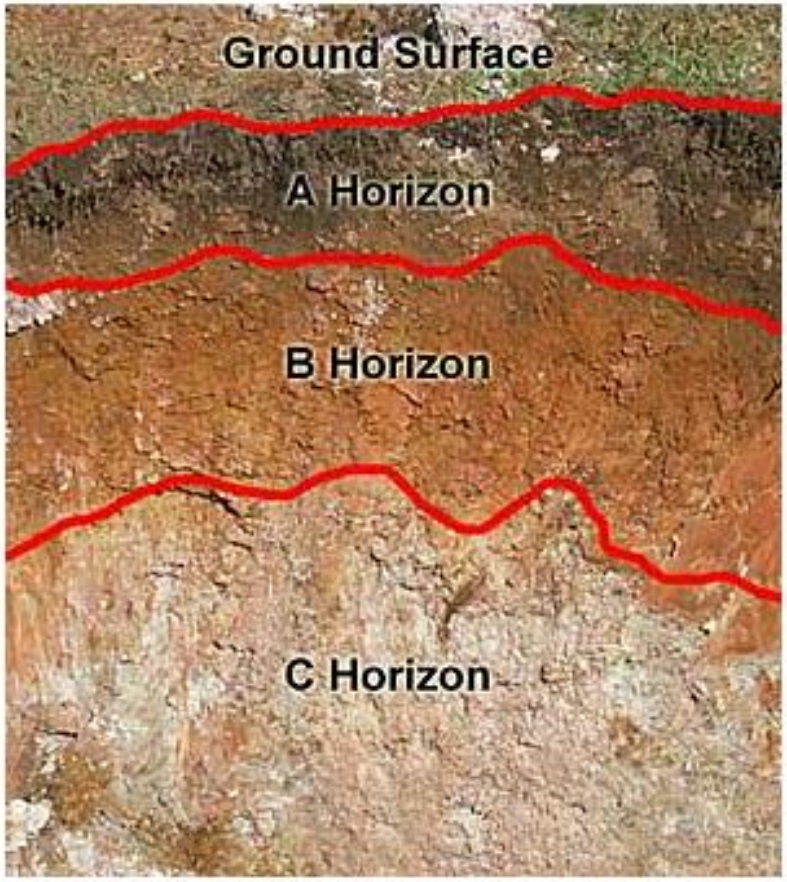
Horizon A

Horizon B

Horizon C

Weathered Bedrock

Profile as recognized in the field (not always perfect horizontal)



The Pedon

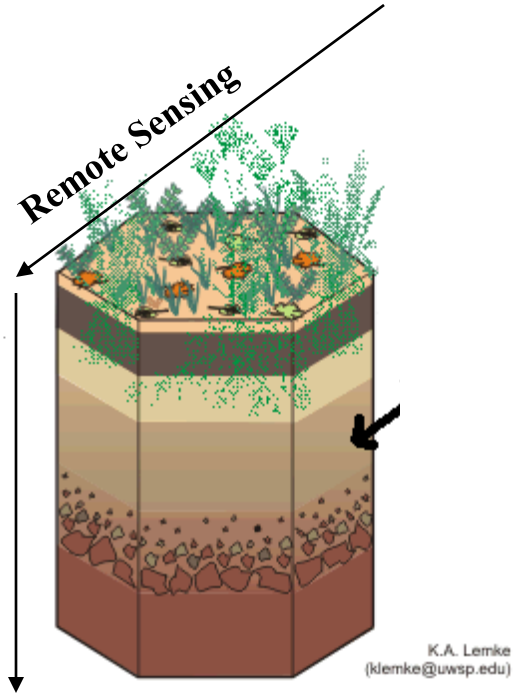
A unique minimal 3D soil entity that composed of soil profile and its spatial occurrence

Buol et al, Soil Genesis and Classification

THE PEDON. A pedon is the smallest volume that can be recognized as a soil individual.

The pedon has been described as follows (Soil Survey Staff 1960):

A pedon is the smallest volume that can be called "a soil." . . . A pedon has three dimensions. Its lower limit is the vague and somewhat arbitrary limit between soil and "not soil." The lateral dimensions are large enough to permit study of the nature of any horizons present, for a horizon may be variable in thickness or even discontinuous. Its area ranges from 1 to 10 square meters, depending on the variability in the horizons. Where horizons are intermittent or cyclic and recur at linear intervals of 2 to 7 meters (roughly 7 to 25 feet), the pedon includes one-half of the cycle. Thus each pedon includes the range of horizon variability that occurs within these small areas. Where the cycle is less than 2 meters or where all horizons are continuous and of uniform thickness, the pedon has an area of 1 square meter. Again, under these limits, each pedon includes the range of horizon variability associated with that small area. The shape of the pedon is roughly hexagonal. One lateral dimension should not differ appreciably from any other.



Factors affecting soil formation

Parent material (geological/organic)

Climate (precipitation, temperature)

Vegetation (plants)

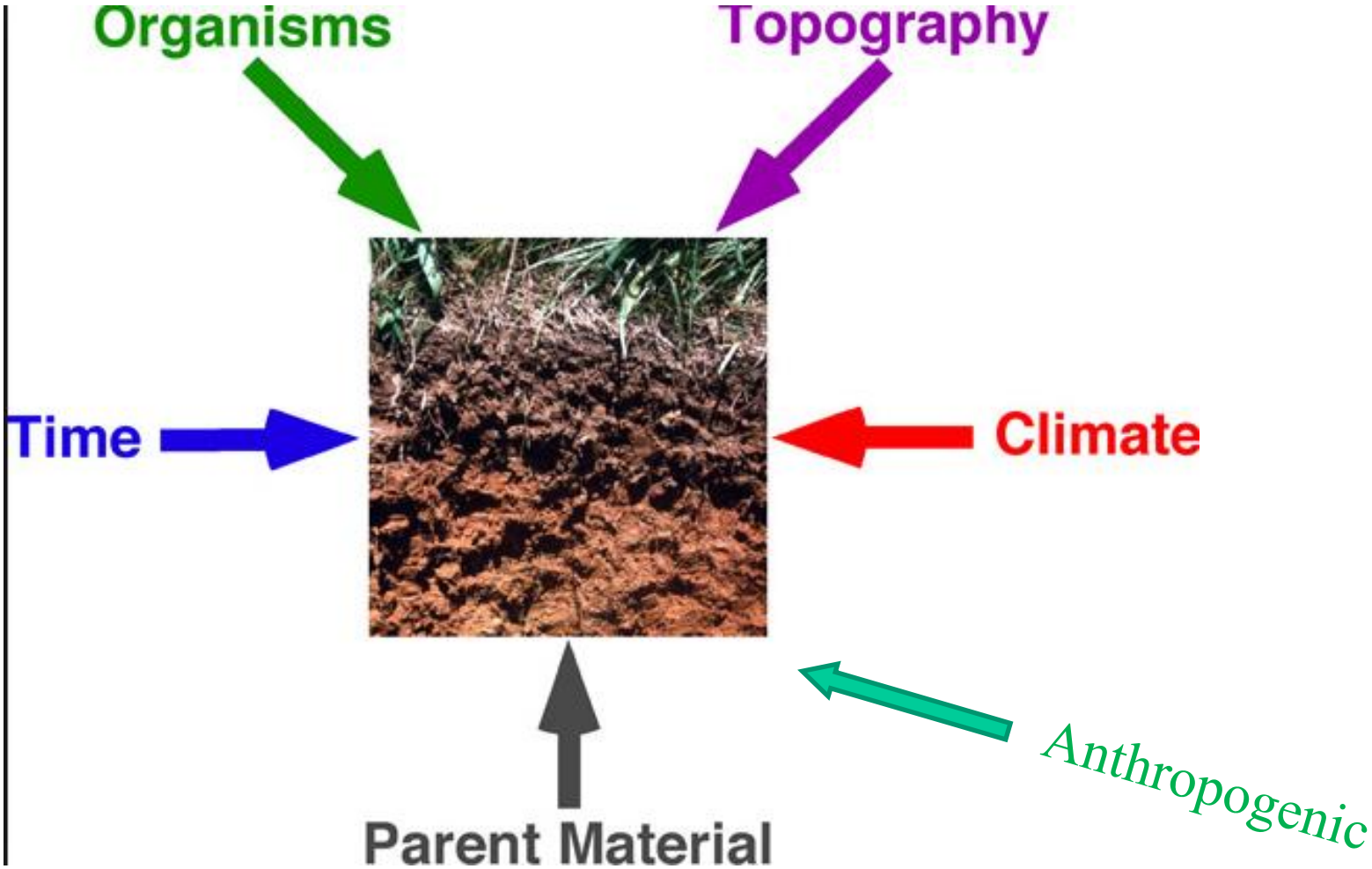
Organisms (soil microbes/fauna)

Relief (configuration of surface)

Soil forming formula

S = f (cl, T, pm, t, o, Ant)

where s is soil property, cl is climate,
T is time, pm is parent material,
t is relief (topography), and
o is soil organisms and Ant is atropogenic activities


Organisms
Topography
Time
Climate
Parent Material
Anthropogenic

Five factors controlling soil formation: Cl, O, Pm, t, T

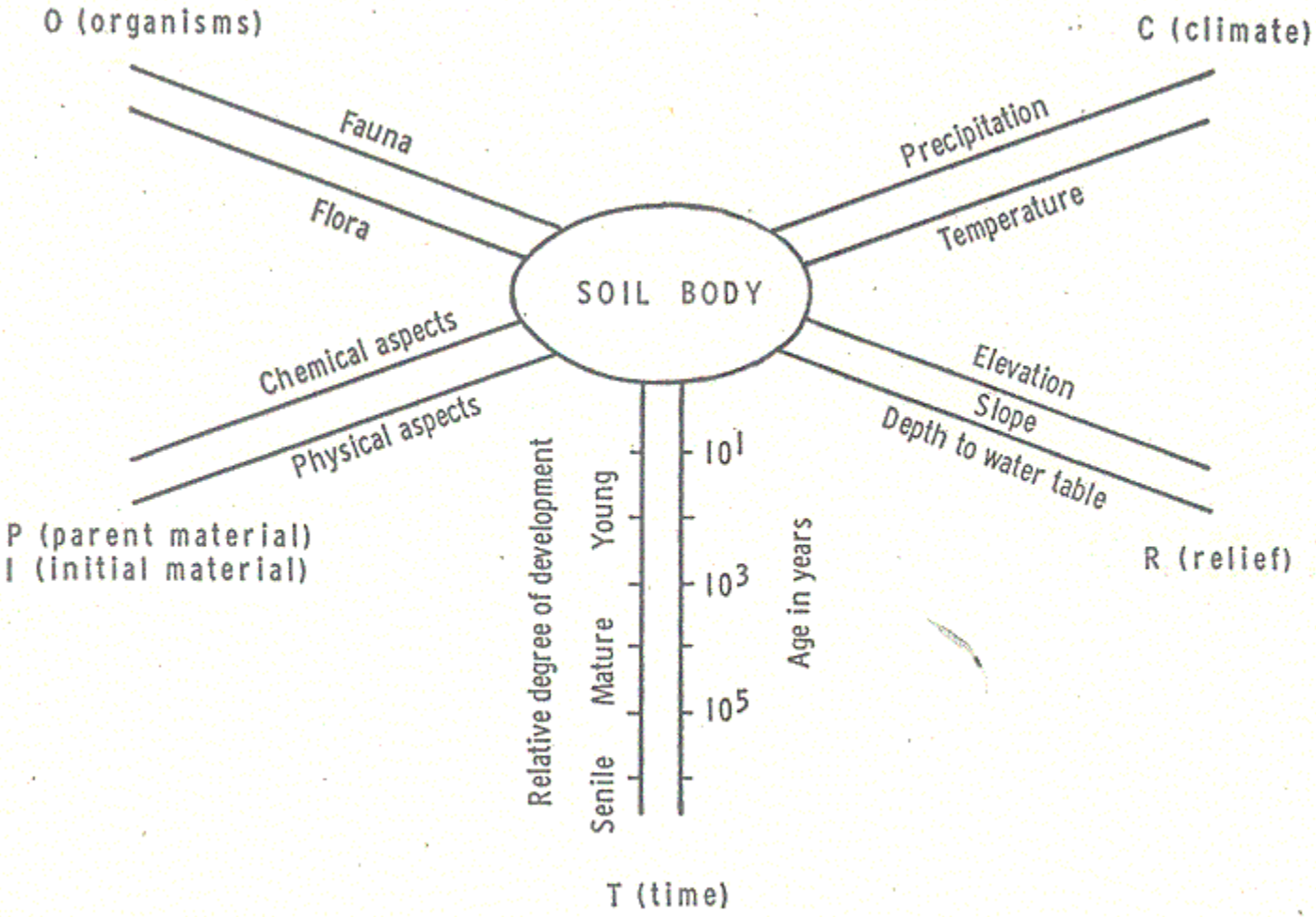


FIG. 7.1. "Flower" diagram of factors of soil formation.

