Chapter 1

Genesis of Soils & Soil Mechanics

AAiT
Addis Ababa Institute of Technology
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Geotechnical Engineering Chair

School of Civil & Environmental Engineering

General Outline

- **Introduction**
- **A Recap of Properties of Rocks**
- **Weathering: A Brief Review**
- **Soil as an Engineering Material**
- **Soil mechanics: An Introduction**

1. Introduction

- Geotech @ AAiT
- Geotechnics: An Introduction
- The Geotechnical Triangle
- Why Love Geotech

Introduction

Geotech@AAiT

Fundamentals of Geotechnical Engineering [FGE]

- FGE-I [Engineering Geology]
- FGE-II [Physical Properties of Soils]
- FGE-III [Mechanical Properties of Soils]

Geotechnical Engineering Design [GED]

- GED-I [Ground Investigation & Shallow Foundation Design]
- GED-II [Deep Foundations & Earth Retaining Systems]
- GED-III [Geotechnical Practice in Tropical Soils]

Introduction

Geotechnics

- ✓ branch of civil engineering concerned with the engineering behavior of earth materials.
- ✓ regarded as the Common Denominator of all Civil Engineering Fields

Coz All structures built, for whatever intent and purposes, need to rest on the ultimate load carrier i.e. the Earth viz either soil or rock.

Introduction

Geotechnical engineering involves (but not limited to)

- investigating existing subsurface conditions and materials;
- determining their physical, mechanical and chemical properties that are relevant to the project considered,
- assessing risks posed by site conditions;
- designing earthworks and structure foundations;
- monitoring site conditions, earthwork and foundation construction.

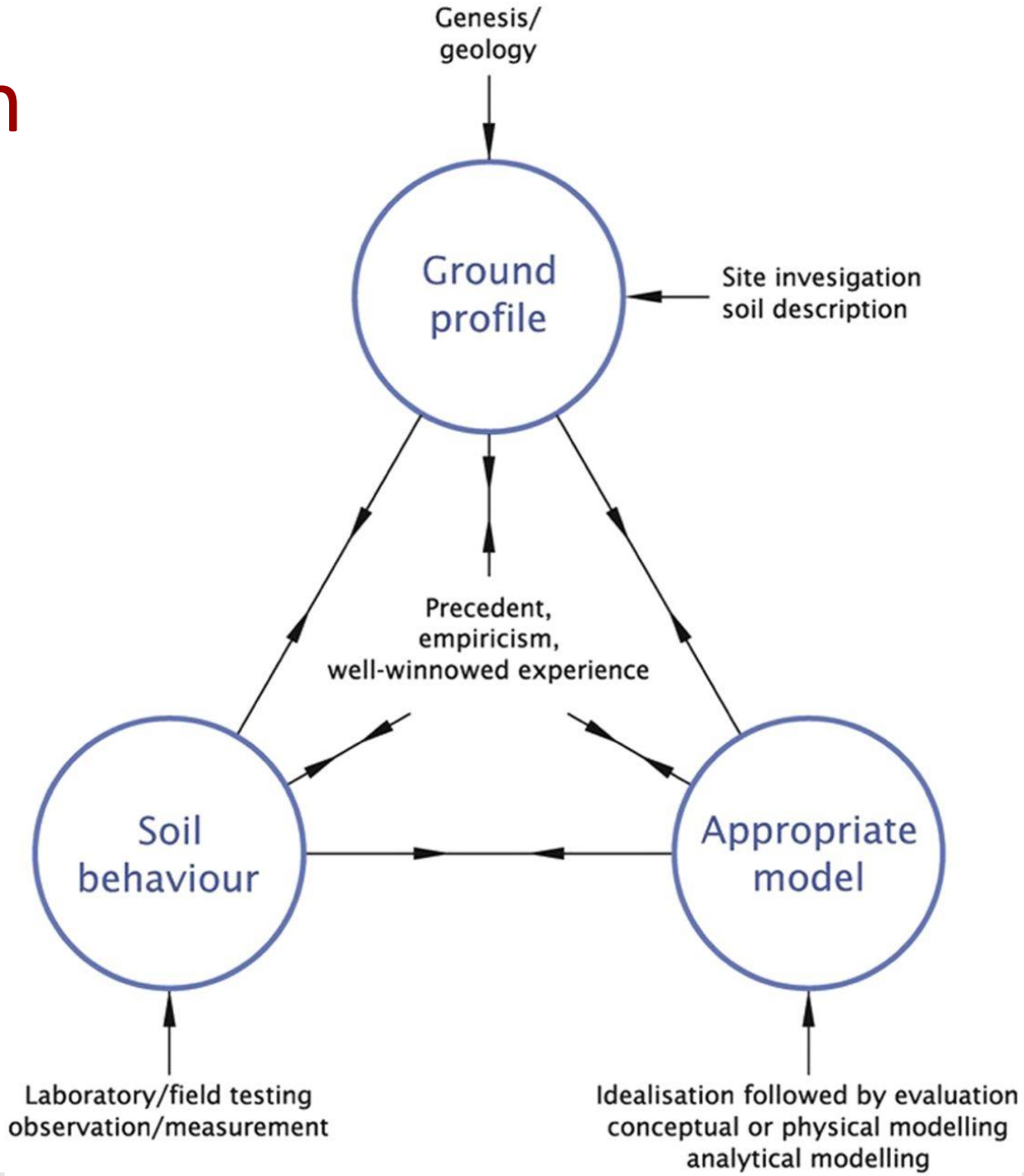
Introduction

Geotechnical engineering is fundamentally composed of three fields.

- **Engineering Geology** – the application of the science of geology to the understanding of geologic phenomena and the engineering solution of geologic hazards and other geologic problems for society.
- **Soil Mechanics** - application of the laws and principles of mechanics and hydraulics to engineering problems dealing with soil as an engineering material.
- **Foundation Engineering** - application of soil mechanics and rock mechanics in the design and construction of foundation elements of structures.

