Module 1: The geological cycle and the origin of soils

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Spring 2022

January 20, 2022

COURSE CONTENTS AND SCHEDULE

Civil and Environmental Engineering

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Tentative schedule

Day	Date	Topic	Lab.
W	1/19/2022	Class introduction, syllabus, policies	Soil
F	1/21/2022	Invited speaker: Topic TBD	components
M	1/24/2022	Introduction: The geological cycle, soil origin	Grain size
W	1/26/2022	Introduction: Site investigation	dist.
F	1/28/2022	Index properties: Phase relationships	
M	1/31/2022	Index properties: Grain size distribution, Atterberg limits	Atterberg
W	2/2/2022	Index properties: Soil classification	limits
F	2/4/2022	Compaction	
M	2/7/2022	Quiz 1: Introduction, index properties, compaction, in-situ testing	Visual
W	2/9/2022	Water in soils: Groundawater table, pore pressure, total and effective stresses	classification
F	2/11/2022	Water in soils: Darcy's law	
M	2/14/2022	Water in soils: Permeability and hydraulic conductivity	Compaction
W	2/16/2022	Water in soils: One-dimensional seepage	
F	2/18/2022	Water in soils: 2D-3D seepage, flow nets, pore pressure, uplift force, seepage force	
M	2/21/2022	President's day: no class	In-situ
W	2/23/2022	Water in soils: piping	density
F	2/24/2022	Quiz 2: Water in soils	
M	2/28/2022	Induced stress: Approximations, Bousinesq's elastic solution	Permeability
W	3/2/2022	Induced stress: Bousinesq's elastic solution, superposition	
F	3/4/2022	Induced stress: Stress tensor, elastic deformations	
M	3/7/2022	Consolidation: Oedometer test, primary and secondary consolidation	Site
W	3/9/2022	Consolidation: Preconsolidation pressure, OCR	investigation
F	3/11/2022	Consolidation: Primary consolidation parameters	
M	3/14/2022	Spring break: no class	
W	3/16/2022	Spring break: no class	
F	3/18/2022	Spring break: no class	
M	3/21/2022	Consolidation: rate of consolidation	Bonus
W	3/23/2022	Consolidation: preloading, radial consolidation	
F	3/25/2022	Quiz 3: Induced stress and consolidaiton	
M	3/28/2022	State of stress: 2D stresses and Mohr's circle	Consolidation
W	3/30/2022	State of stress: principal stresses, stress invariants, rotations	
F	4/1/2022	State of stress:: Usage of Mohr's circle	
M	4/4/2022	State of stress: stress paths, simple shear, triaxial compression	Settlement
W	4/6/2022	Quiz 4: State of stress	estimates
F	4/8/2022	Shear strength: Mohr-Coulomb failure criteria	
M	4/11/2022	Shear strength: drained and undrained behavior	Unconfined
W	4/13/2022	Shear strength: Shear strength of clays	compression
F	4/15/2022	Shear strength: Shear strength of sands	test
M	4/18/2022	Quiz 5: Shear strength	Direct
W	4/20/2022	Lateral earth pressure: at-rest, passive, and active conditions [2]	shear
F	4/22/2022	Intro to slope stability [2]	
M	4/25/2022	Intro to bearing capacity [2]	Direct
W	4/27/2022	Maine's day: no class	shear
F	4/29/2022	Classes end: Q&A session	
M	5/2/2022	Final exam (1:30 PM- 3:30 PM) Williams Hall 110	

M: Monday - W: Wednesday - F: Friday

RECAP

- We read the syllabus and discussed the course policies.
- We watch Maria's presentation about geotechnical engineering in practice!!
- Homework 1 is due next Monday (1/31/2022) with the memo.

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CIE-365 Spring 2022: Homework assignment 1

Due date: 01/24/2022 at 10:00 AM
Possible points: 30

Answer the following questions based on the presentation given by María Limas and the contents of Module 1.

