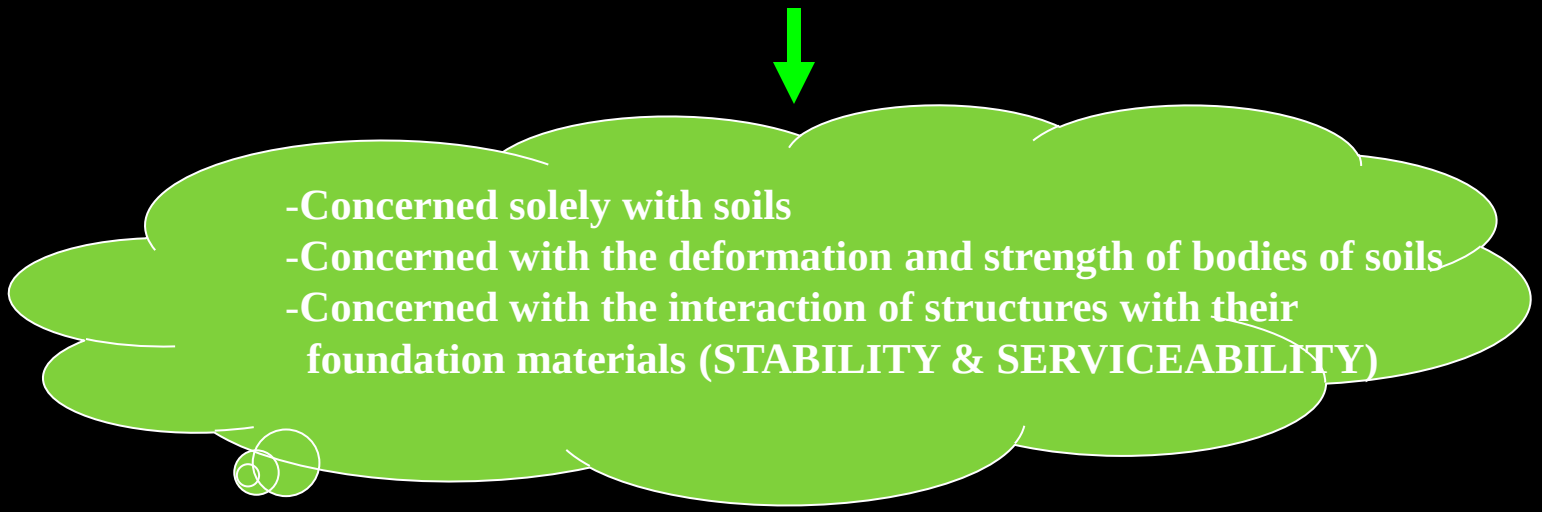
SOIL MECHANICS
SAB1713

DR. HETTY

INTRODUCTION

SOIL MECHANICS



" Soil mechanics is the application of 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 constituent" (Terzaghi, 1948)

What is Soil???

- Un-aggregated or un-cemented deposits of mineral and/or organic particles or fragments covering large portion of the earth's crust.
- An uncemented aggregate of mineral grains and decayed organic matter (solid particles) with liquid and gas inempty spaces between solid particles. (Das)
- Any uncemented or weakly cemented accumulation of mineral particles formed by the weathering of rock, the void space between the particles containing water and air. (R.F.Craig)

Figure 1: Air, Water and Solid phases in a typical soil

The Source of Soils?????

The Differentiation between SOIL & ROCK

- **SOIL** – removed without blasting
- **ROCK** – required blasting

ROCKS → The Source of Soils

- Soil particles are the result of *weathering* (disintegration and decomposition) of rocks and decay of vegetation.
- Some soil particles may, over a period of time, become consolidated under the weight of overlying material and become rock.