Introduction

The Geotechnical Triangle



Introduction

Why love Geotech?

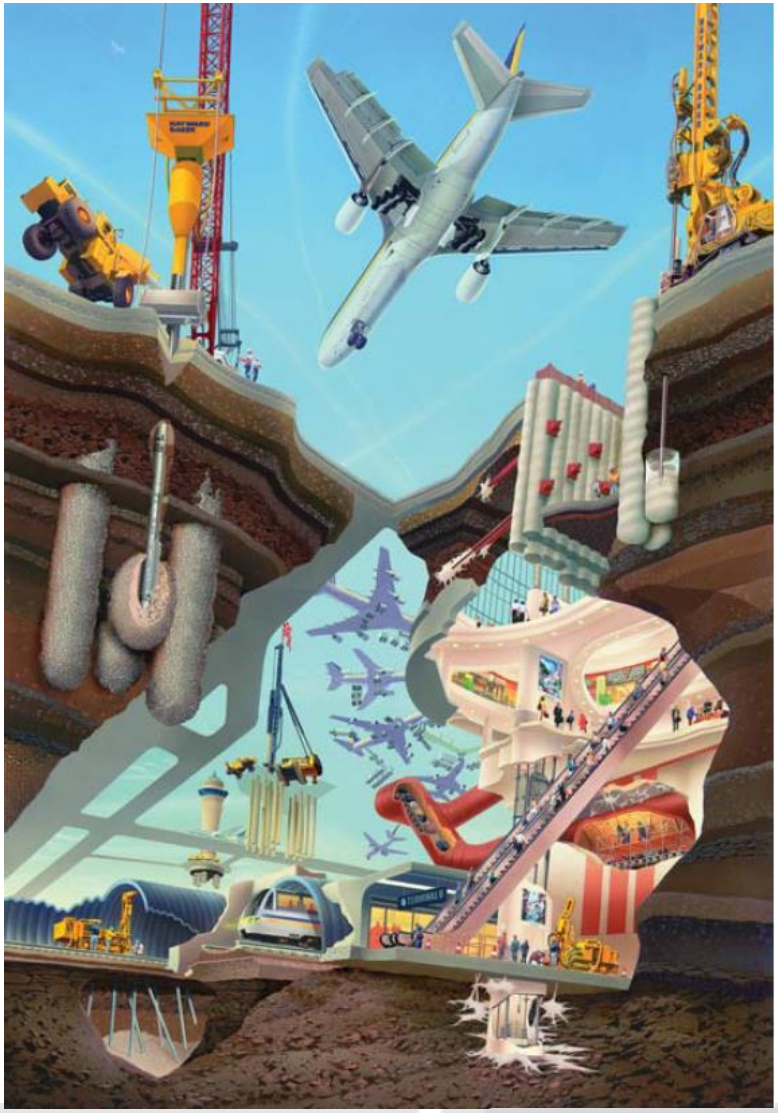
- Civil engineers, go head-to-head with nature and natural phenomena to make the world a better place to live in and accommodate the ever growing human needs.
- Geotechnical engineers feel nature's wish not to be disturbed and her wrath when we do so.
- There is no glory in foundations. Our work is buried.

Introduction

- Unlike many engineering disciplines, it is not a pure science but rather it is an art form that requires both judgment and experience to arrive at a satisfactory solution.
- We deal with uncertainties on daily basis arising from material property, design methodology, testing drawbacks and mysterious & obvious natural forces working against us and for us (in our favor) highly motivates me to become one.
- The passion is in the risk.

Introduction

- There is more to it than identifying which part of nature is your friend and which is your enemy; it somehow connects an engineer to nature on another level.
- Our scientific desire to be in control of ("efficiently manage") these uncertainties is an interesting challenge.



2. A Recap of Properties of Rocks

- Definition
- Classification of Rocks
- The Rock Cycle
- Physical Properties of Rocks
- Strength of Rocks

A Recap of Properties of Rocks

- Rock can be defined as a natural aggregate of minerals that are connected by strong bonding or attractive force.
- In some rocks there is only one mineral.

E.g. Marble may consist entirely of calcite

- Most rocks however contain 2, 3 or 4 main minerals and a few so-called accessory minerals.
- The properties of rocks are clearly dependent upon the amounts of the different minerals in their composition plus size, shape, orientation of minerals and the binding forces between minerals.

A Recap of Properties of Rocks

Some distinctive features of rocks

- ***Inhomogeneity***: as a result of mineralogical composition.
- ***Anisotropy***: properties of rock are different in different directions compared to common construction materials.

Rock versus rock mass

The term rock mass means the in-situ material which consist of intact rock, all joints and other discontinuities.

NB. The properties of the rock mass may be quite different from the properties of intact rock.

A Recap of Properties of Rocks

Geological Investigations **-READING ASSIGNMENT**

Geological Maps **-READING ASSIGNMENT**

Classification of rocks

- The rocks that form the earth's surface are classified as to origin as:
  - Igneous
  - Sedimentary
  - Metamorphic

A Recap of Properties of Rocks

Igneous rocks - formed through the cooling and solidification of a molten magma within or on the surface of the earth's crust (by fissure eruption or volcanic eruption)

Granite

Basalt

Trachyte

Scoria

Pumice

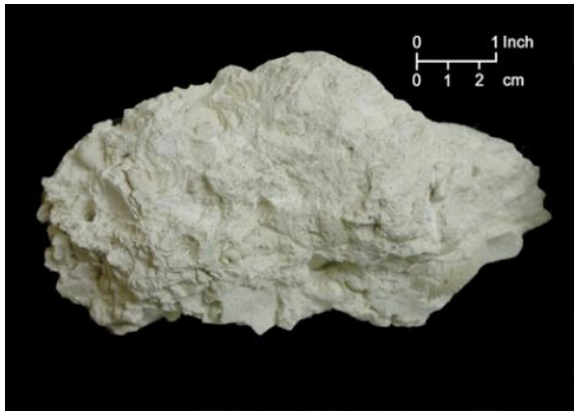
Obsidian

A Recap of Properties of Rocks

Sedimentary Rocks - formed from accumulated deposits of soil particles or remains of certain organisms that have become hardened by pressure or cemented by minerals.