Interaction with the 5 soil factors

Topography

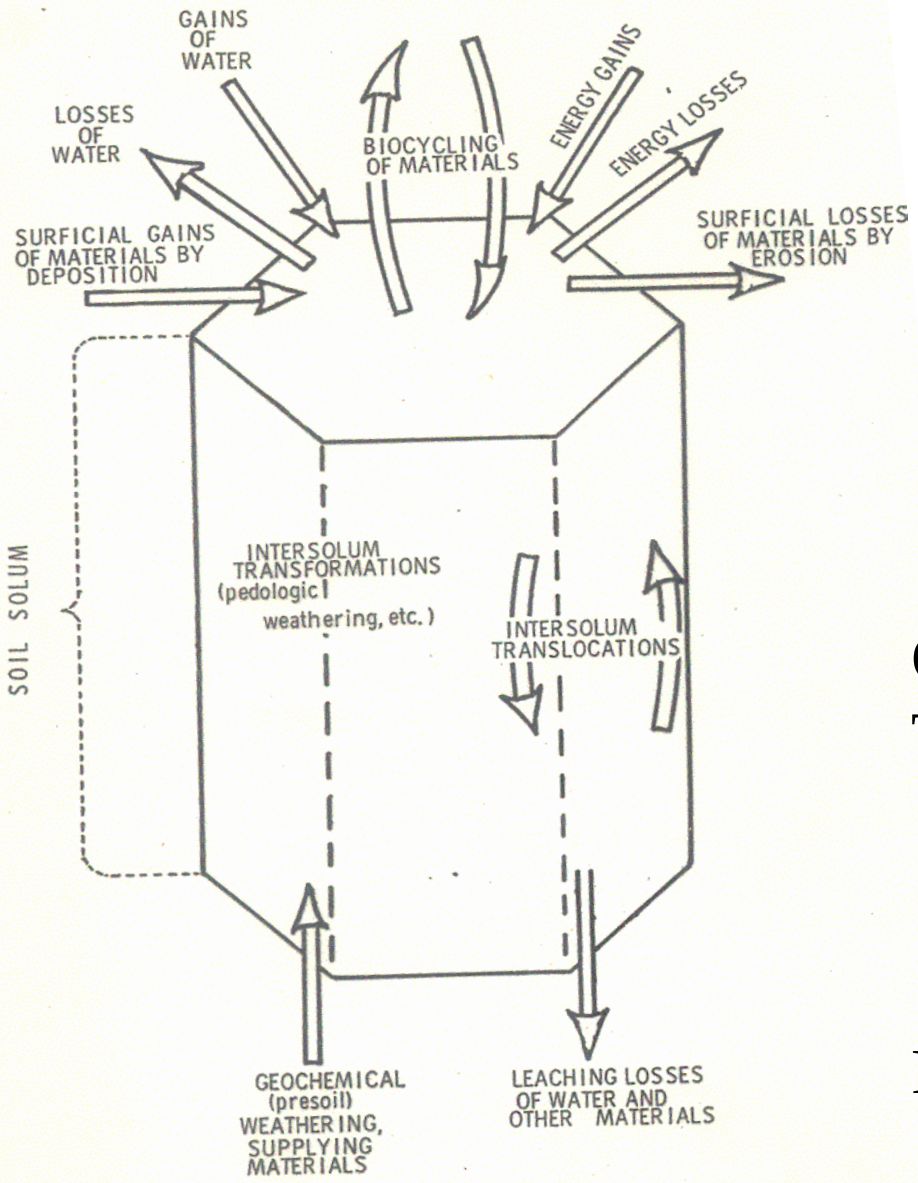


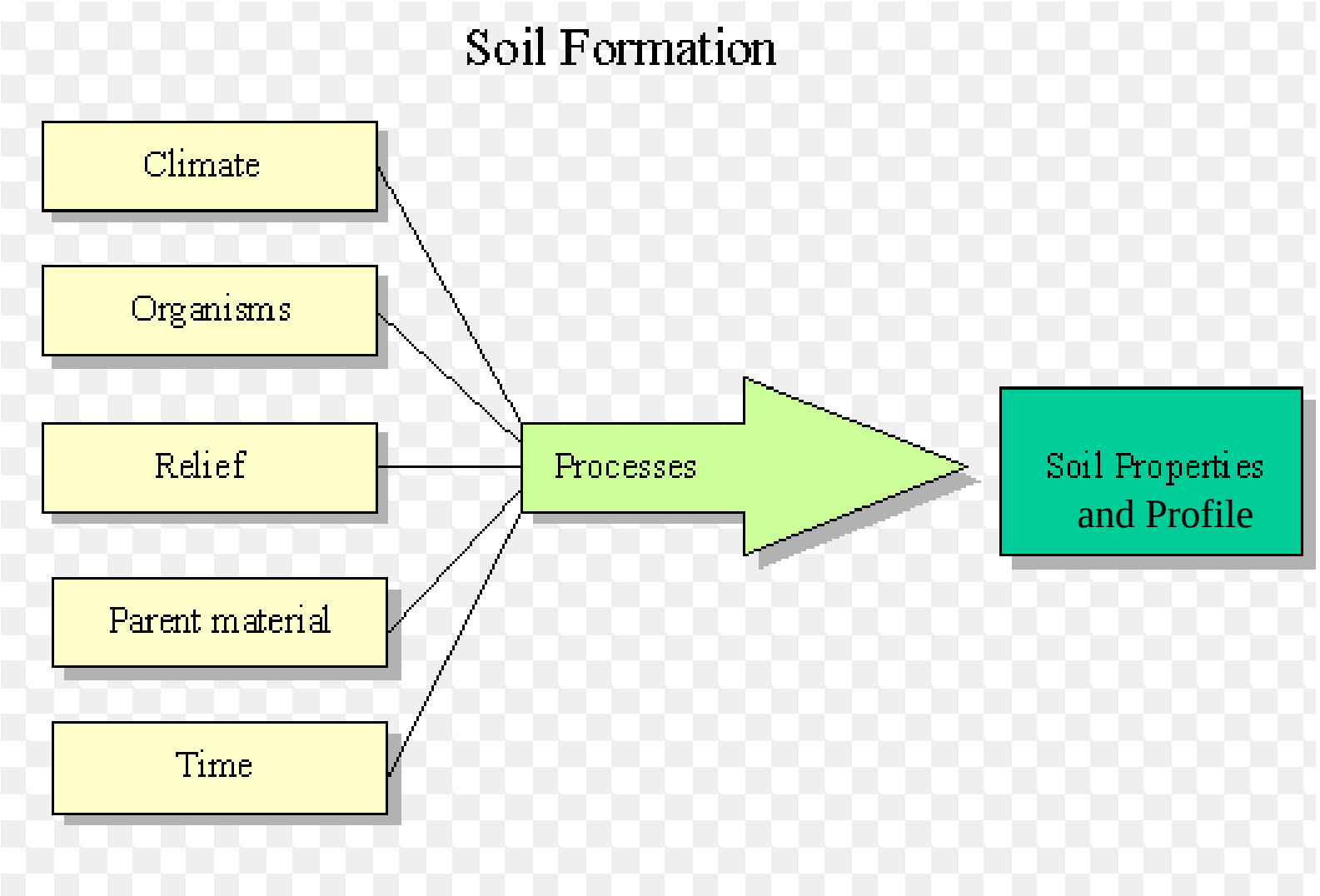
FIG. 1.4. Schematic representation of the solum of a soil pedon as an open system.

Climate

Organic Matter
Time

Parent Material

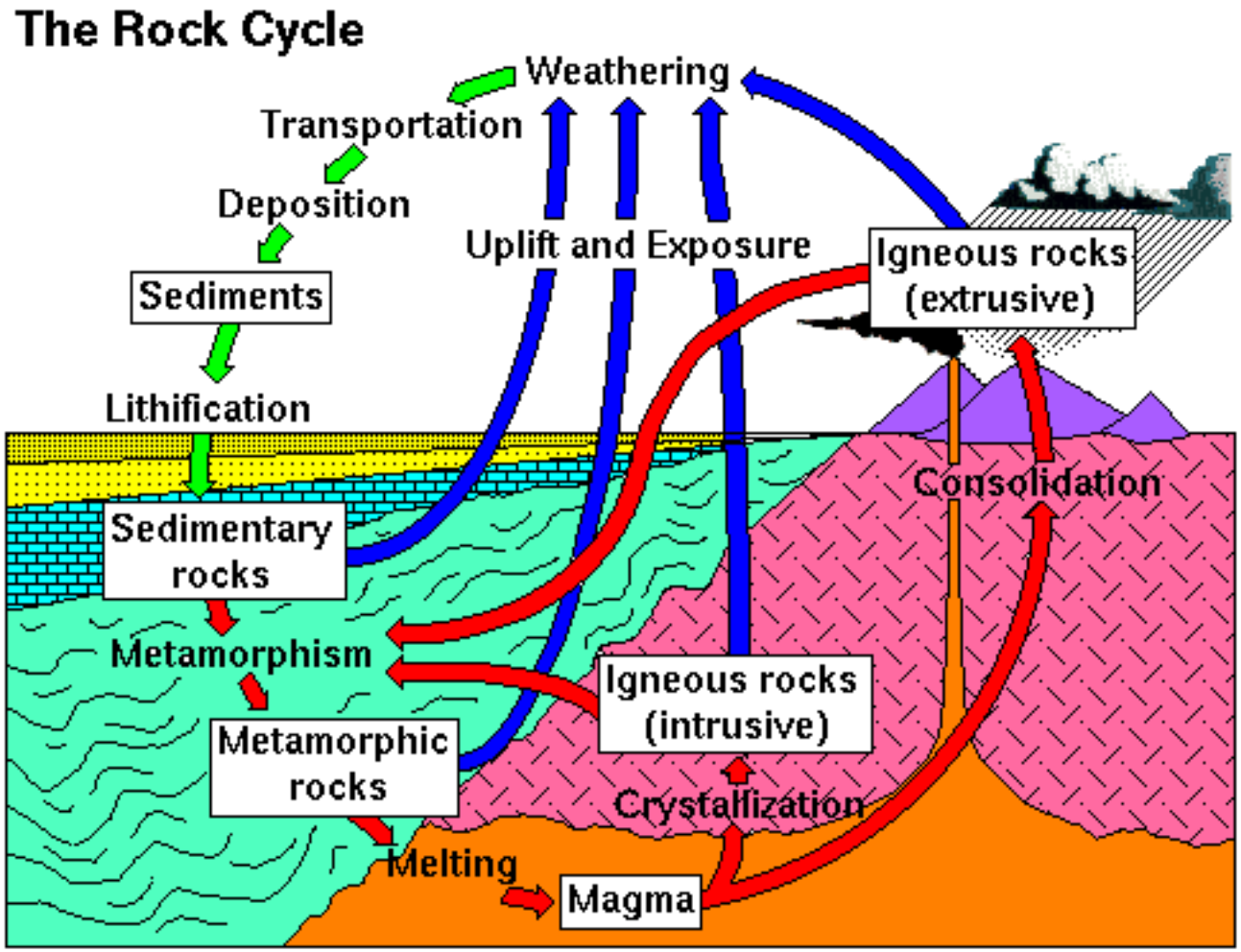
Soil Formation



Types of parent material (rocks)

- Magma: molten rock
- Igneous : cold, solid magma
- Sedimentary: materials deposited from suspension or precipitated from solution (marine and air)
- Metamorphic: rocks changed by heat and pressure

The Rock Cycle (Reeves, 1998)