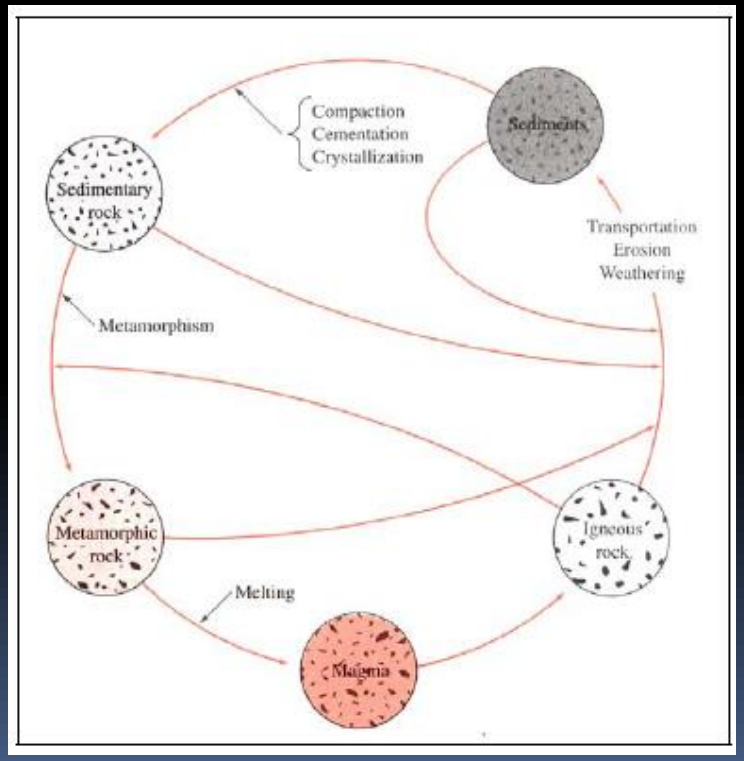


Figure2: Rock Cycle

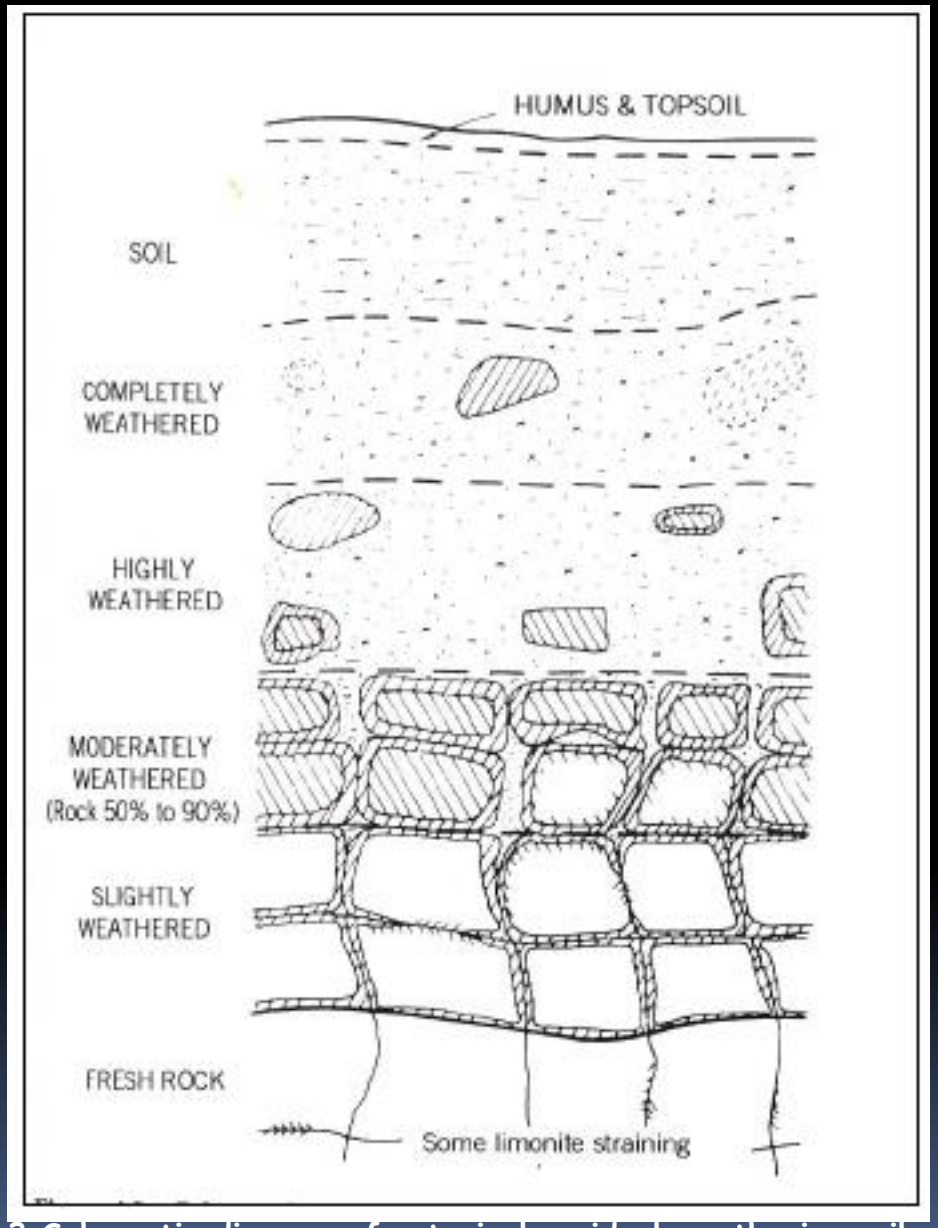
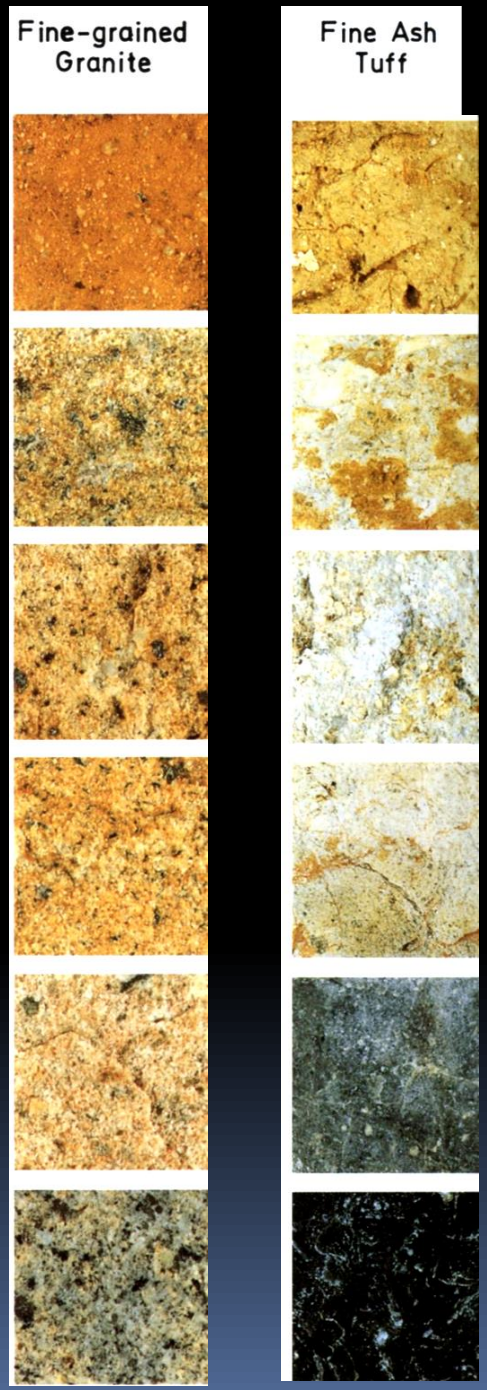