-cementing agents can be iron oxide, calcite, quartz, silica

e.g. Limestone

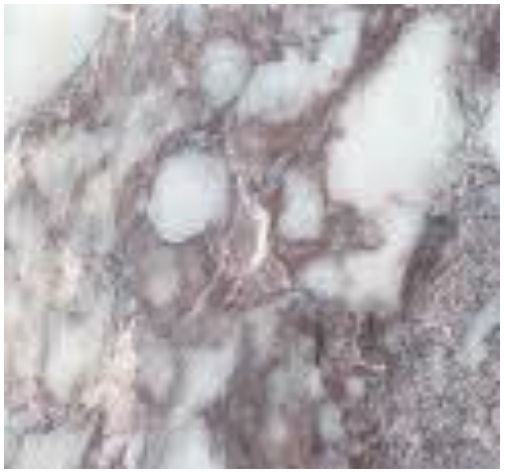


Sandstone

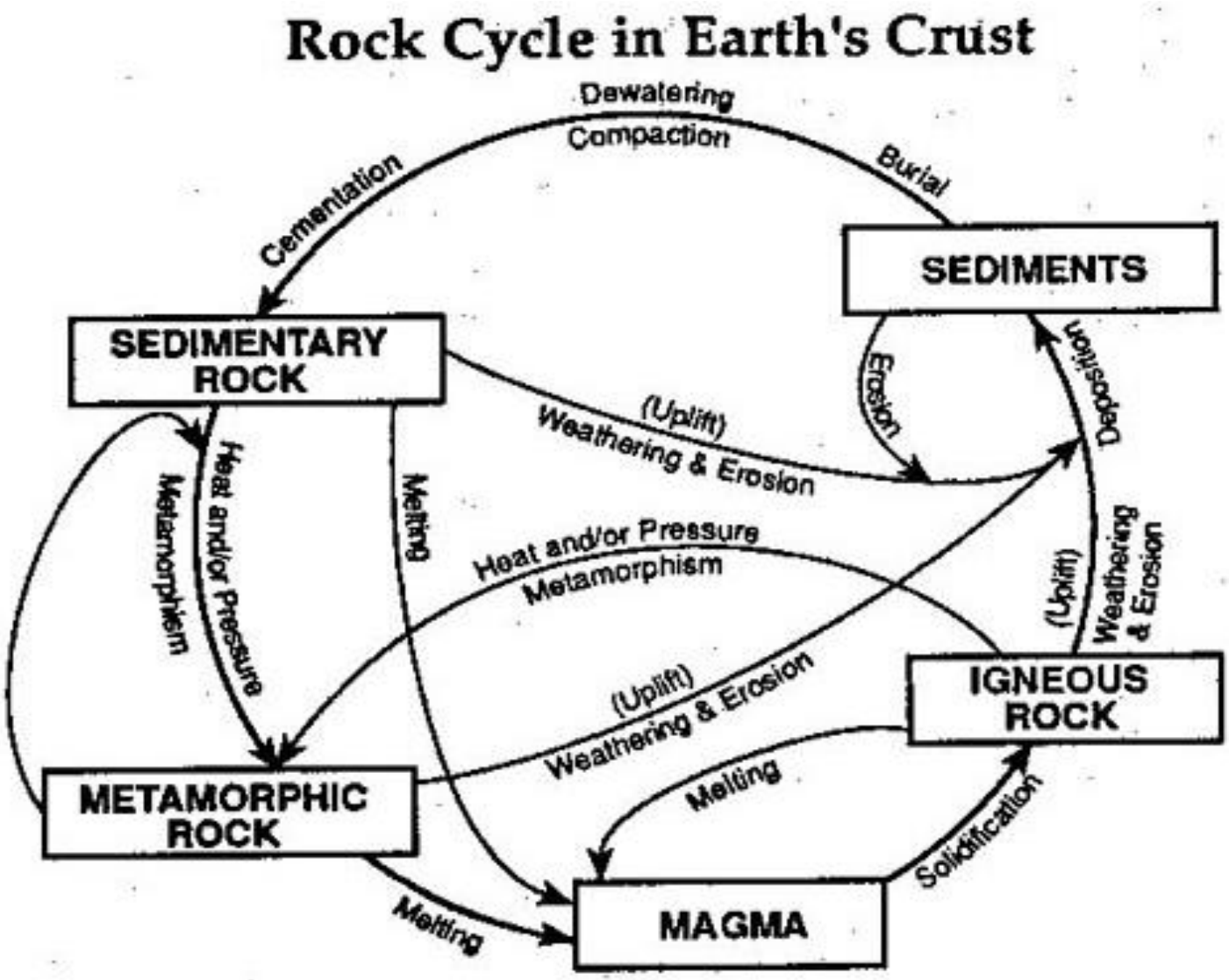
A Recap of Properties of Rocks

Metamorphic Rocks - Results when any type of existing rock is subject to metamorphism, the change brought about by combinations of heat and pressure so that the original rock structure and mineral composition are changed.

[Limestone – Marble] [Granite - Gneiss] [Sandstone - Quartzite]



A Recap of Properties of Rocks



A Recap of Properties of Rocks

Physical Properties of Rocks

- Density: commonly in the range 2.5 -3.2 g/cm^3
- Porosity: normally 1% or less;
- Wave velocity: affected by porosity & degree of saturation.