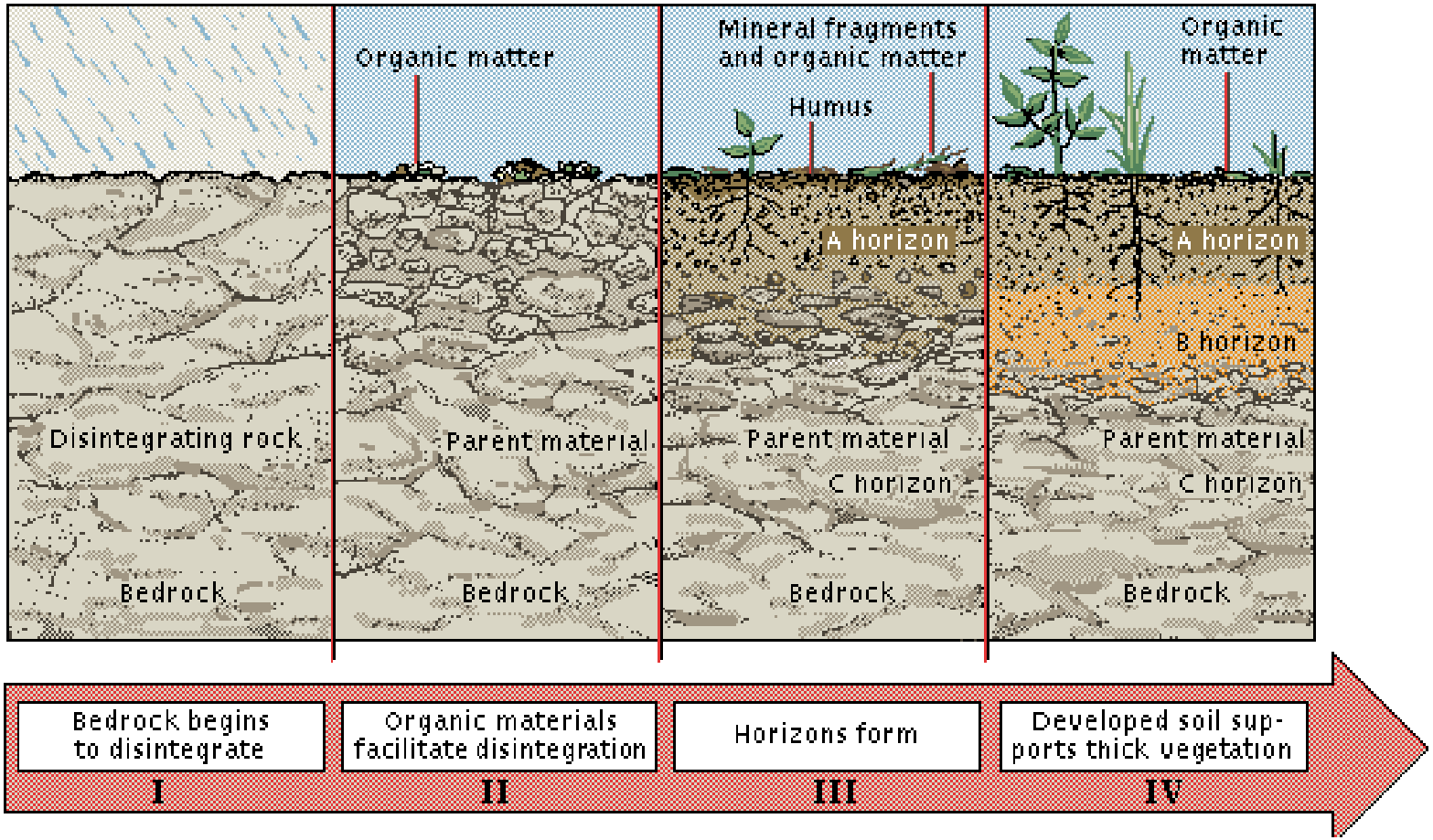


Parent Material

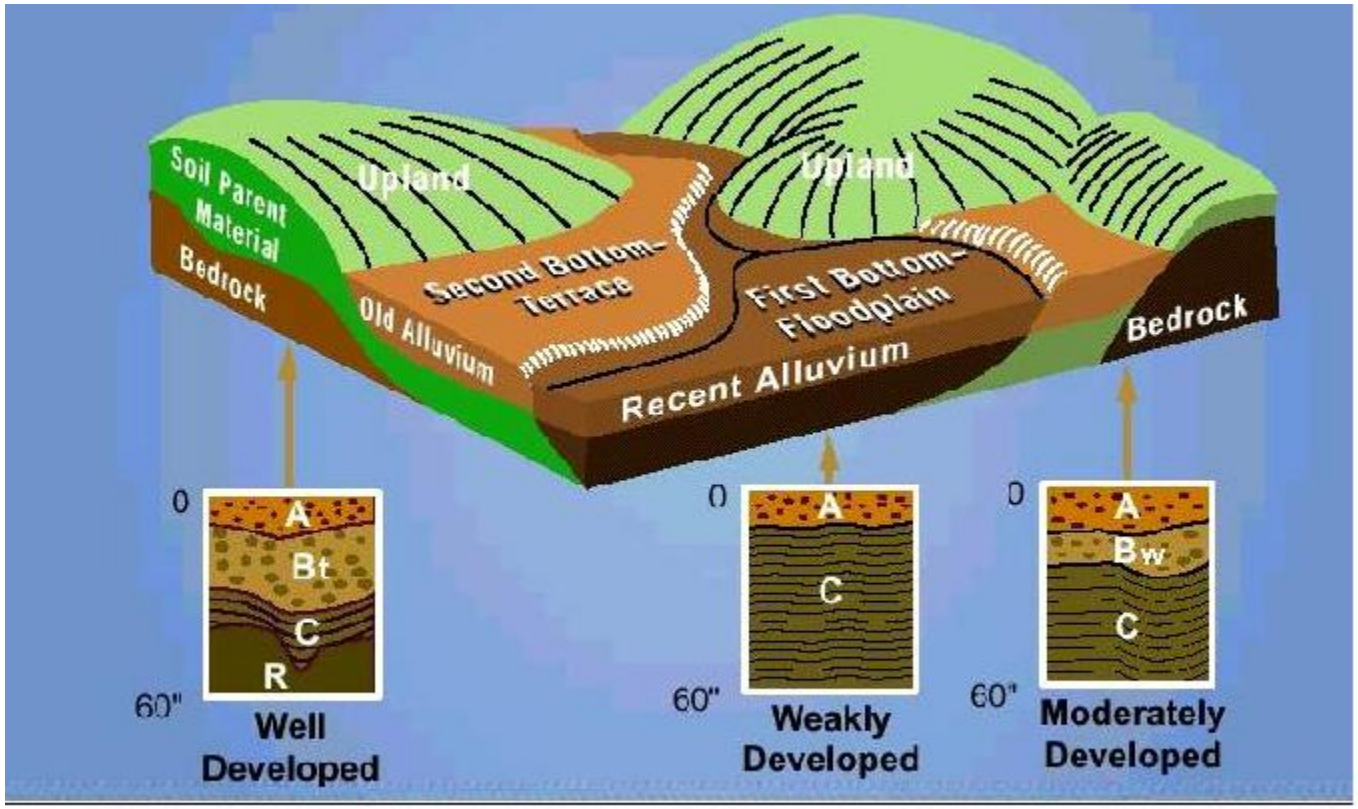
Lime Stone

Basat

Time

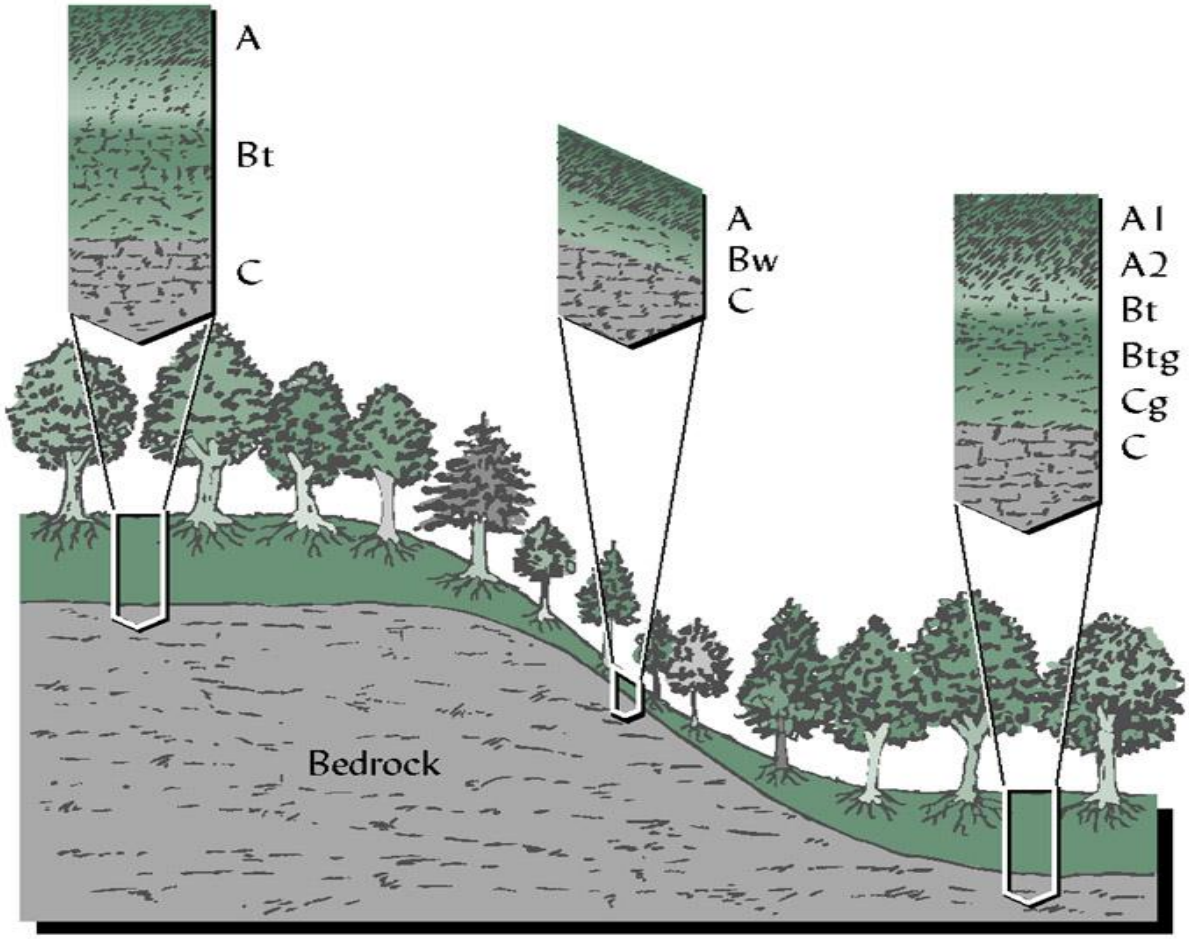

Organic matter
Mineral fragments and organic matter
Humus
Organic matter
A horizon
A horizon
B horizon
Disintegrating rock
Parent material
Parent material
Parent material
C horizon
C horizon
Bedrock
Bedrock
Bedrock
Bedrock
Bedrock begins to disintegrate
Organic materials facilitate disintegration
Horizons form
Developed soil supports thick vegetation
I
II
III
IV

Topography

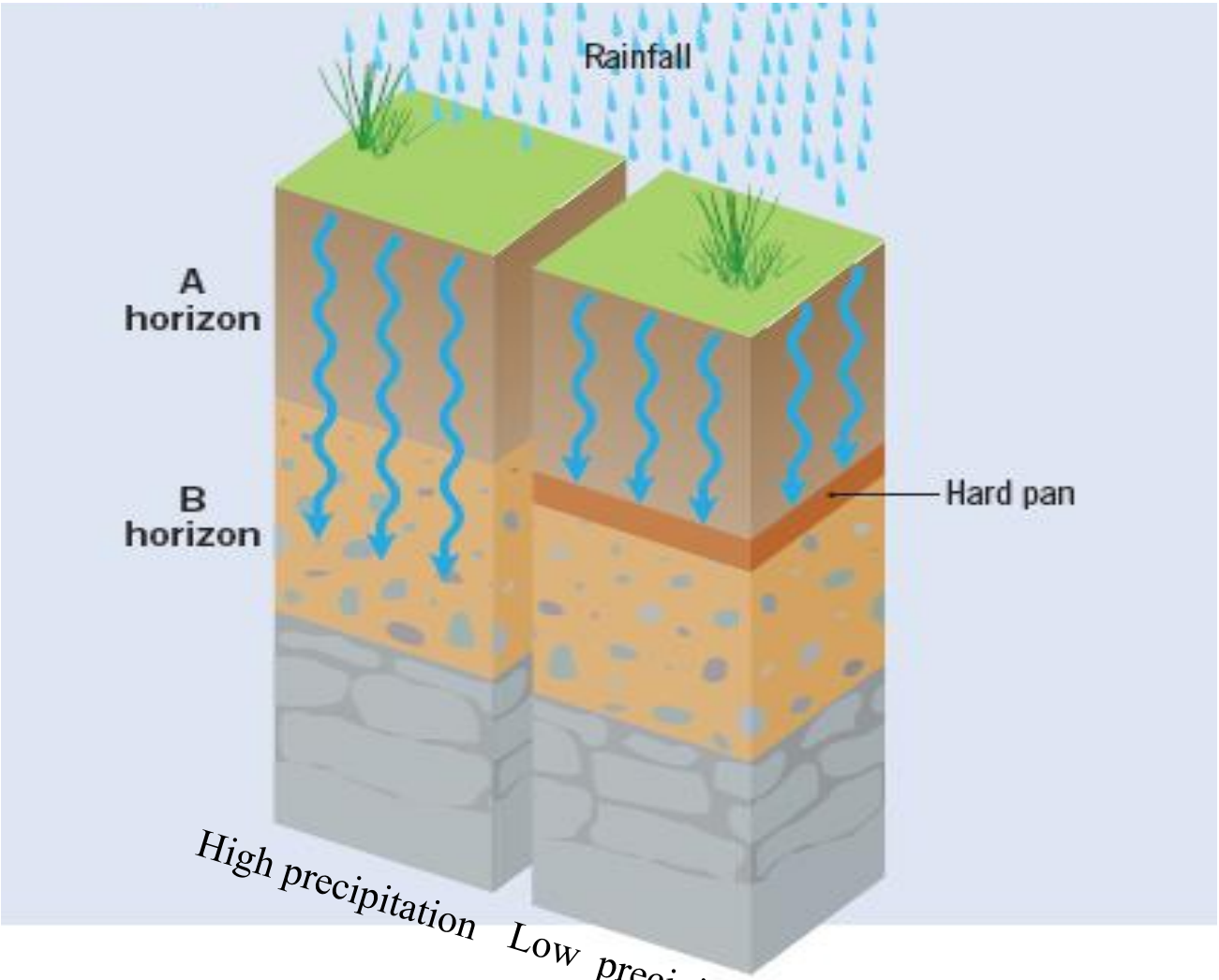


Topography, climate, time, organisms, and parent materials influence soil development.