Figure 3:Schematic diagram of a typical residual weathering soil profile

VI	Residual soils
V	Completely decomposed
IV	Highly decomposed
III	Moderately decomposed
II	Slightly decomposed
I	Fresh



Weathering Process

- **DISENTEGRATION (Mechanical weathering)**

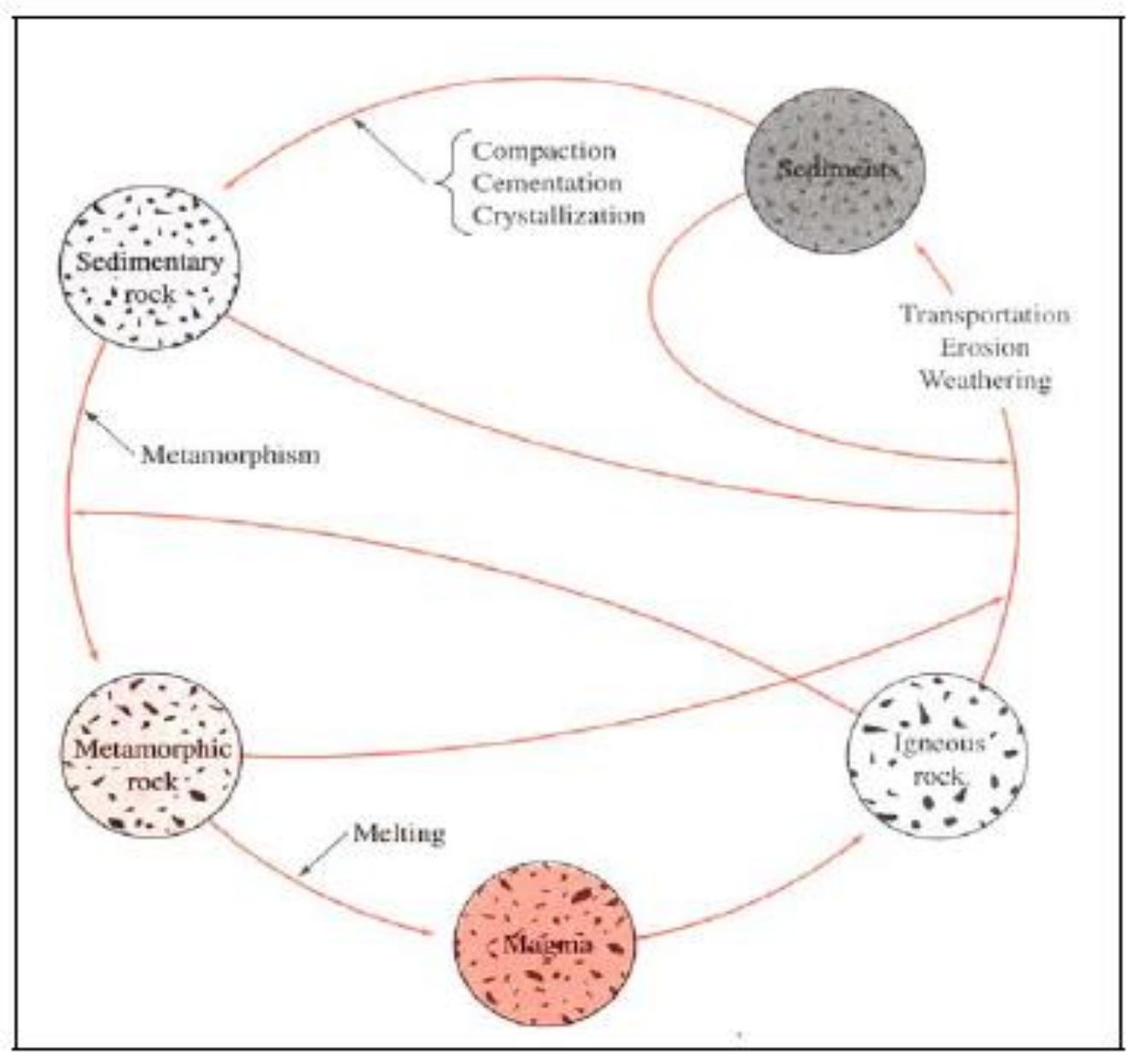
- **Disintegrates rocks into small particles by temperature changes, frost action, rainfall, running water, wind, ice, abrasion, and other physical phenomena.**

- **DECOMPOSITION (Chemical weathering)**

- Chemically decomposed rocks, which can drastically change it physical and chemical characteristics.
- Results from reactions of rock minerals with oxygen, water, acids, salts and…..