  High porosity – 2,000-3,000 m/s

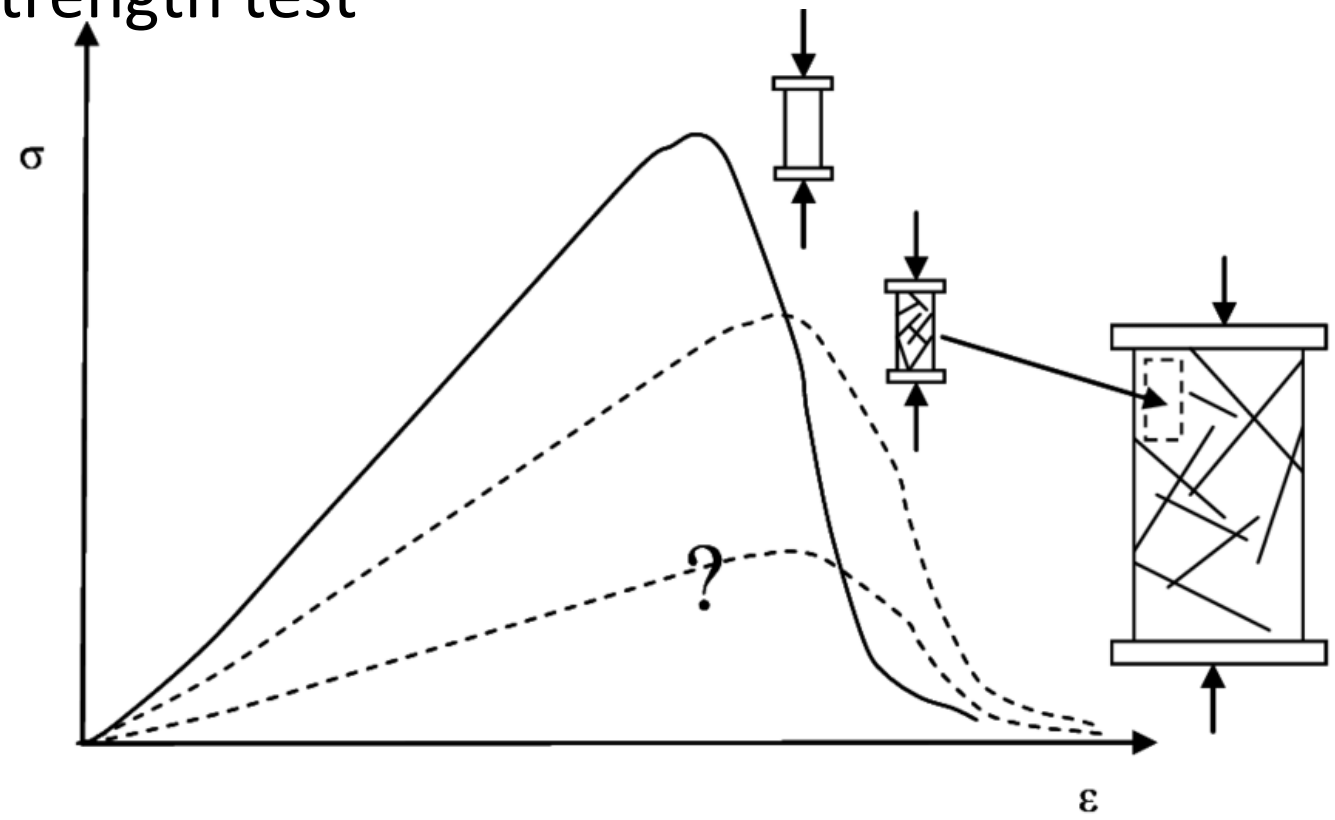
  Low porosity – 5,000-6,000 m/s
- Heat transfer/Thermal expansion: largely governed by the unique properties of quartz.

E.g. calcite; heat transfer capacity= 7 kcal/(m·h·^{o}C)