1. [O1] (6 points) List three aspects of Maria's geotechnical engineering presentation that you found most interesting. Please elaborate on your response in 100-word paragraphs.
2. [O1] (8 points) Describe the soil transportation processes depicted in Figure 1. What can you expect from these soils in terms of grain shape and size distribution?

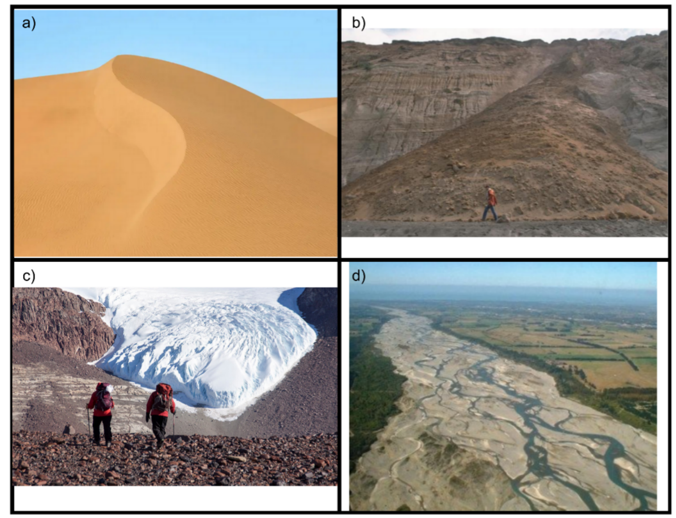


Figure 1: Figure depicting different soil deposits for question 2

3. [O1] (12 points) Make a conceptual map of the various forms of transported sediment, identifying key features discussed in class.

1

CONTENTS

Is there any structure or moving machine that doesn't interact with geological materials?


credits: Shutterstock

Geology matters, and we need to understand soil and rock mechanics.

SOIL MECHANICS

- Is a fundamental discipline of geotechnical engineering.
- According to Holtz et al (2002):

  "Is the branch of geotechnical engineering concerned with the engineering mechanics and properties of soils".

- Soil mechanics integrates kinematics, dynamics, fluid mechanics, and material mechanics to soils. Soil, rather than water, steel, or concrete, becomes the engineering material whose properties and behavior we must understand to build with or upon it (Holtz et al. 2002).
- We can add: to protect our society from geohazards.

SOIL MECHANICS

What is a key difference between these materials?

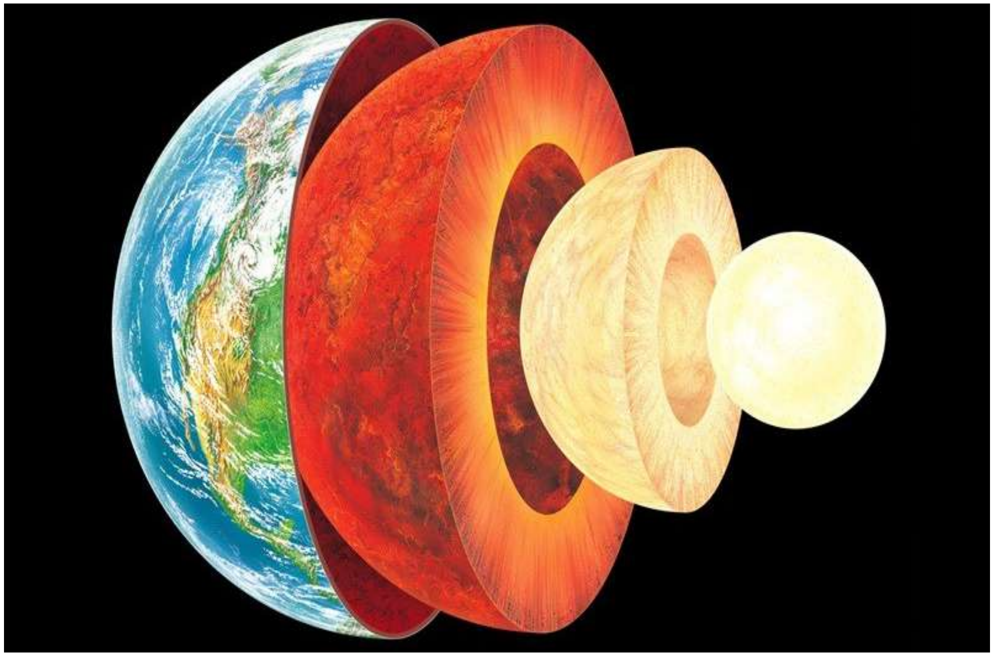
Concrete and steel are prescribed materials. Soils are natural and not prescribed. We must investigate and characterize them first!