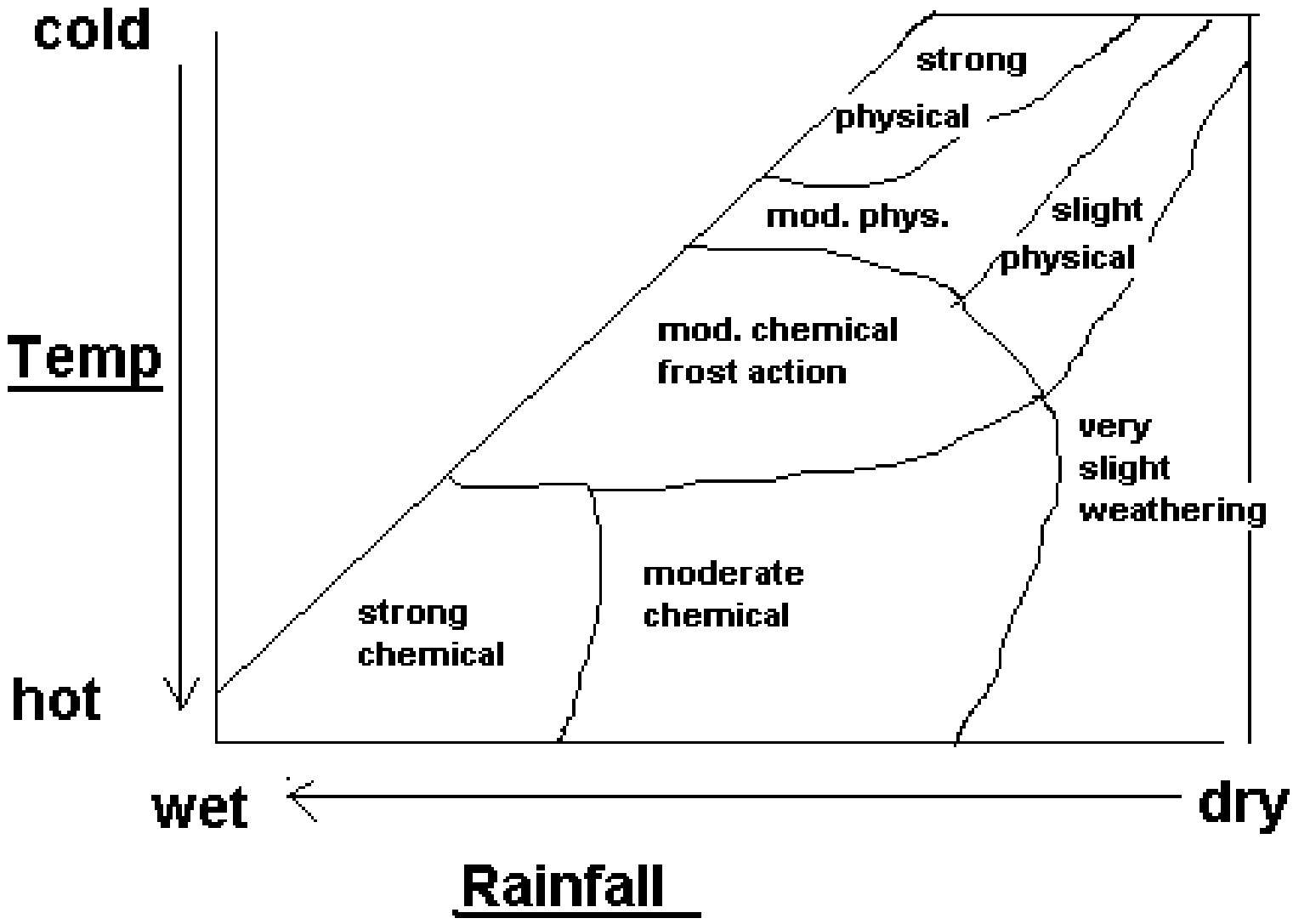
. Topography



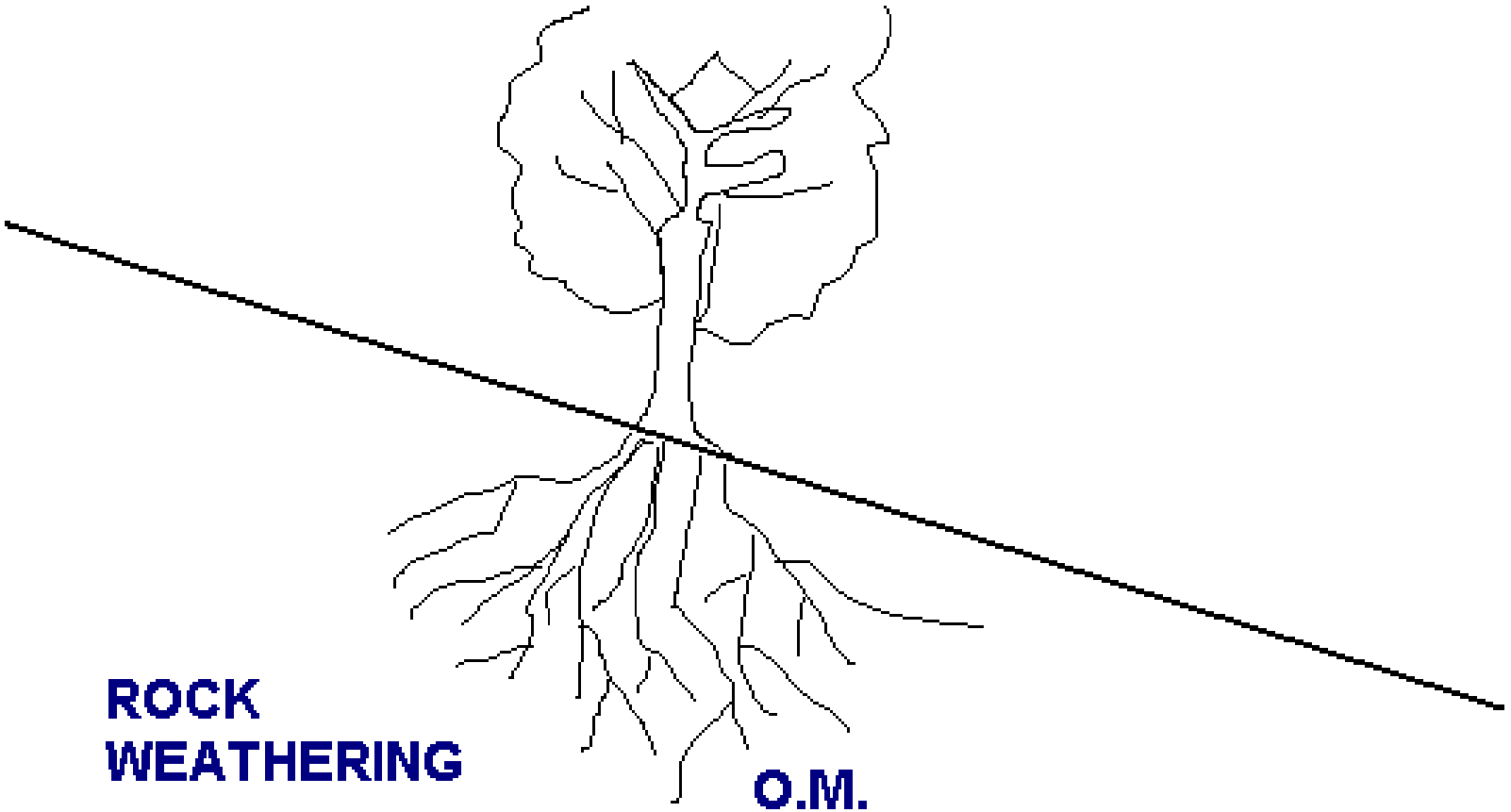
Climate


Rainfall
A horizon
B horizon
Hard pan
High precipitation
Low precipitation

Climate Schema of Soil Formation



Organic Matter



Weathering

Breakdown of Rock near the Surface Due to Surface Processes

Chemical Alteration

- Solution & Leaching
- Biological Action
- Hydration
- Oxydation

Chemical bonds and constituents are changing

Physical Alteration (Mechanical)

- Gravity
- Wedging: Frost, Plant Roots, Salt Crystal Growth, Expansion of Hydrated Minerals

Particle size is changing with out chemical changes

Weathering of rocks and minerals

- Rocks weather into minerals
- Physical and chemical processes
- Continues until primary particles formed
- Primary and secondary particles can be further altered to secondary minerals

- Primary minerals: Those who present in the parent material |(no alteration)
- Secondary minerals: Those who present in the (chemically) altered phases

Chemical weathering

Accelerated by the presence of

- water (and its dissolved solutes)
- oxygen
- organic and inorganic acids
- Decomposition

Chemical weathering

- converts primary minerals into secondary minerals
- e.g. feldspars and micas into clays
- dissolves essential elements out of minerals and makes them available to plants and organisms

Physical Weathering

- Disintegration
- Temperature
- Water, Ice and Wind
- Plants and Animals

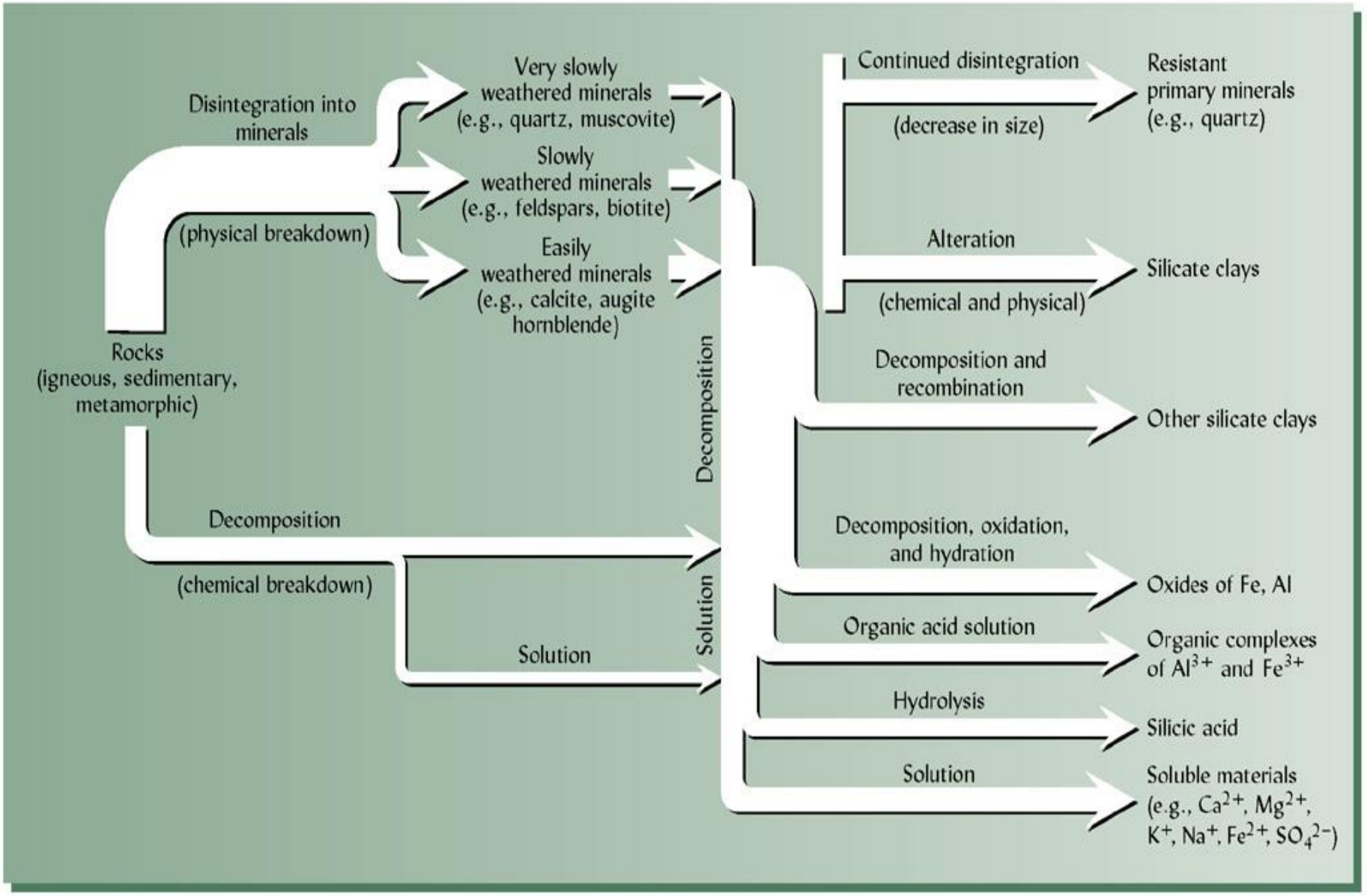
Leaching

- Leaching occurs when heavy rainfall washes minerals, nutrients and humus down into the B horizon.

- This means the A horizon loses fertility as the roots of plants cannot reach the nutrients in the B horizon.

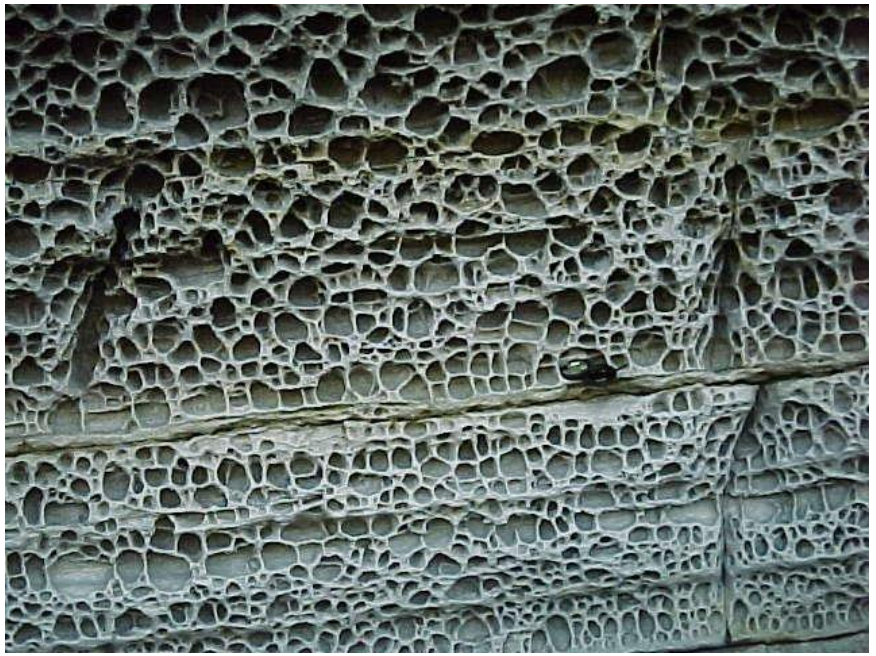
- With severe leaching, minerals can accumulate at the bottom of the A horizon, where they are cemented together into a hard impermeable crust. This can cause water logging in the soil above.