A Recap of Properties of Rocks

Strength of Rocks

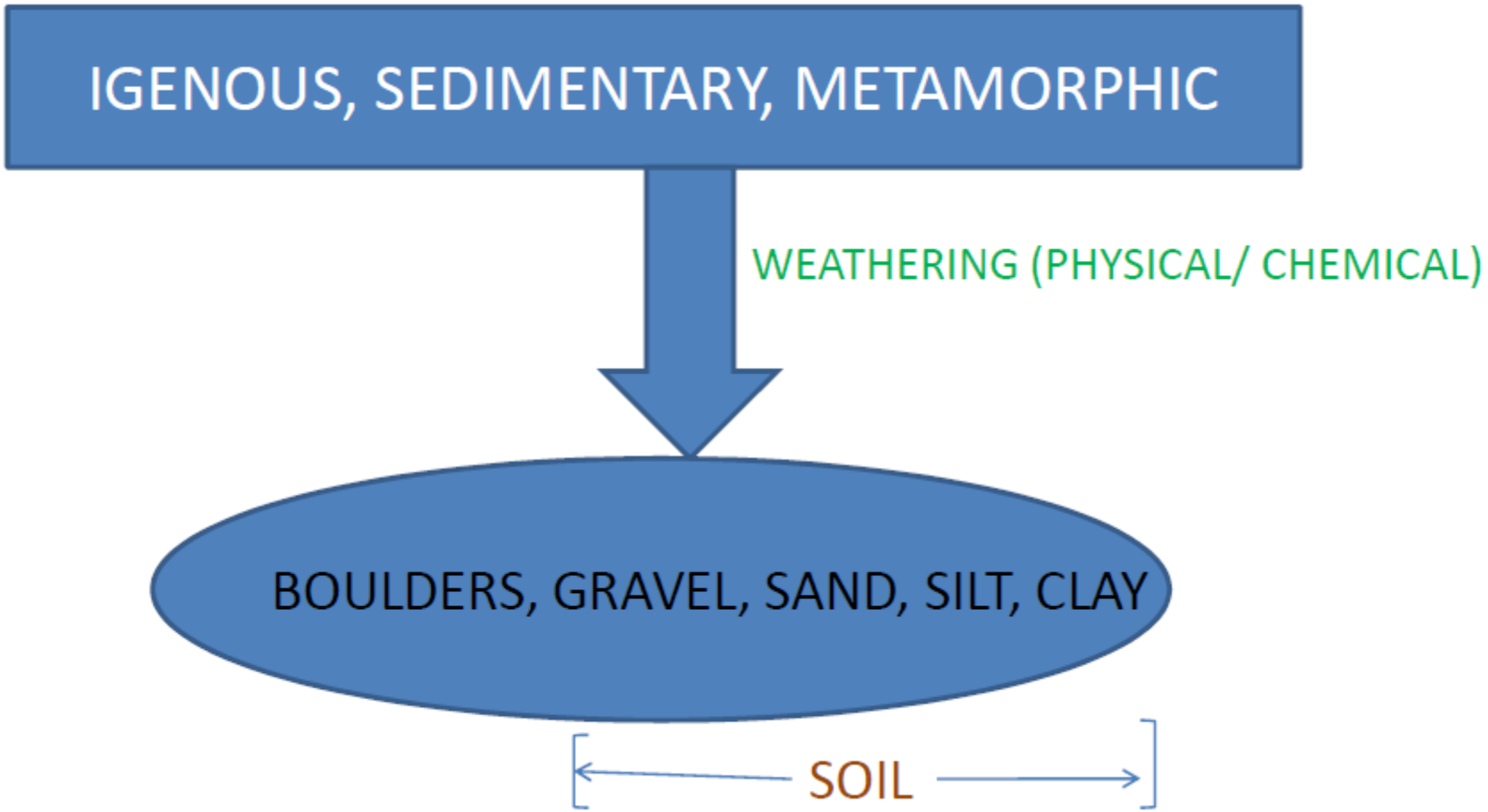
- Uniaxial compressive strength test
- Point load strength test
- Triaxial test



3. Weathering: A Brief Review

- Definition
- Physical Weathering
- Chemical Weathering

Weathering: A Brief Review



The formation of soil happens over a very long period of time. It can take 1000 years or more.

Weathering: A Brief Review

Weathering is the process of breaking down of rocks by mechanical and chemical processes into smaller pieces.

The physical agencies causing mechanical weathering of rocks are:

- Daily and seasonal temperature changes.
- Flowing water, glaciers and wind, which produce impact and abrasive action on rock.
- Splitting action of ice.
- Growth of roots of plants in rock fissures and to a minor degree burrowing activities of small animals like earthworms.

Weathering: A Brief Review

Chemical weathering changes the composition of rocks by decomposing the parent minerals, transforming them into new compounds such as clay silica particles, carbonates and iron oxides.

The decomposition of rock is the result of the following reactions:

- Oxidation: reaction of minerals with O_2
- Carbonation: caused by CO_2 in the presence of water.
- Hydration: involves the rigid attachment of H+ and OH- ions to the atoms and molecules of a mineral.
- Leaching: percolating water washes out water-soluble salts from the soil.

4. Soil as an Engineering Material

- Definition
- Peculiar Features
- Residual & Transported Soils
- Common Soil Types
- Soil Horizon
- Clay Mineralogy

Soil as an Engineering Material

Soil is

- weathered material in the upper layers of the earth's crust.
- oldest and most complex engineering material.
- natural aggregate of mineral grains, loose or moderately cohesive, inorganic or organic in nature, that have the capacity of being separated by means of simple mechanical processes.
- the loose unconsolidated inorganic material on the earth's crust produced by the disintegration of rocks, overlying hard rock with or without organic matter.

Soil as an Engineering Material

Peculiar Features

- Particulate material - made up of countless particles of a variety of shapes and sizes with little or no bonding between them.
- Multi-phase material – solid, liquid, gas
- Water affected – water within pores of the soil contributes to the stress transfer in the soil; may also be flowing with respect to the granular particles, which creates friction stresses between the fluid and the solid material.
- Variability – spatial and depth wise