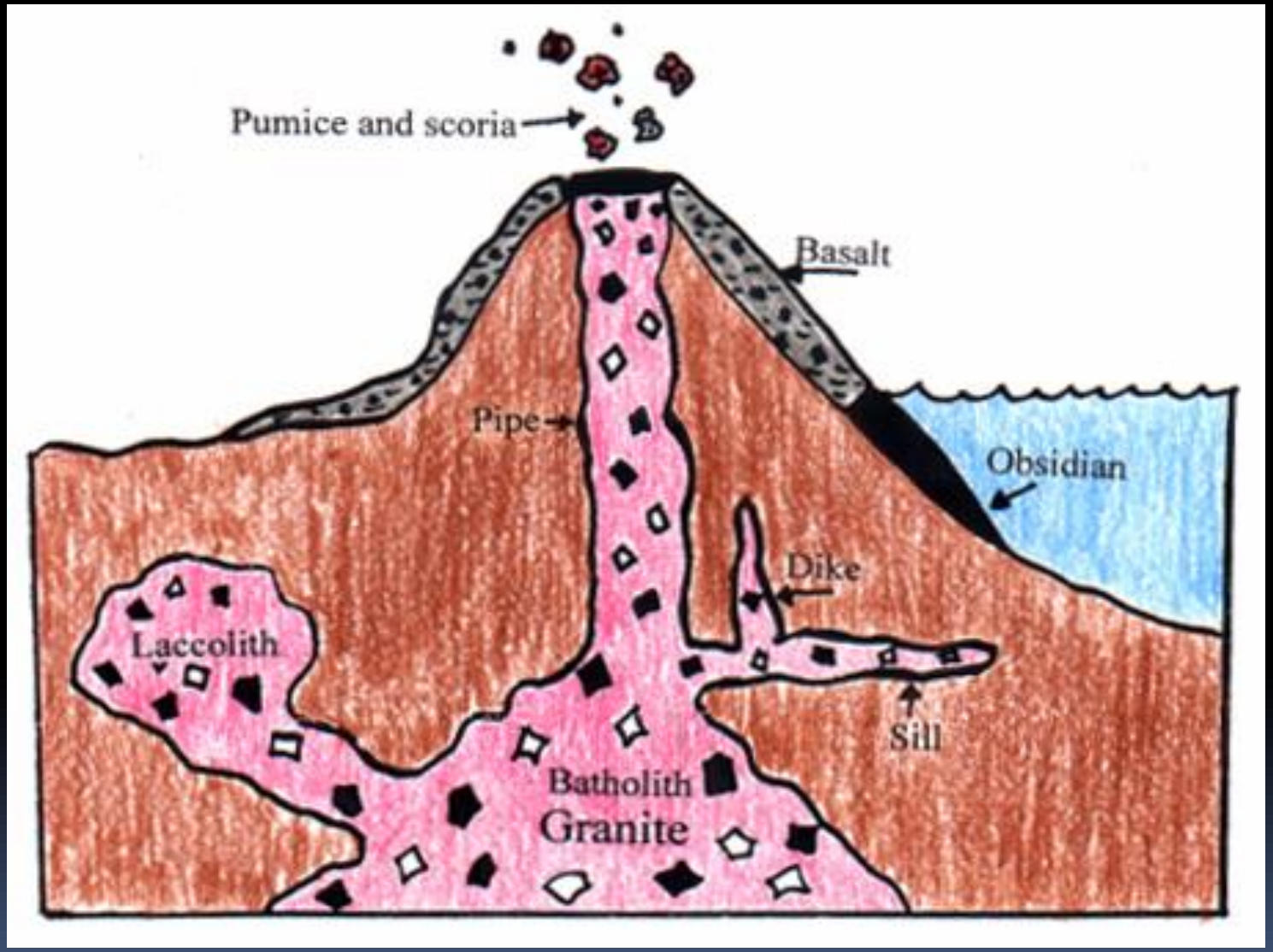
Rock Classification

- Igneous
- Sedimentary
- Metamorphic


Compaction
Cementation
Crystallization
Sediments
Sedimentary rock
Transportation
Erosion
Weathering
Metamorphism
Metamorphic rock
Igneous rock
Melting
Magma

Igneous Rock

- Formed by the cooling of molten magmas, or by the recrystallization of the older rocks under heat and pressure.
- 2 main classes of igneous rock:
  - Intrusive (cooling and solidifying slowly beneath the earth) – coarse grained
  - Extrusive (poured out at the surface and cooling rapidly) – fine grained
- *Granite and Basalt*
- Hard, Dense and durable
- Good construction materials
- Have high bearing capacity – good for foundation