A schematic chart that illustrates the soil weathering process



Weathering Rates

Differential Weathering and Erosion



Soil Analysis

Soil Sampling

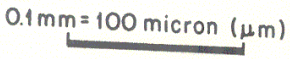
Grinding to <2mm

Soil Texture (Mechanical Composition)

Ratio of sand, silt and clay

Soil Texture is important to Water-retention properties: e.g. Loam textures are the best for plant growth

Mechanical Composition

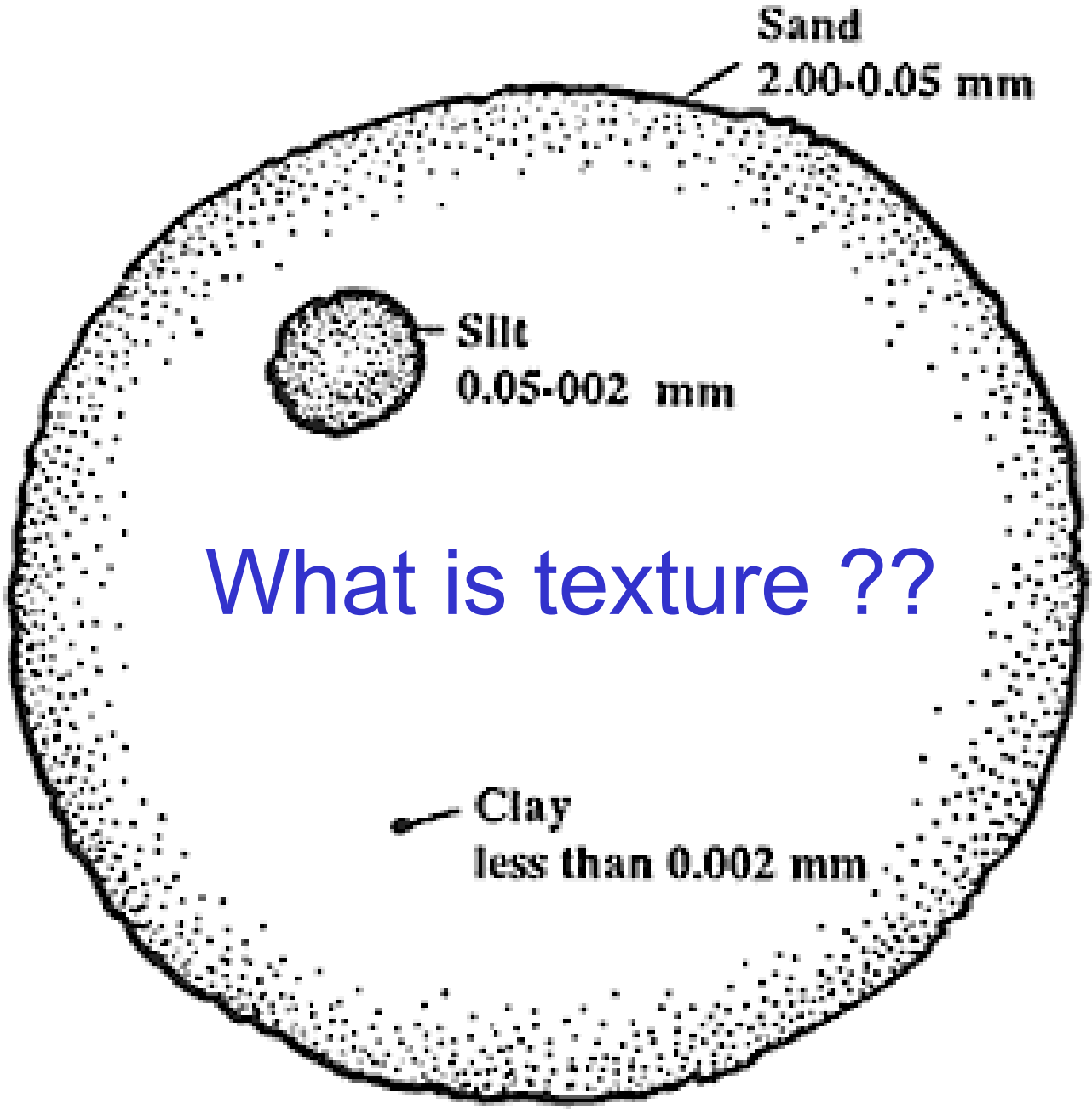


Sand

Silt

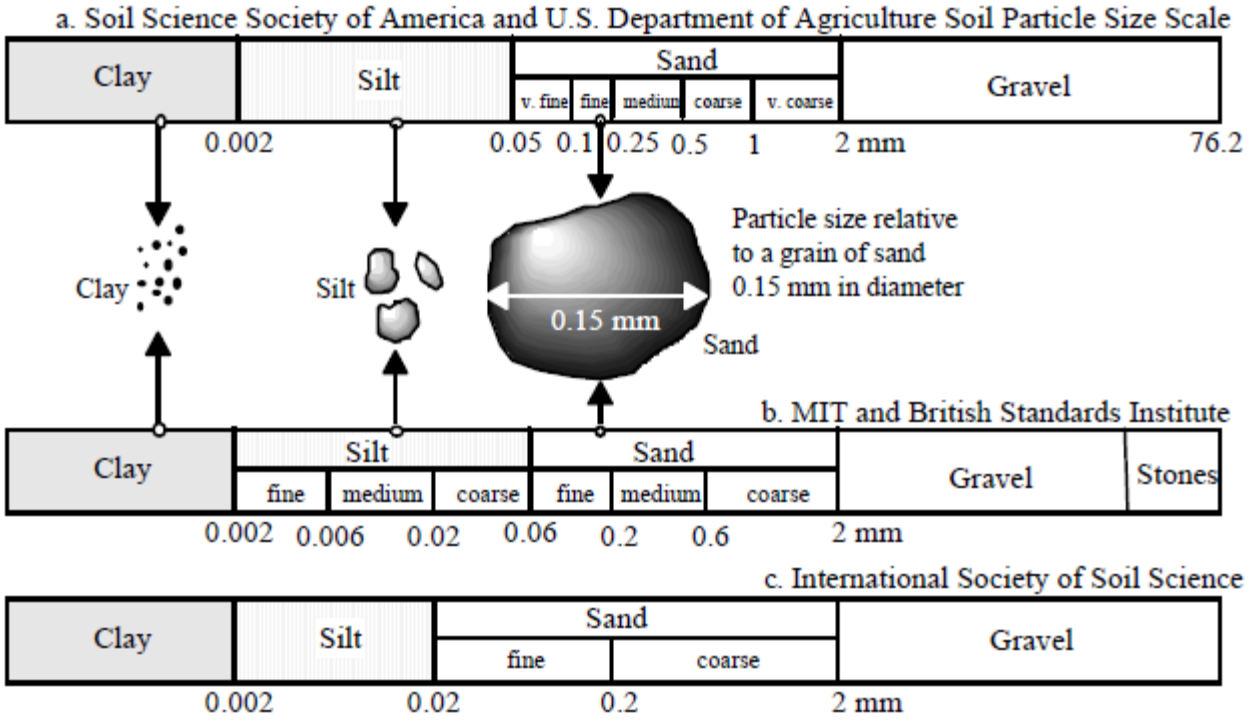
Clay

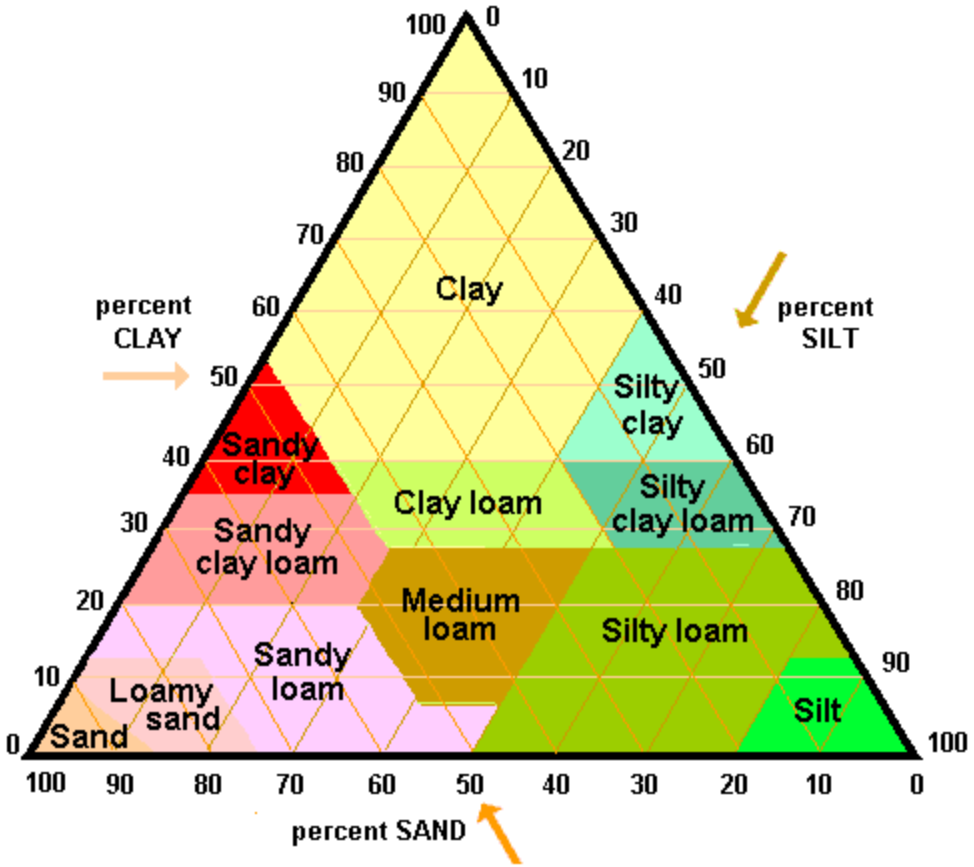
D(mm)	Name
2.0 - 0.2	חול גס (coarse sand)
0.2 - 0.02	חול דק (fine sand)
0.02 - 0.002	סילט (silt)
<0.002	חרסית (clay)



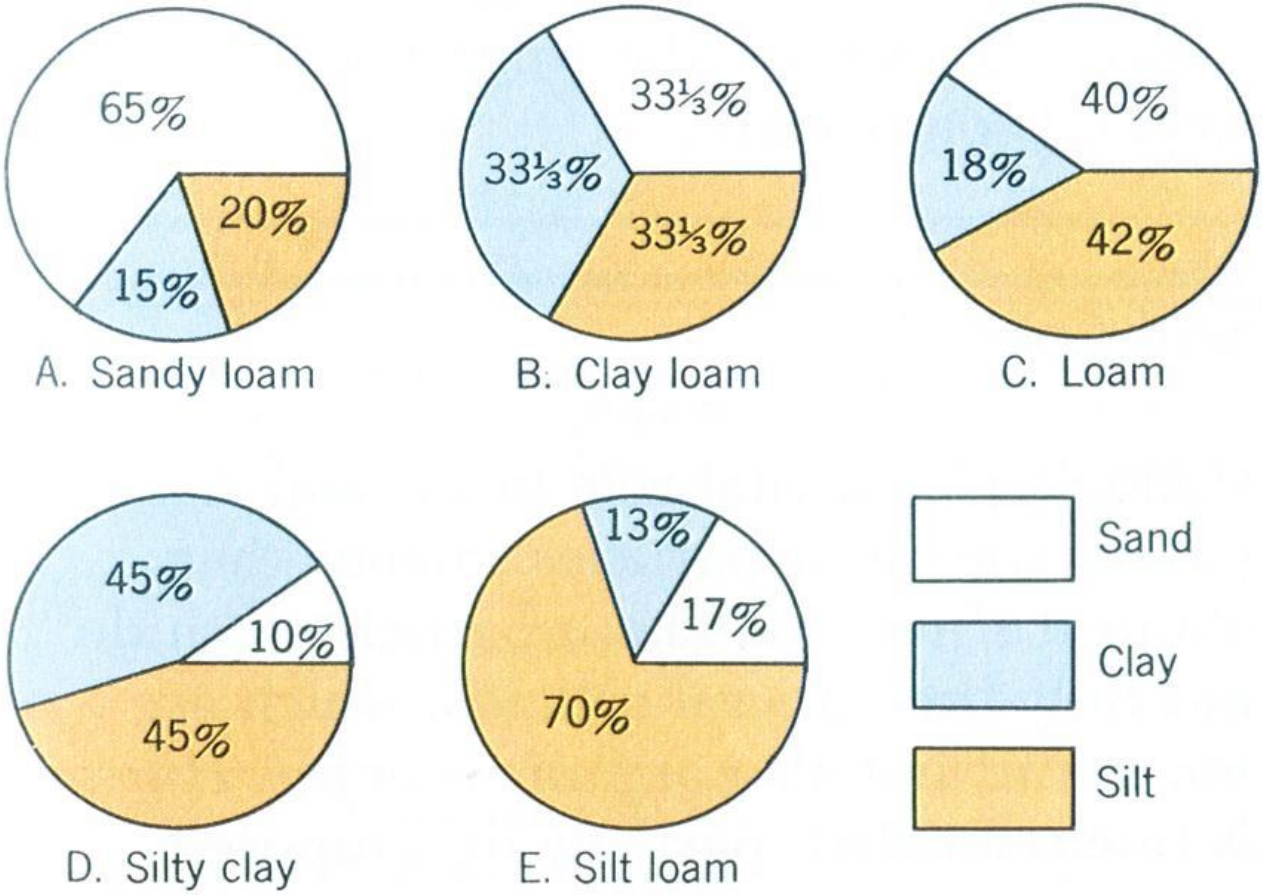
What is texture ??