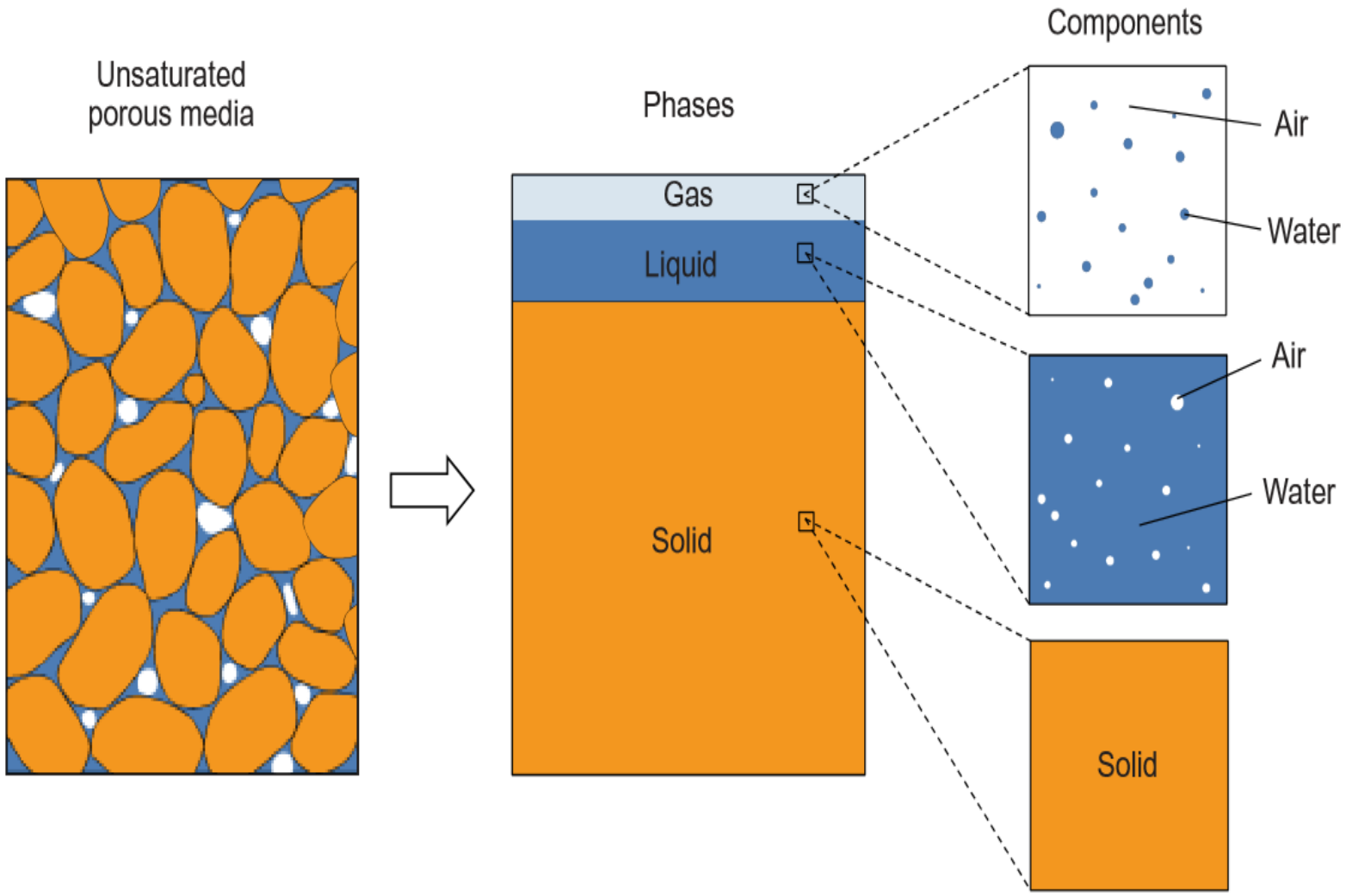
Video: JohnBurland_The Particulate Nature of Soil

Soil as an Engineering Material

- Stress dependent stiffness – not governed by Hooke's Law and the stiffness and strength of a given soil is not fixed but depends on the confining pressure.
- Shear strength - critical than compressive strength and the virtually zero tensile strength.
- Dilatancy – volume change as a result of shear deformation
- Creep – (clay in particular) – secular deformation continuing through long ages practically forever
- Memory capacity for stress history – [YES for vertical stress; NO for horizontal stress]

Video: JohnBurland_The Effect of Water on Soil Strength

Soil as an Engineering Material



Soil as an Engineering Material

Soil formed by weathering may be classified as

- Residual soil: soil located in the place of formation.
- Transported soil: soil transported by water, wind, ice and deposited in an area different from their origin.
  - Alluvial soil: transported in running water (river)
  - Aeolian soil: transported by wind
  - Lacustrine soil: deposited in quiet lakes
  - Colluvial soil: deposited through action of landslide.
  - Marine soil: deposited in sea water
  - Glacial soil: transported by ice

Soil as an Engineering Material

Common soil types

- Important soil types found in general practice.
  - Coarse grained cohesionless
    - Sand 0.06-2mm
    - gravel 2-60mm
    - Cobble 60-200mm
    - Boulder >200mm
  - Fine grained soil cohesive
    - Silt 0.002-0.06mm
    - Clay <0.002mm

Video: JohnBurland_The Effect of Particle Size and Strength on Soil Strength

Soil as an Engineering Material

Soil Horizon

O HORIZON
Surface litter: Partially decomposed organic matter

A HORIZON
Topsoil: Humus, living creatures, inorganic minerals

E HORIZON
Zone of leaching, materials move downward

B HORIZON
Subsoil: iron, aluminium humic compounds are accumulated and clay leached down from A and E horizons

C HORIZON
Weathered parent material: Partial breakdown of inorganic minerals

R HORIZON
Bedrock

Soil as an Engineering Material

Clay Mineralogy

The minerals constituting a clay are hydrates of aluminium, iron or magnesium silicate generally combined in such a manner, as to create sheet-like structures only a few molecules thick.