Pumice and scoria
Basalt
Pipe
Obsidian
Dike
Laccolith
Sill
Batholith
Granite

Granite

Basalt

Sedimentary Rock

- Results from weathering process that being transported, redeposited, and partly or fully consolidated or cemented into a new rock.
- Sediment = loose particle material (clay, sand. Gravel, etc)
- Sediment becomes sedimentary rock through lithification, which involves:

1) Compaction
2) Cementation
3) Recrystallization

- Can be identified easily when their layered is observable

Shale

Siltstone

Layered gypsum

Quartz Sandstone

Metamorphic Rock

- Produced when sedimentary or igneous rocks literally change their texture and structure as well as mineral and chemical composition, as a result of heat, pressure and shear.
- Granite metamorphose to *gneiss*
- Shale → Slate → *Schist*
- Limestone → *Marble*


gneiss


schist


marble
limestone

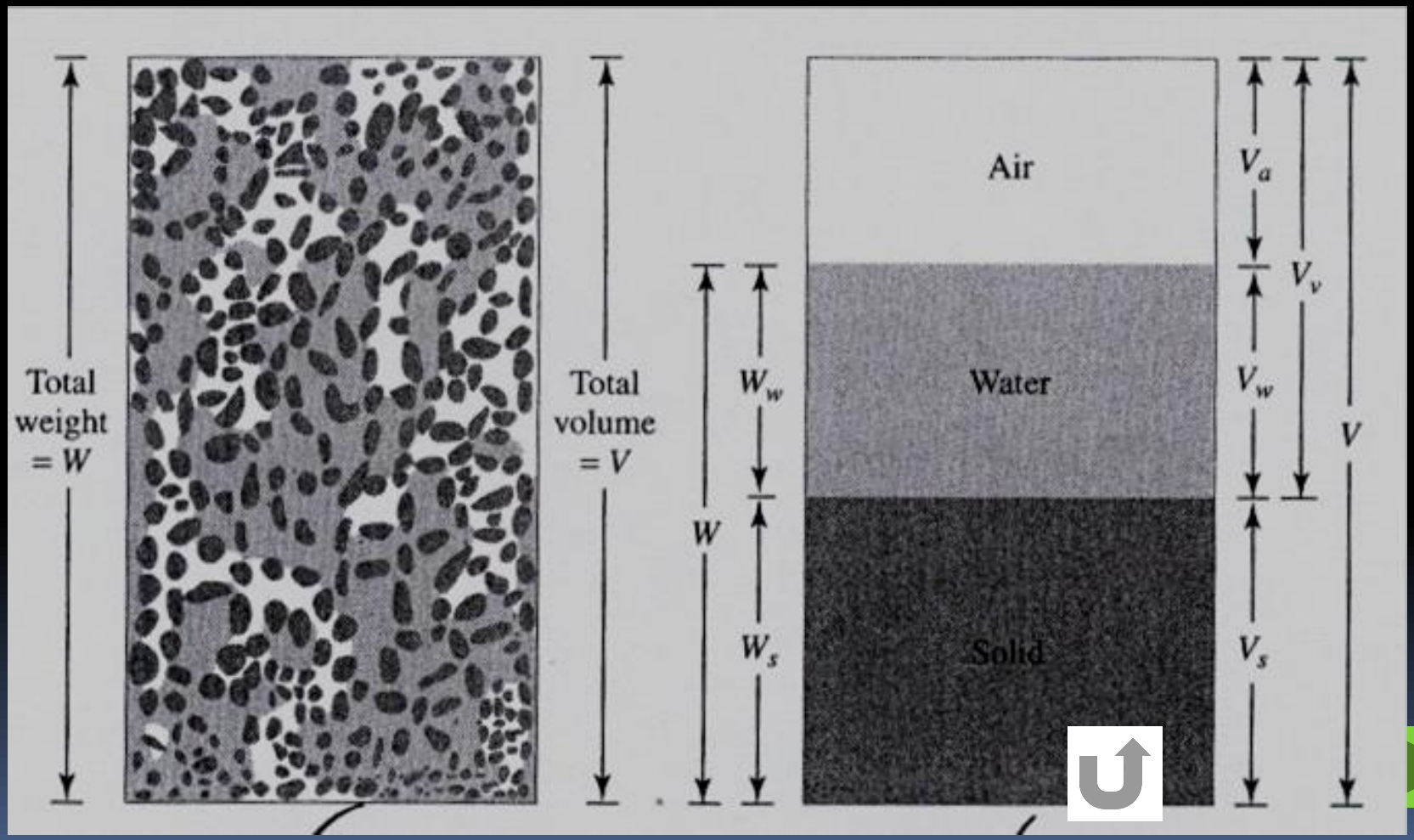
SOIL COMPOSITION