Soil Particle Size Scales

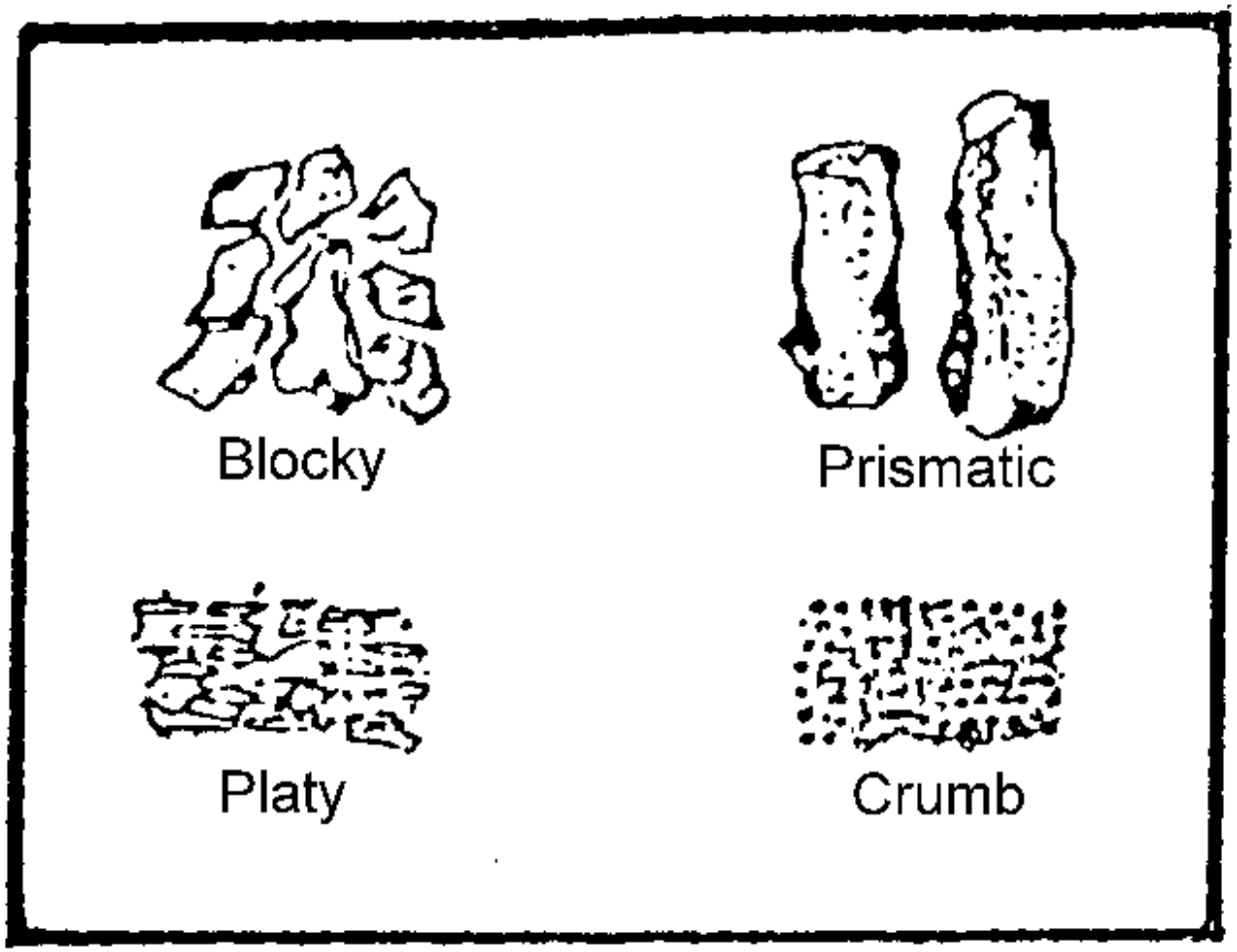



Clay
Silty clay
Sandy clay
Clay loam
Silty clay loam
Sandy clay loam
Medium loam
Silty loam
Sandy loam
Loamy sand
Sand
Silt
percent CLAY
percent SILT
percent SAND
100
90
80
70
60
50
40
30
20
10
0

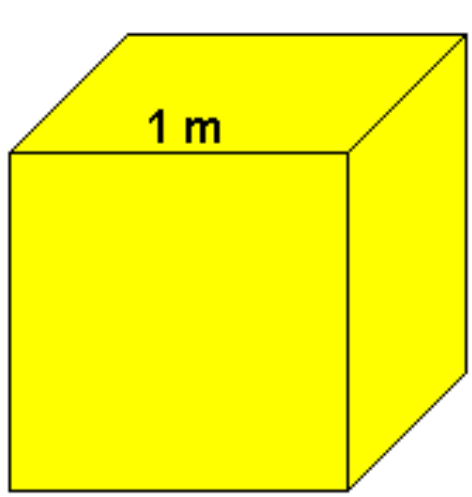
Soil Texture



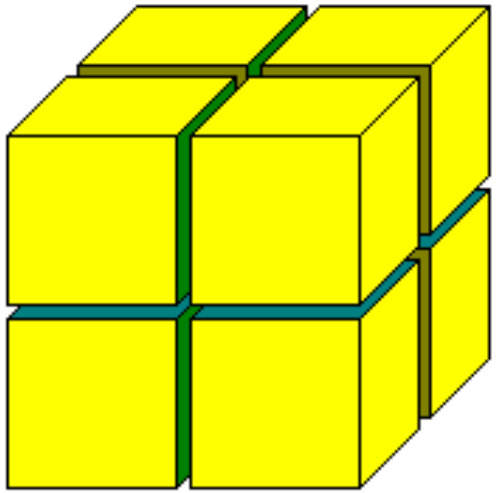
Soil Structure



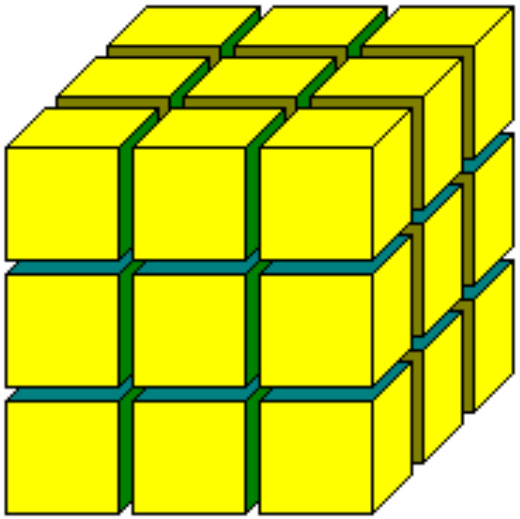
Surface Area and Weathering



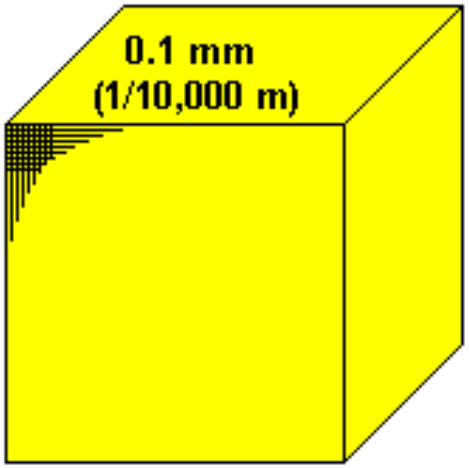
Area = 6 x $1m^2$ = 6 m^2



Area = 6 x $(1/2m)^2$ x 8 = 12 m^2



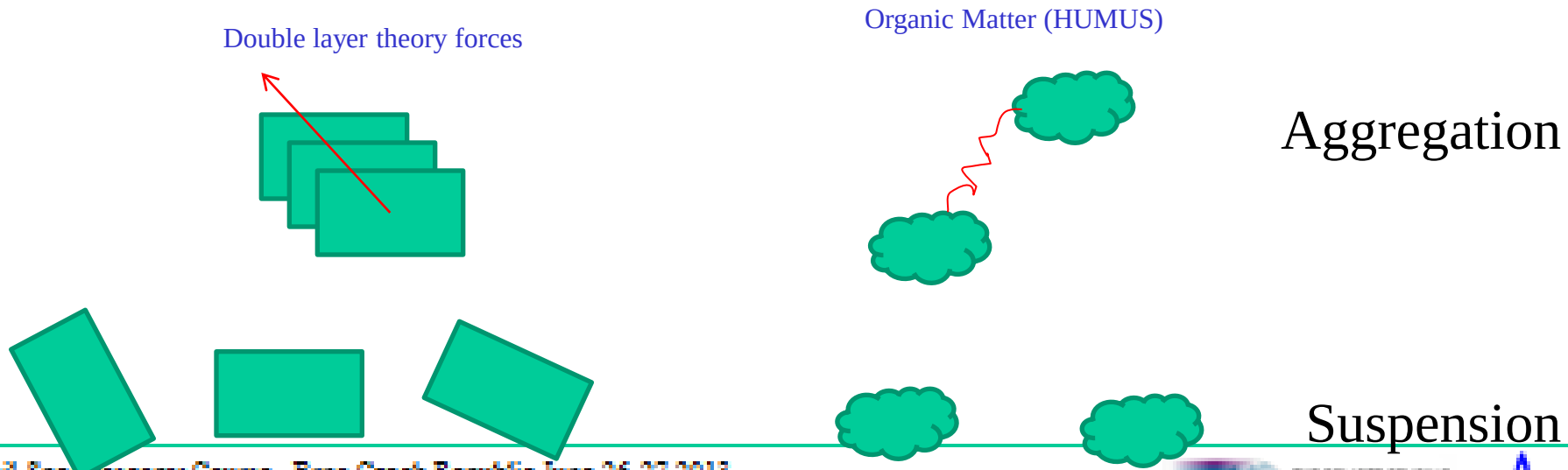
Area = 6 x $(1/3m)^2$ x 27=18 m^2



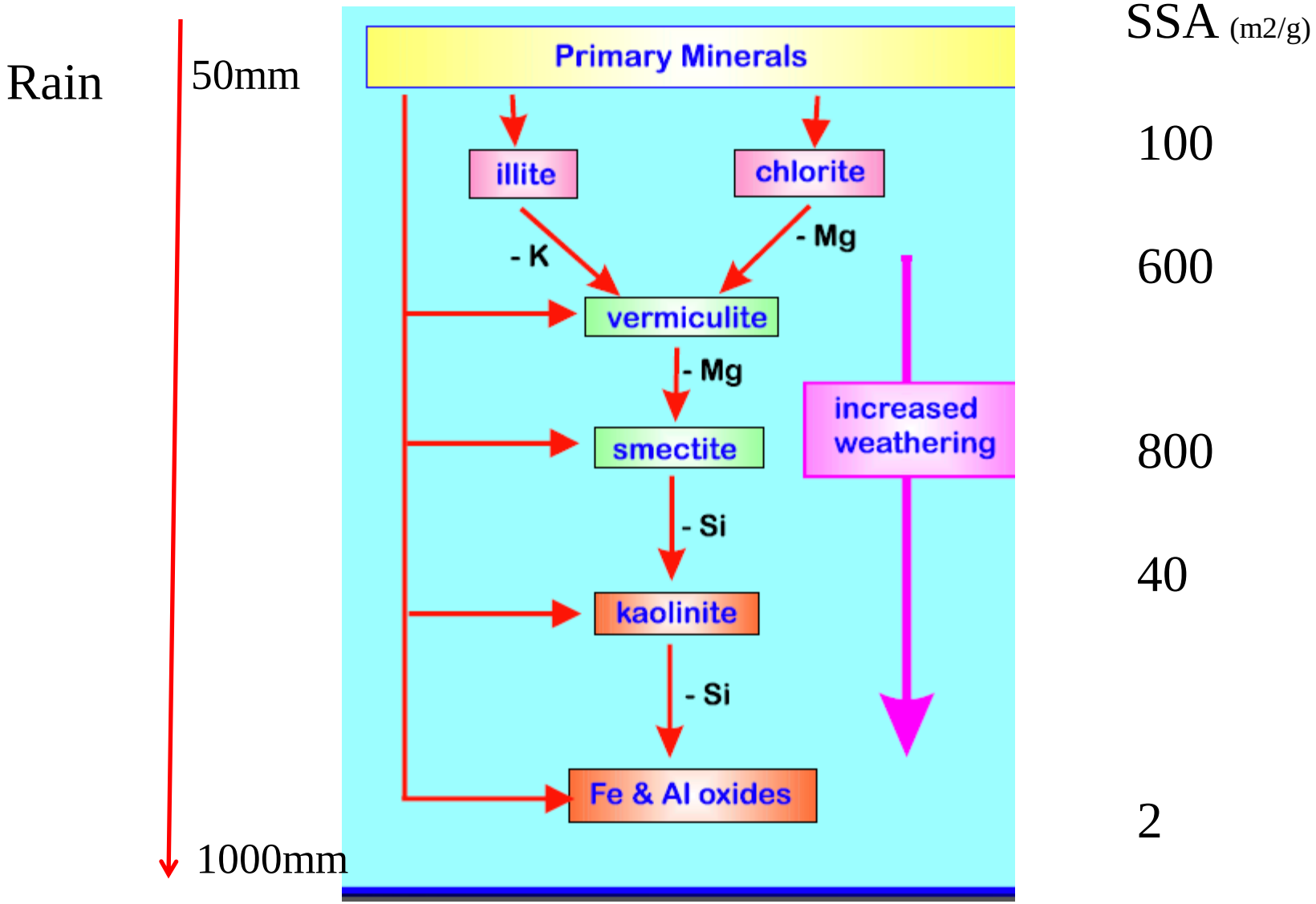
Area = 6 x $(1/10,000m)^2$ x 10^8 = 10^4 m^2 = 2.5 acres