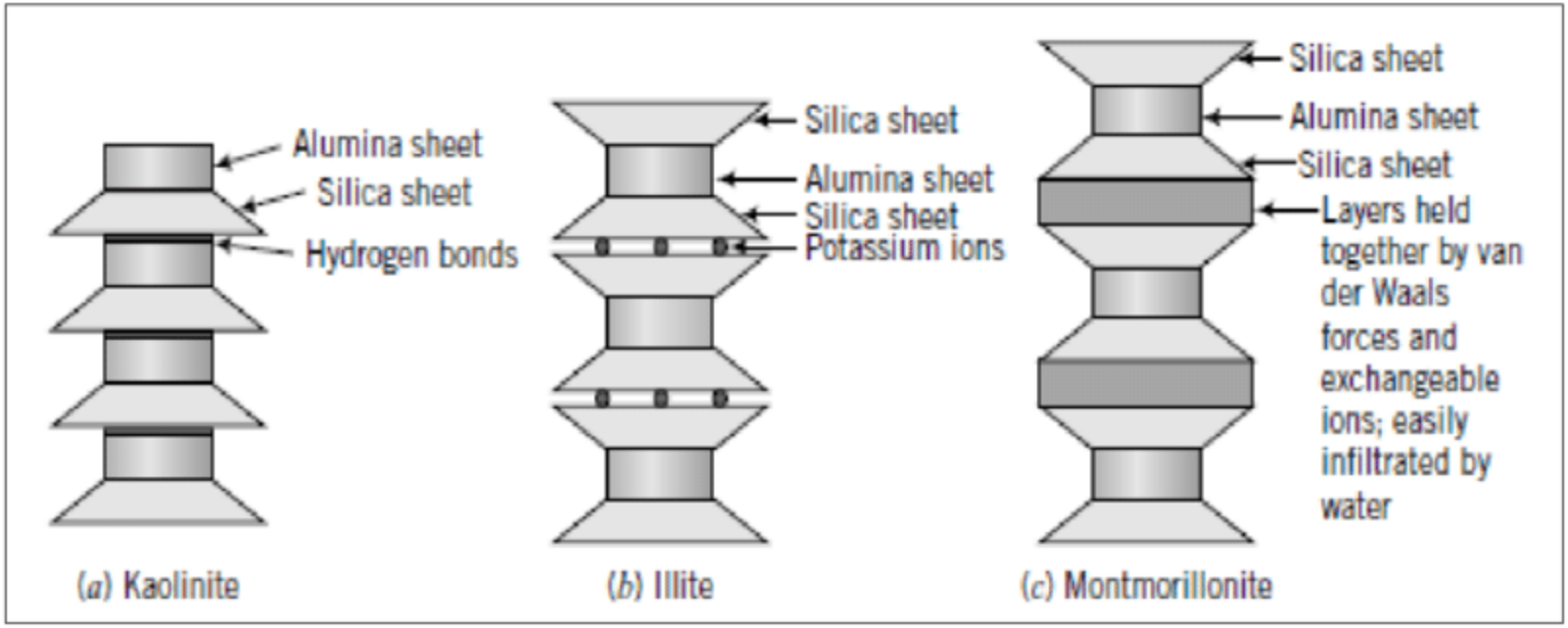
These sheets are built from two basic units, the tetrahedral unit of silica and the octahedral unit of the hydroxide of aluminium, iron or magnesium.

- Kaolinite group
- Illite group
- Montmorillonite group

Soil as an Engineering Material

Clay Mineralogy

- Kaolinite: e.g. China clay
- Illite: e.g. Marine clays
- Montmorillonite: e.g. Black cotton soil



5. Soil Mechanics: An Introduction

- What?
- Karl von Terzaghi
- Pseudo-Branches of Soil Mechanics
- Mechanics of Soil Mechanics

Soil Mechanics: An Introduction

Mechanics: science of motion and equilibrium of bodies.

- Solid mechanics
- Fluid mechanics

Engineering Mechanics: application of principles of mechanics for engineering analysis and design.

- Soil Mechanics is the branch of science that deals with the study of the physical properties of soil and the behavior of soil masses subjected to various types of forces.
- In other words, soil mechanics is the study of both solid and fluid mechanical characteristics of soils.

Soil Mechanics: An Introduction

Solid mechanics issues

- How much soil will deform when it is loaded?
- When loads are applied, on what rate does soil deform?
- How much load can we apply to soil before it fails?
- How does soil fail?

Fluid mechanics issues

- How does water flow through soil? (how fast?)
- How can fluid flow through soil cause it to fail?

Video: JohnBurland_What is soil mechanics?

Soil Mechanics: An Introduction

Karl von Terzaghi: Father of Soil Mechanics

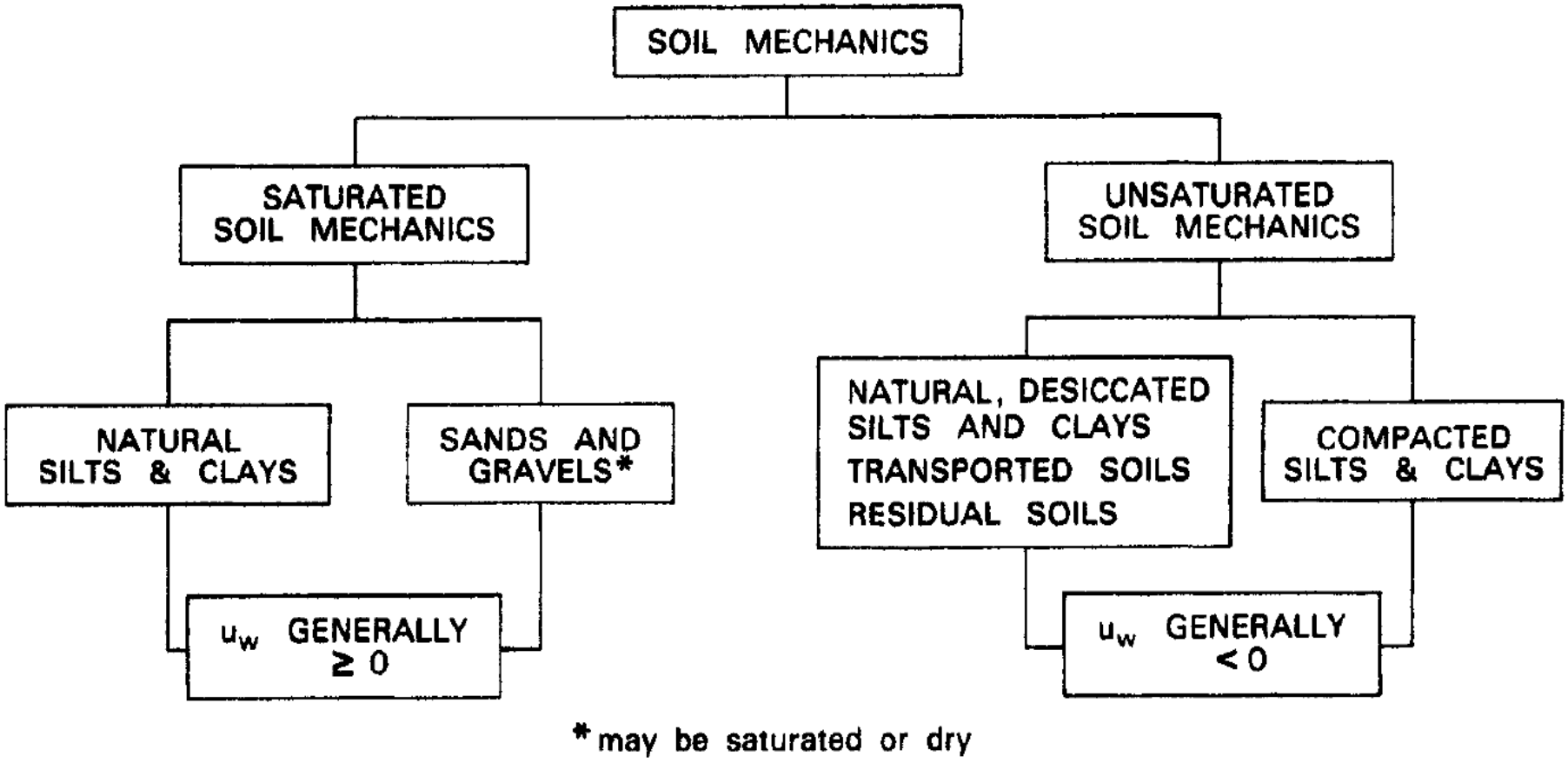
-published the book 'Theoretical Soil Mechanics' in 1943 which provided a science-based context for analyzing the physical behavior of saturated soils.