BASIC PHYSICAL SOIL PROPERTIES

SOIL COMPOSITION

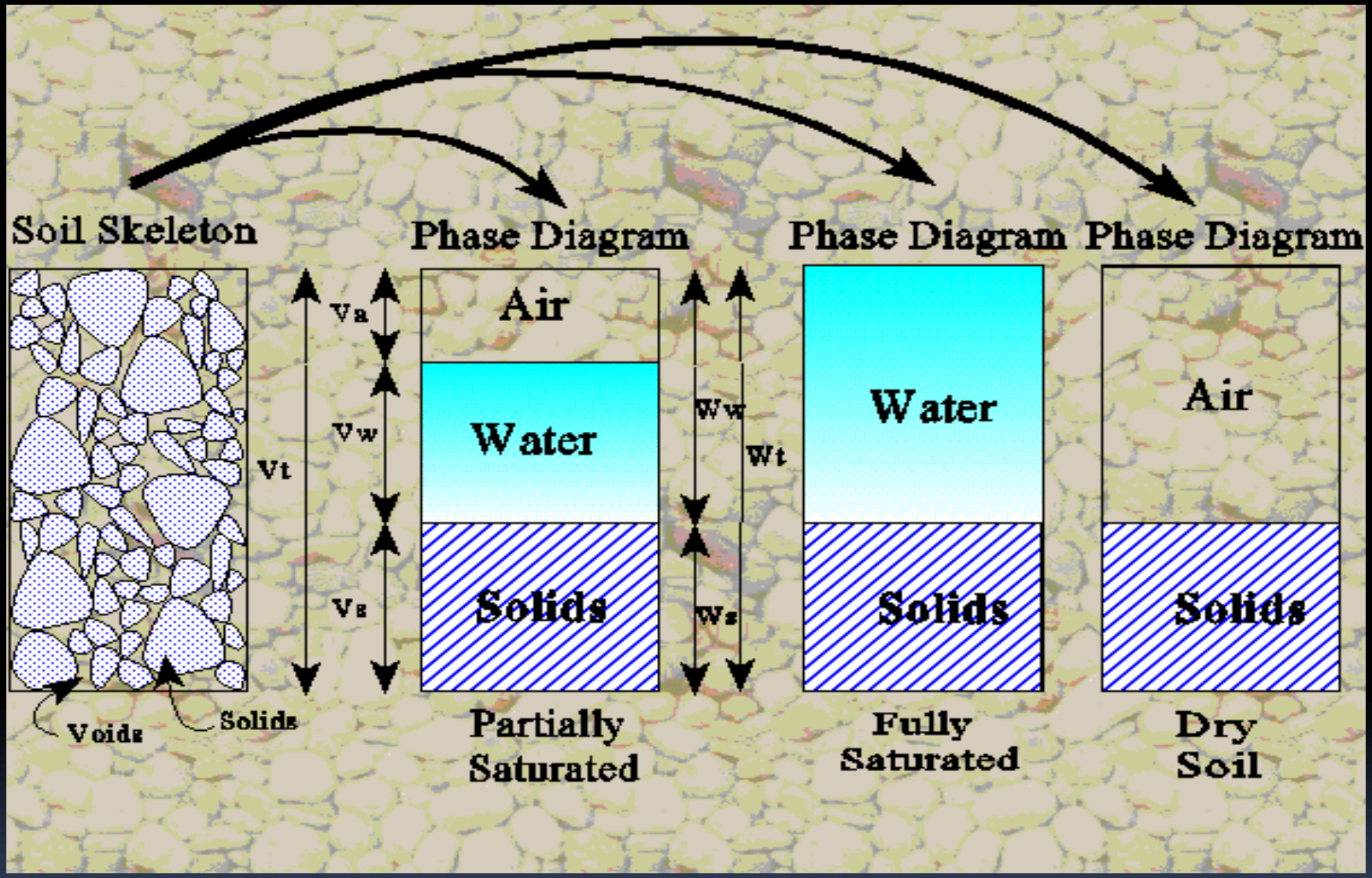
- Generally soil can be divided to three components in natural occurrence
- This separation know as three phase systems or three phase diagram
- It consists of soil solids, water and air

Soil components in natural occurrence



Volume-Weight relationships

- As a result from 3 phase diagram several relationship were produce
- This relationship known as volume weight relationships.
- Refer to 3 phase diagram


Soil Skeleton
Phase Diagram
Phase Diagram
Phase Diagram
Va
Vw
Vt
Vs
Air
Water
Solids
Ww
Wt
Ws
Water
Air
Solids
Solids
Voids
Solids
Partially Saturated
Fully Saturated
Dry Soil

Relationship equations

$$V = V_s + V_v \qquad \text{(eq. 1)}$$
$$= V_s + V_w + V_a$$

where

V_s = volume of soil solids

V_v = volume of voids

V_w = volume of water in the voids

V_a = volume of air in voids

Relationship equations

W = Ws + Ww (eq. 2)