Soil Surface Area

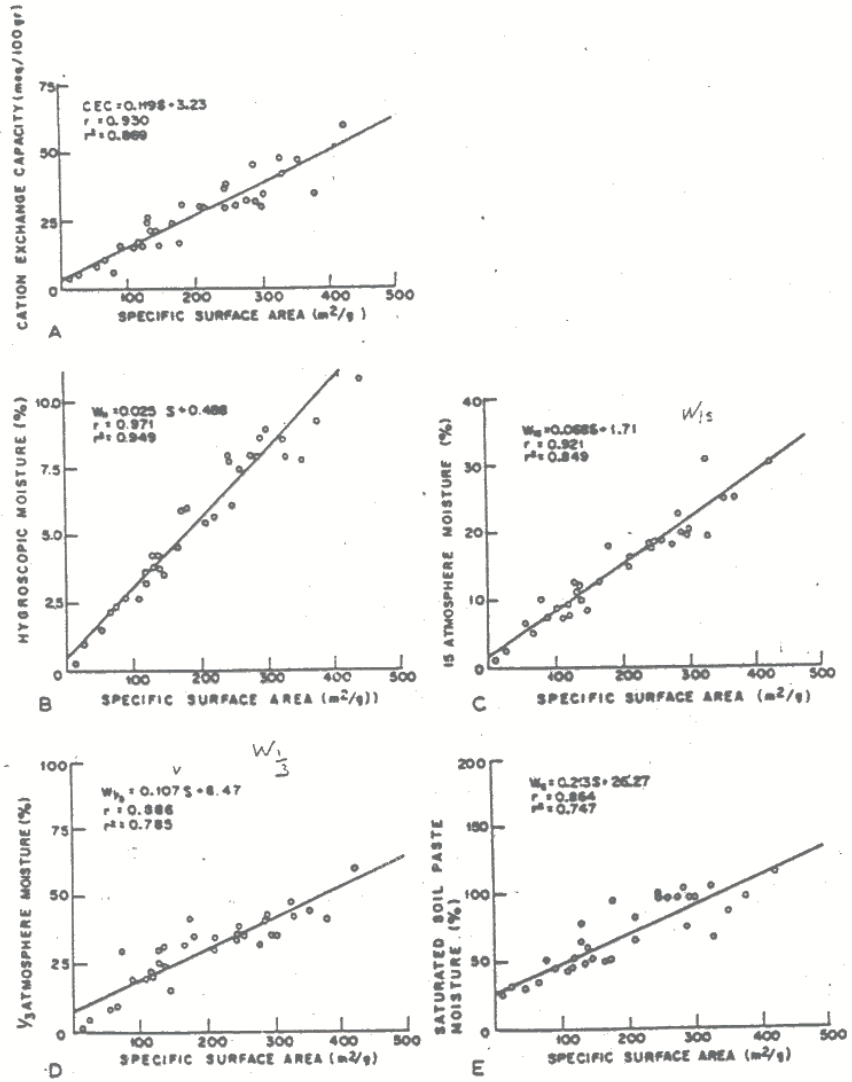
Aggregation – primary particle adhese to each other (SSA, SOM)
Suspension – aggregate disperse to primary particle (H2O, Na)



Soil Weathering and SSA (clay content)



Correlation of several soil properties to SSA



Field Description of Soil

Color (OM, minerals)

CaCO3

Texture

Structure

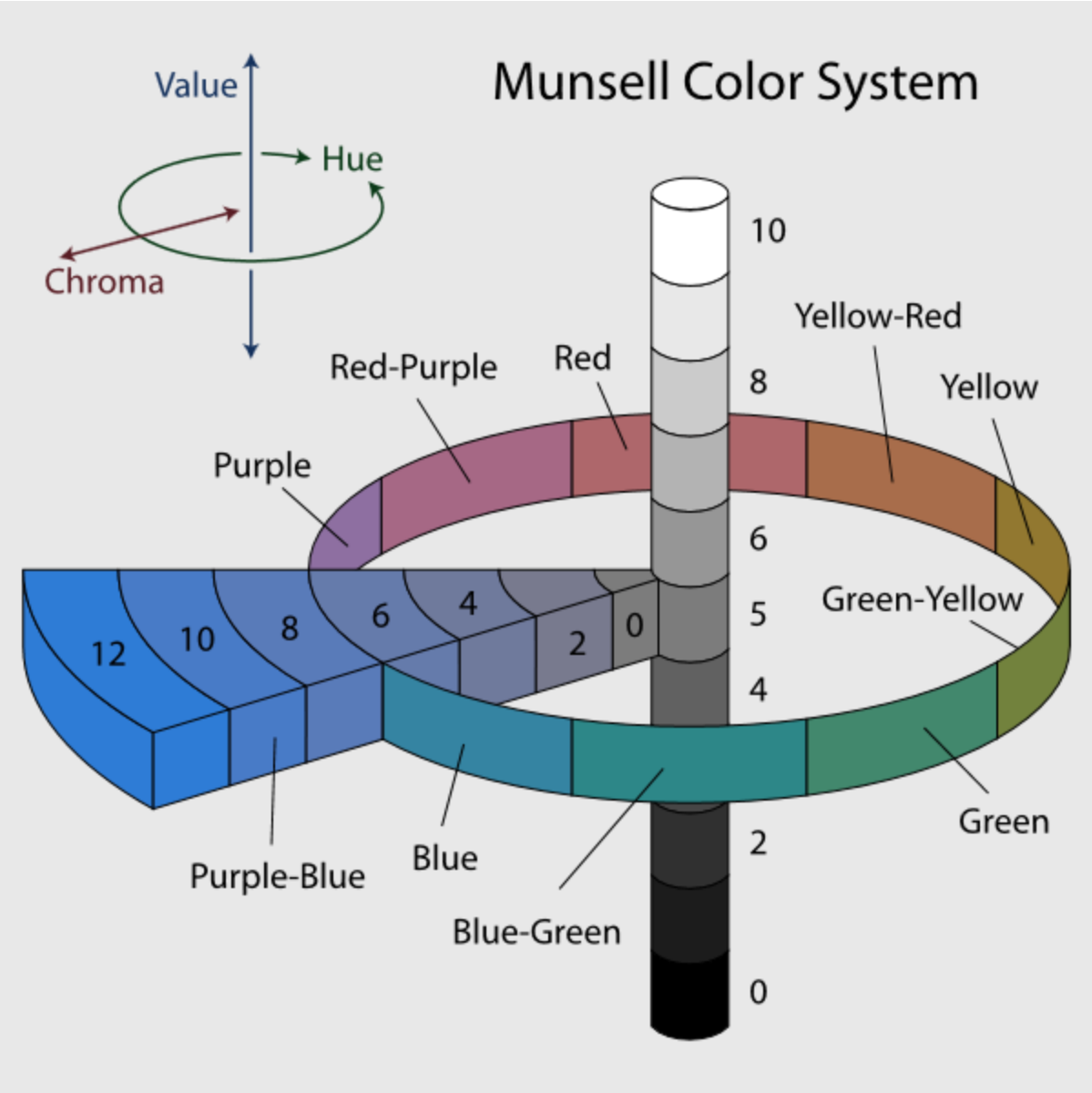

20
40
60
80

Field: Sampling

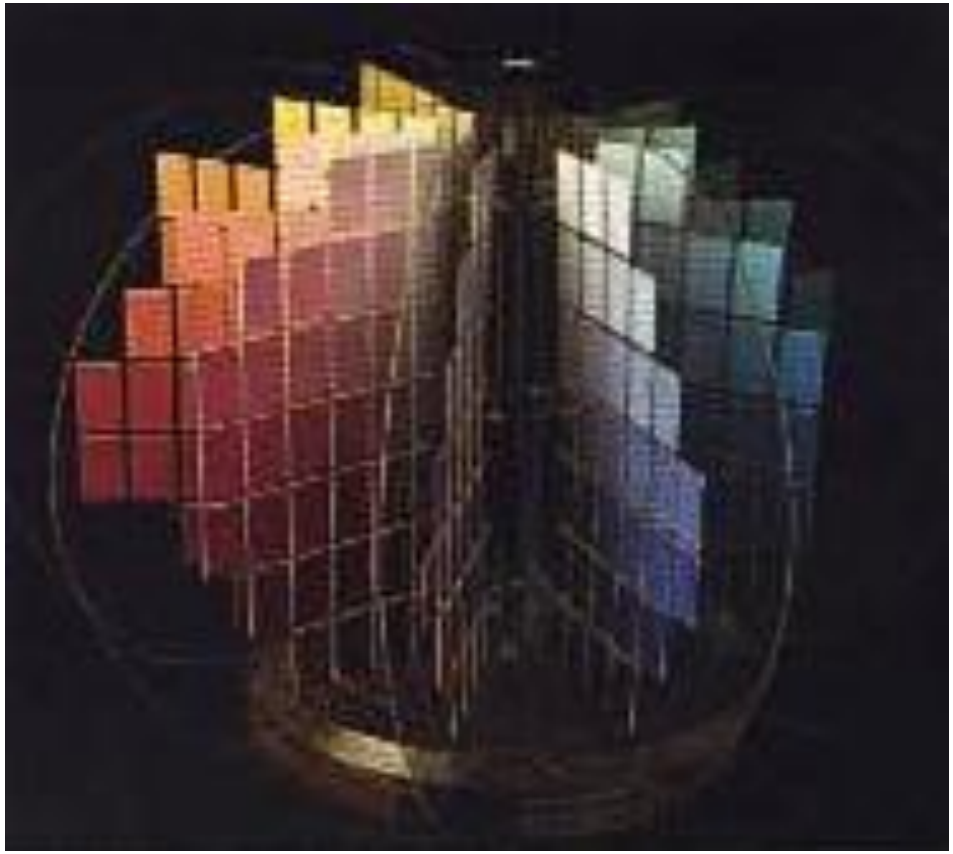
Field Determination

Laboratory analysis

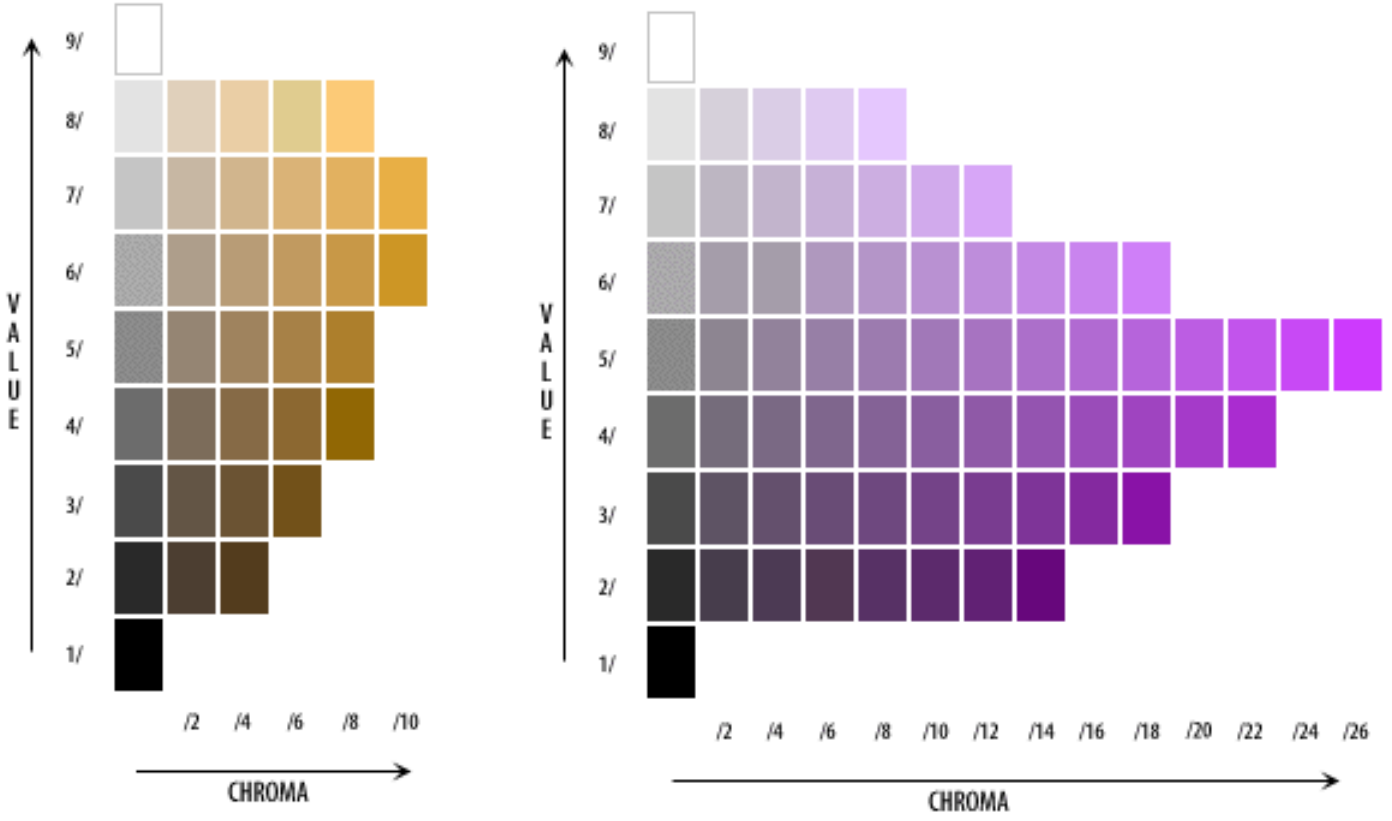
Sper –A


Munsell Color System
Value
Hue
Chroma
10
8
6
5
4
2
0
Yellow-Red
Yellow
Red
Red-Purple
Purple
Green-Yellow
Green
Blue-Green
Blue
Purple-Blue
12
10
8
6
4
2
0