- defined Soil Mechanics as *the application of the laws of mechanics and hydraulics to engineering problems dealing with sediments and other unconsolidated accumulations of solid particles produced by the mechanical and chemical disintegration of rocks regardless of whether or not they contain an admixture of organic constituents.*

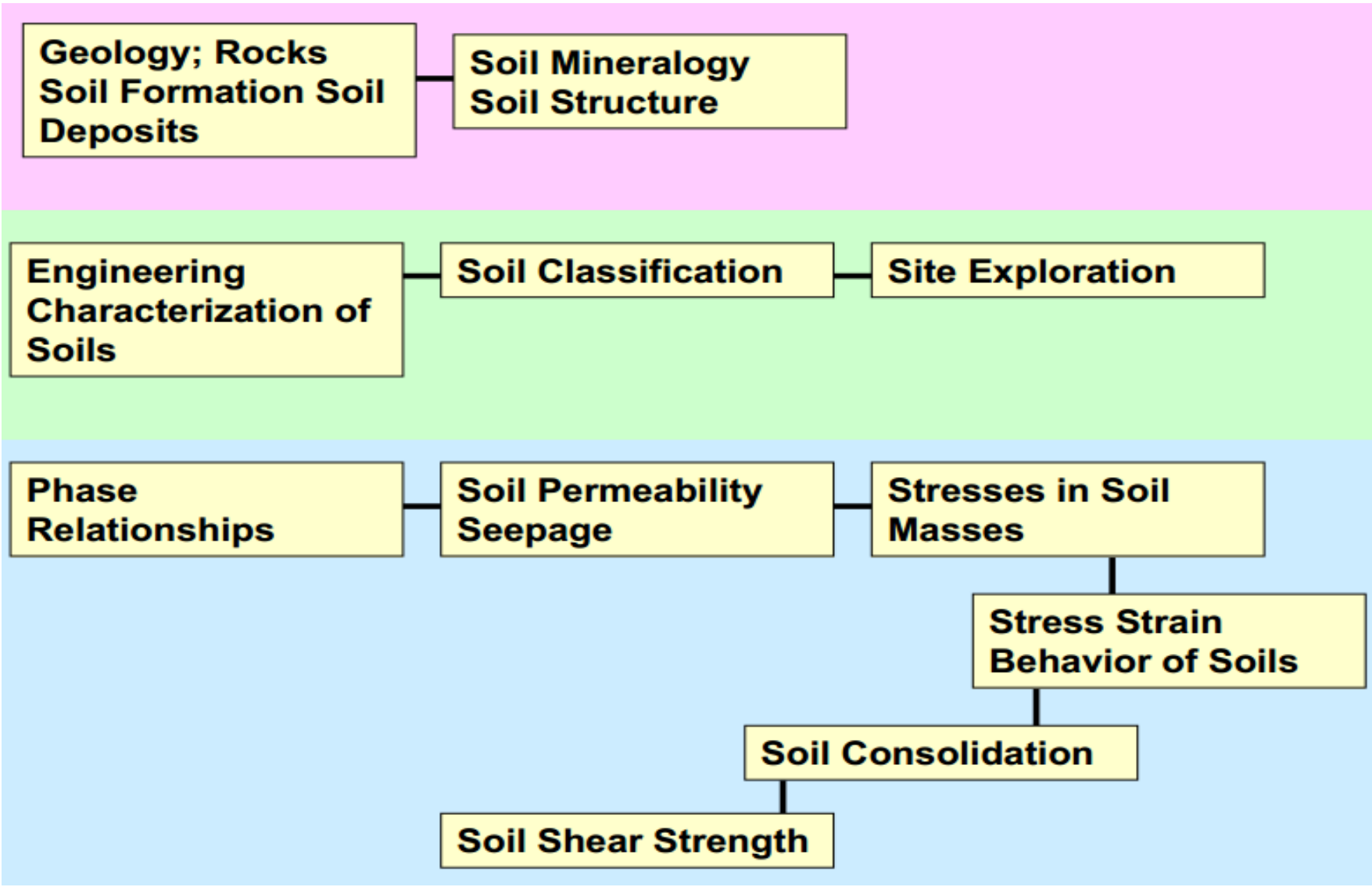
Video: Civil engineering- An Oral History

Soil Mechanics: An Introduction

Pseudo - Branches of Soil Mechanics



Soil Mechanics: An Introduction



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