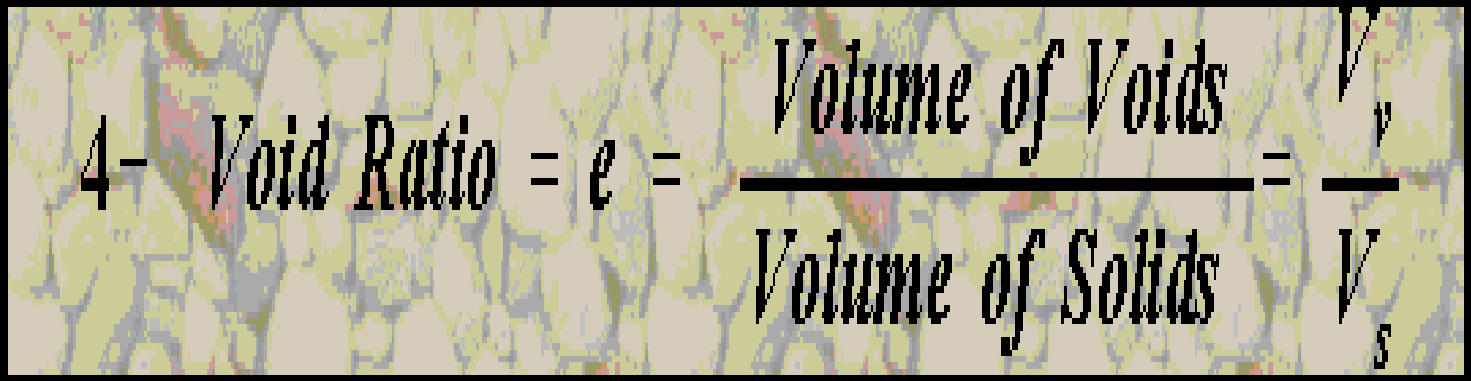
where,

Ws = weight of soil solid

Ww= weight of water

Wa = zero (negligible)

Void ratio, e



The **ratio** of the **volume of voids Vv** to the **volume of soil solid Vs**

Porosity, *n*

$$5- \quad Porosity = n = \frac{Volume\ of\ Voids}{Total\ Volume} = \frac{V_v}{V_t} \times 100\%$$

The **ratio** of the **volume of voids**, **Vv** to **total volume, V** expressed as either a decimal or a percentage.

Relationship between void ratio and porosity

$$e = \frac{Vv}{Vs} = \frac{Vv}{V - Vv} = \frac{(Vv/V)}{1 - (Vv/V)} = \frac{n}{1-n}$$

$$n = \frac{e}{1 + e}$$

Degree of saturation, S_r

$$6- \ Degree\ of\ Saturation = S_r = \frac{Volume\ of\ Water}{Volume\ of\ Voids} = \frac{V_w}{V_v}$$

The **ratio** of the **volume of water, Vw** to the **volume of voids, Vv.** It's commonly in percentage

Water content@ Moisture content

$$3-\ \text{Water Content} = W_c = \frac{\text{Weight of Water}}{\text{Weight of Solids}} = \frac{W_w}{W_s} \times 100\%$$