Munsell Book of Colors

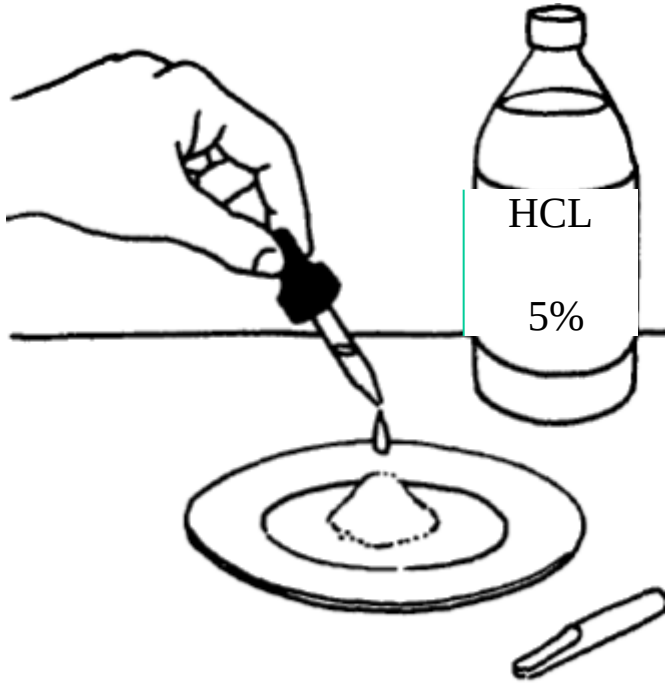


Munsell Book of Colors

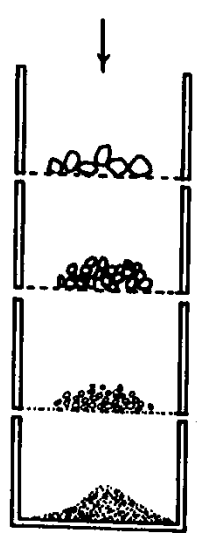


Colors plate in a book

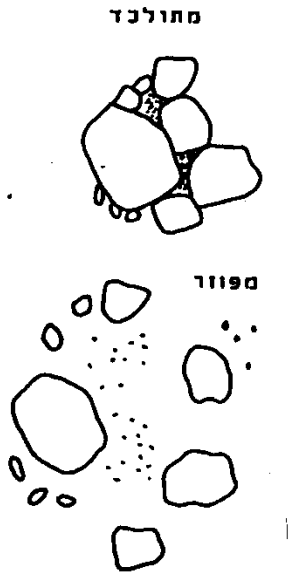
$$(CaCO_3 + MgCO_3 \text{ etc .}) + 2\,HCl \rightarrow (CaCl_2 + MgCl_2 \text{ etc .}) + H_2O + CO_2 \uparrow$$



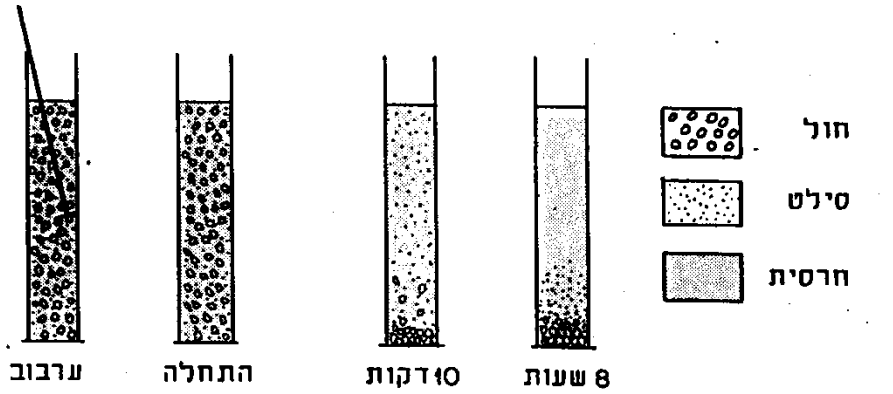
Texture Analysis



איור א־20. סכמה של סדרת נפות.



איור א־19. שכמות של תמרדת ומיזור של חלקיקים ראשוניים המרכיבים אותם. המים מחמיר המפזר חדירים בין החלקיקים ומרחיקים להתרחקותם זה מזה.



איור א־27. תיאור סכמטי של שקיעת חלקיקי קרקע, חמצורים באופן מלא במים (בעקבות Courtney and Trudgill, 1976).

Field Manuel

מגדיר לבדיקת מרקם בשדה

1. בקרקע יש רגבים –	עבור ל-2
בקרקע אין רגבים הקרקע שפיכה, נראים ומורגשים אך ורק גרגרי חול -	חול
2. הרגב אינו מתפורר במגע קל ביד –	עבור ל-4
הרגב מתפורר במגע קל ביד –	עבור ל-3
3. ע"י גלגול קרקע רטובה בין הידים הסרט שנוצר אינו יציב, גרגרי חול רבים מורגשים -	חול סייני
ע"י גלגול קרקע רטובה הסרט מעט יציב –	סיין חולי
4. ע"י גלגול קרקע רטובה אפשר ליצור סרט יציב –	עבור ל-5
הסרט שנוצר אינו יציב, מורגשים מעט גרגרי חול –	סיין
5. הסרט שנוצר נדבק בלישה באצבעות –	עבור ל-6
הסרט שנוצר אינו נדבק, הוא פלאסטי ונוח לעיבוד –	סיין סילטי
6. בסרט שנוצר אין מרגישים כלל גרגרי חול –	עבור ל-7
בסרט שנוצר מורגשים מעט גרגרי חול –	סיין חרסיתי חולי
7. הסרט שנוצר הינו פלאסטי ויוצר התנגדות בינונית בלישה באצבעות –	סיין חרסיתי
הסרט הינו יציב ביותר, גמיש, ניתן לטלטול, נדבק לאצבעות או יוצר התנגדות בלישה באצבעות –	חרסית

הערות למגדיר

מלבד יחסי המקטעים, נקבעות התכונות הפלאסטיות גם ע"י גורמים אחרים העלולים להשפיע על תוצאות בדיקת המרקם בשיטה זו.

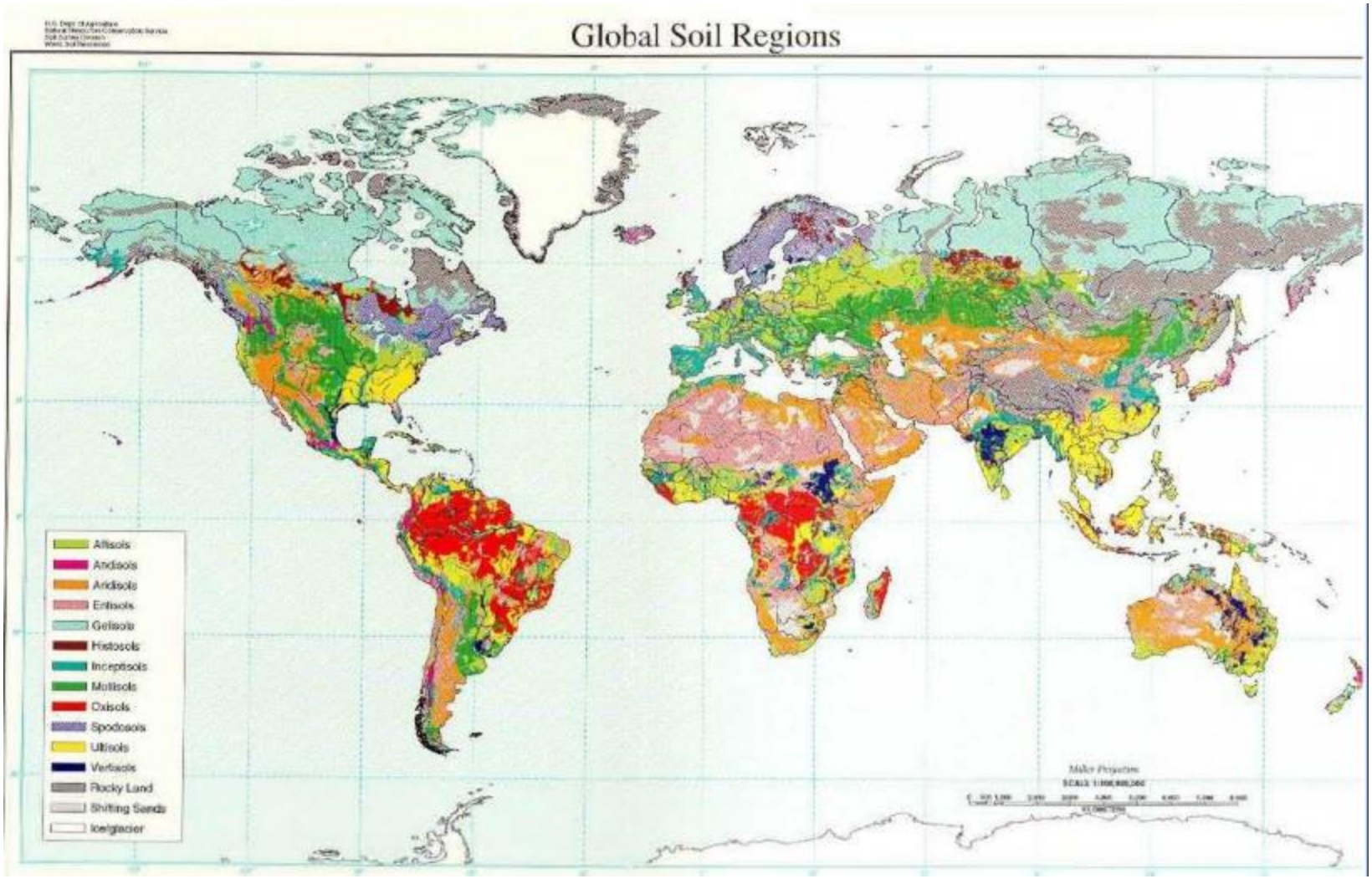
הגורמים הנוספים הינם:

א. גיר - ריבויו משנה התכונות הפלאסטיות של החרסית והקרקע מתנהגת כקלה יותר משהיא באמת.

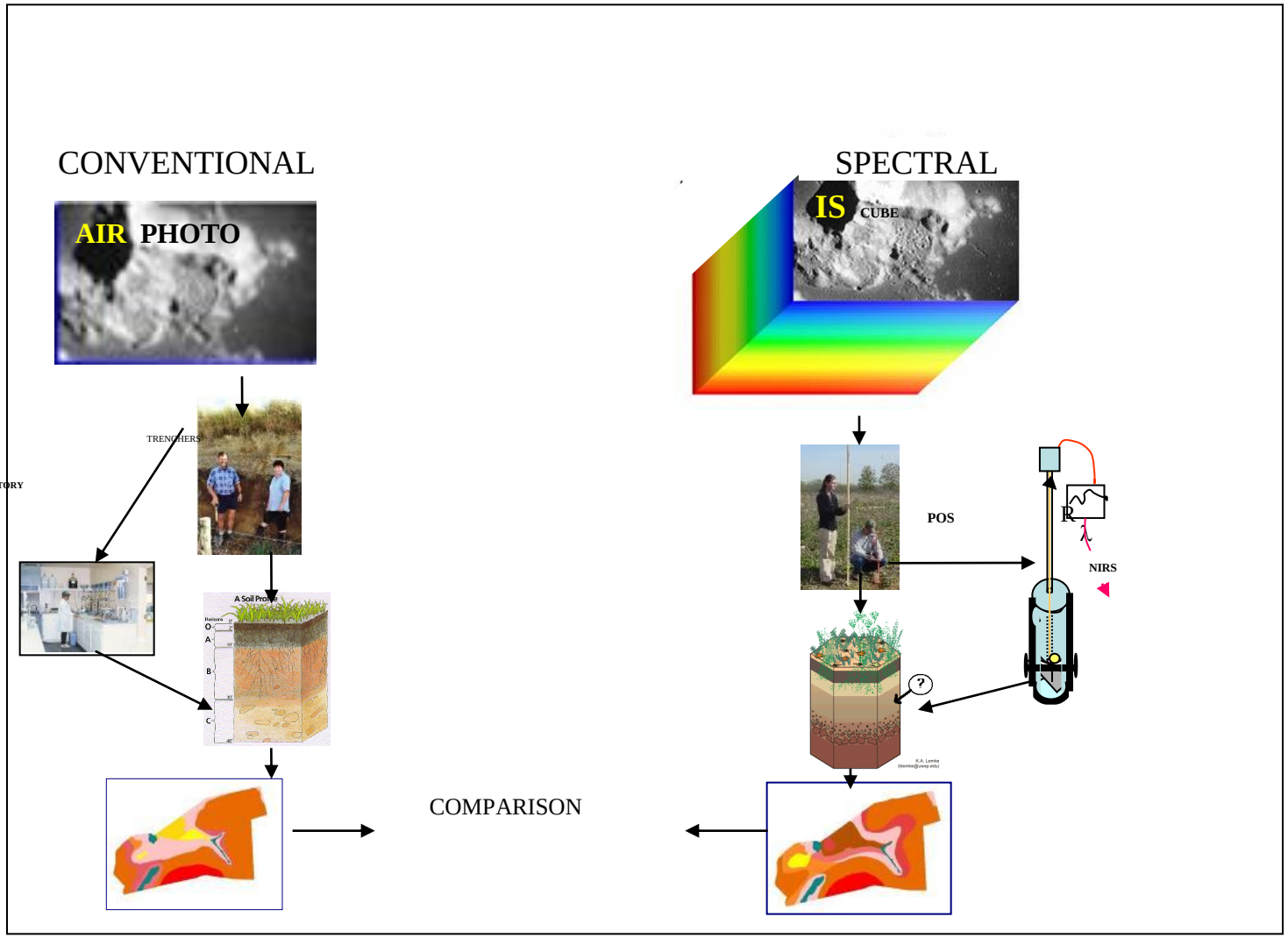
ב. חומר אורגני - יוצר תלכידים שפיזורם קשה ולפיכך נראית הקרקע קלה בשעה שהיא כבדה.

ג. סילט - התכונות הפלאסטיות של הסילט גורמות לכך שהקרקע, במצבה היבש, נראית קלה משהינה למעשה בעוד שבמצבה הרטוב היא נותנת תחושה של קרקע כבדה יותר מדי.

It is difficult to obtain a regional map in a temporal basis due to the heavy duty load of the traditional “soil mapping”



The Spectral concept for Soil Mapping



If Spectroscopy can be quantitatively accounted
for all soil properties in the field

Then:

Soil Spectroscopy is VERY important !!!!

and thus has to be studied

Next Lessons