Unit weight, W

$$\gamma_{soil} = \frac{Total\ Weight}{Total\ Volume} = \frac{W_t}{V_t}$$

The **weight of soil** per **unit volume**

Relationship between dry unit and bulk unit weight

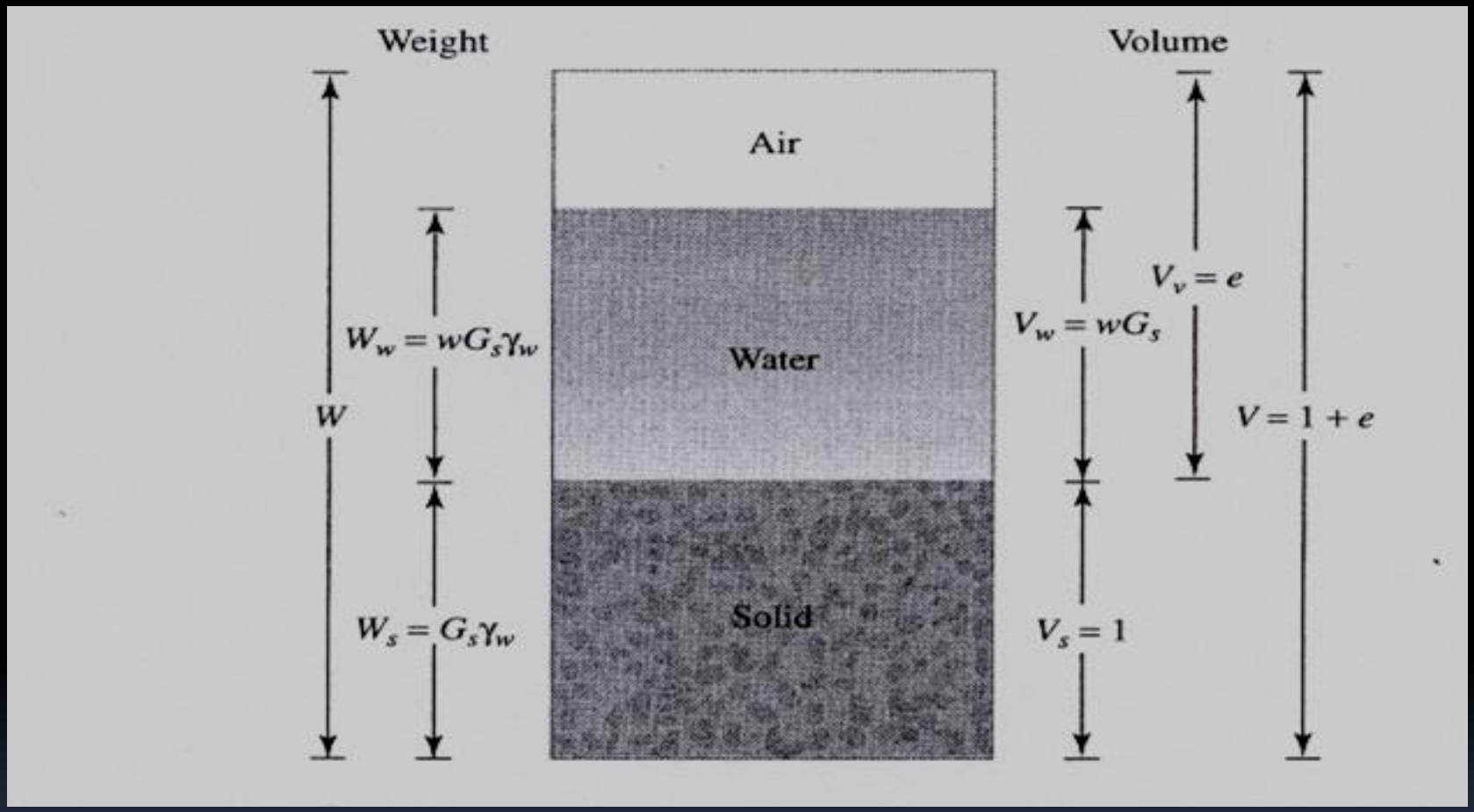
- $\gamma d = \gamma /(1 + w)$

Specific Gravity

$$G_s = \frac{W_s}{V_s \gamma_w}$$

Specific gravity can be determined as a ratio of the weight of the soil solids to weight of water of equal volume

Relationships between Unit weight, Moisture Content and Specific gravity



let *us consider a volume of soil in which the volume of the soil solids is one*

Derivation of equations

Therefore Gs will be substituted as

$$W_s = G_s \gamma_w$$

$$Gs = Ws/\gamma_w = Ms/\rho_w = \gamma_s/\gamma_w$$

$$W_w = wW_s = wG_s\gamma_w$$

Derivation – cont'd

$$\gamma = \frac{W}{V} = \frac{W_s + W_w}{V} = \frac{G_s \gamma_w + wG_s \gamma_w}{1+e} = \frac{(1+w) G_s \gamma_w}{1+e}$$

$$\gamma_d = \frac{W_s}{V} = \frac{G_s \gamma_w}{1+e}$$

Therefore

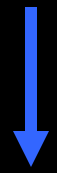
$$S = \frac{Vw}{Vv} = \frac{wGs}{e}$$

How Vw become wG_s???

$$Vw = \frac{W_w}{\gamma_w} = \frac{wGs \gamma_w}{\gamma_w} = wGs$$

So if S = 1 (100%)

$$Se = wGs$$



$$e = wGs$$

$$\gamma_{sat} = \frac{W}{V} = \frac{W_S + W_W}{V} = \frac{Gs\,\gamma_w + e\,\gamma_w}{1+e} = \frac{(Gs+e)\,\gamma_w}{1+e}$$

Beside bulk unit weight, dry unit weight and saturated unit weight there is another type of unit weight that is submerge unit weight, $\gamma' = \gamma sat - \gamma w$

Table 1: Void ratio, moisture content, and dry unit weight for some typical soil

Type of soil	Void ratio, e	Natural moisture content in a saturated state (%)	Dry unit weight, γ_d	
			lb/ft^3	kN/m^3
Loose uniform sand	0.8	30	92	14.5
Dense uniform sand	0.45	16	115	18
Loose angular-grained silty sand	0.65	25	102	16
Dense angular-grained silty sand	0.4	15	121	19
Stiff clay	0.6	21	108	17
Soft clay	0.9–1.4	30–50	73–93	11.5–14.5
Loess	0.9	25	86	13.5
Soft organic clay	2.5–3.2	90–120	38–51	6-8
Glacial till	0.3	10	134	21

Derivation –cont'd

- So what is the different between unit weight and density?
- Unit Weight is influence by gravity forces while mass isn't (Unit Weight=Weight/ Volume while Density= Mass/Volume)- Weight = Mass x Gravity acceleration
- So we can use the similar equations on related calculation if there is only density

- For example: If the equations use unit weight you must use weight in the calculation but if you are only given density you must substituted weight with mass or vice versa.

$$\text{Density} = \rho = \frac{(1 + w)G_s\rho_w}{1 + e}$$

$$\text{Dry density} = \rho_d = \frac{G_s\rho_w}{1 + e}$$

$$\text{Saturated density} = \rho_{sat} = \frac{(G_s + e)\rho_w}{1 + e}$$

- The air content, A can be expressed as
- **A = e- wGs / 1+ e**
- ***or*** **A = e/ 1+e (1- wGs/e)**
- Since n = e/1+e
- Therefore, **A = n (1-Sr)**
- **Beside using symbol A as air content sometimes authors use N_a**
- **Exercise**