SOIL MECHANICS

- We assume some materials are CHILE: continous, homogeneous, isotropic, linear-elastic.
- Soils are DIANE materials: discontinous, inhomogeneous, anysotropic, non-elastic.
- Soil heterogeneity makes soil mechanics complex.
- Soil mechanics is highly empirical.

THE GEOLOGICAL CYCLE

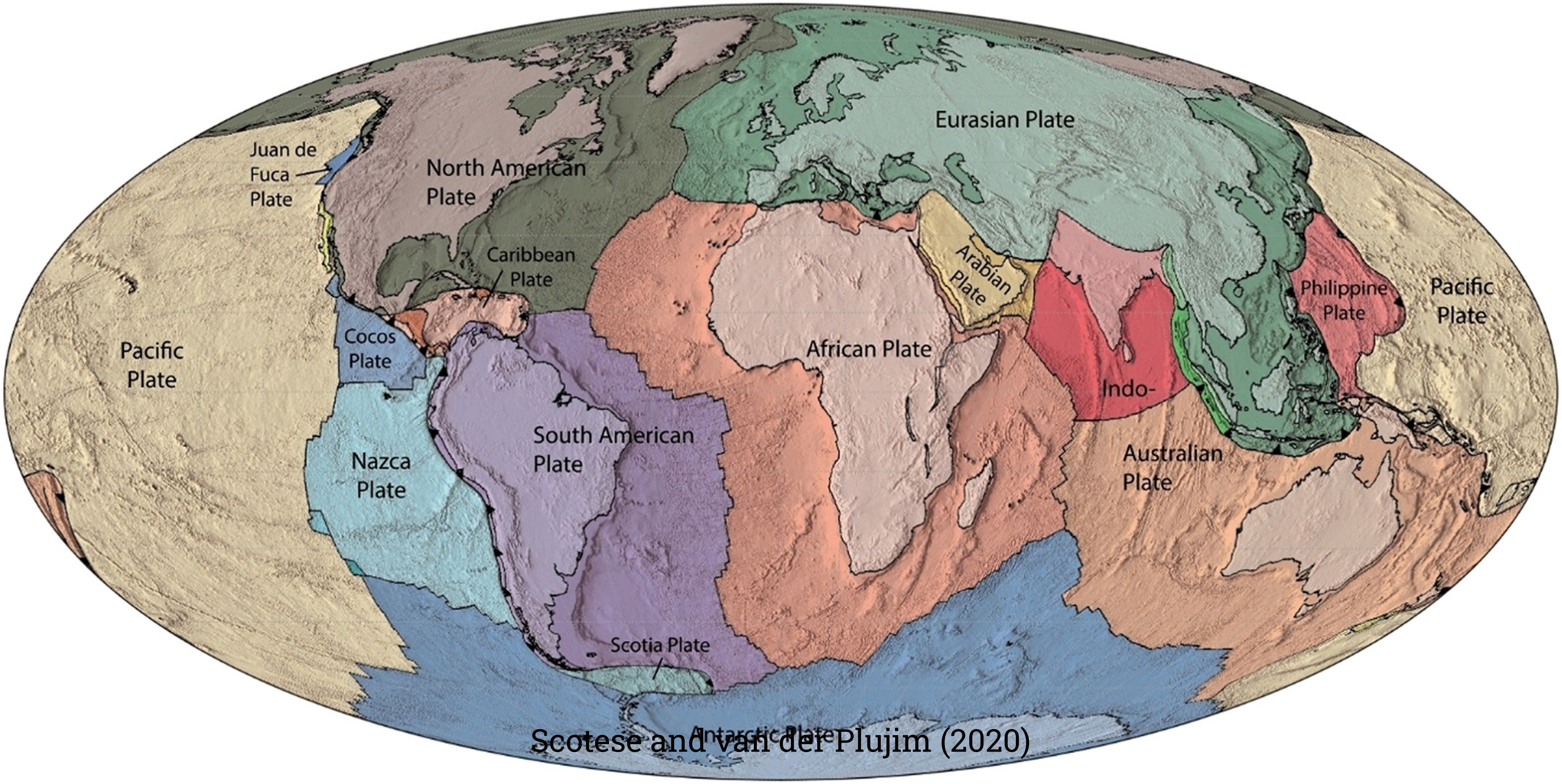
EARTH'S STRUCTURE



Earth's structure

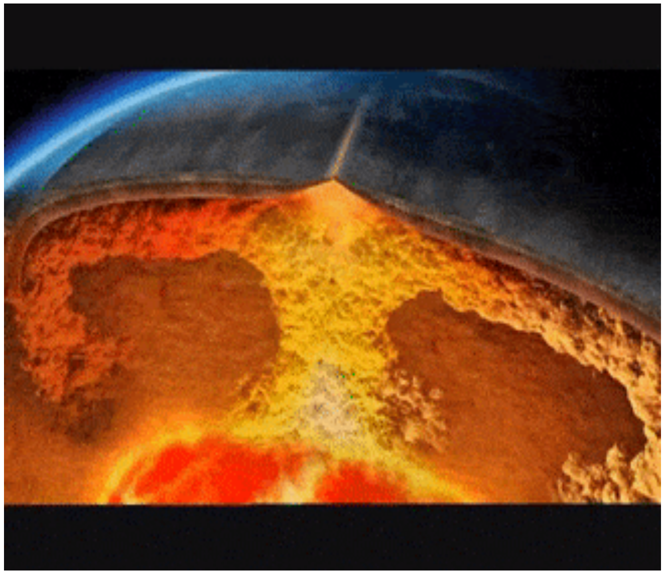
- Crust: 5-70 km (3.1-43.5 mi).
- Mantle: 2890 km.
- Outer core: 2400 km.
- Inner core: 1220 km.

PLATE TECTONICS

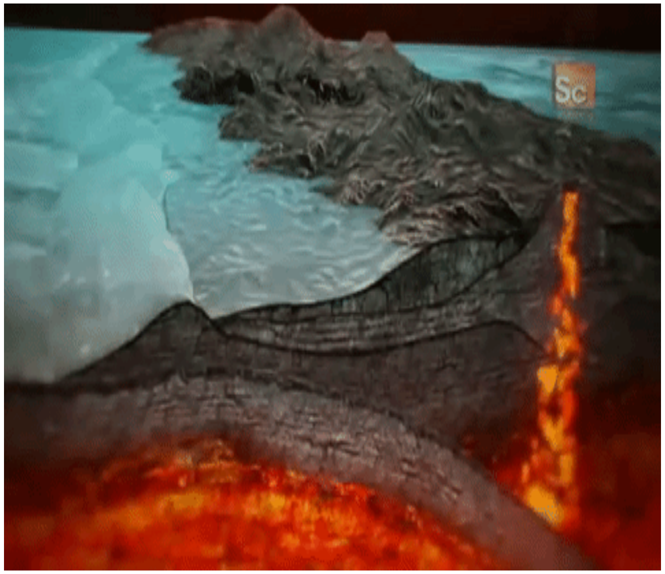


Scotese and van der Plujim (2020)

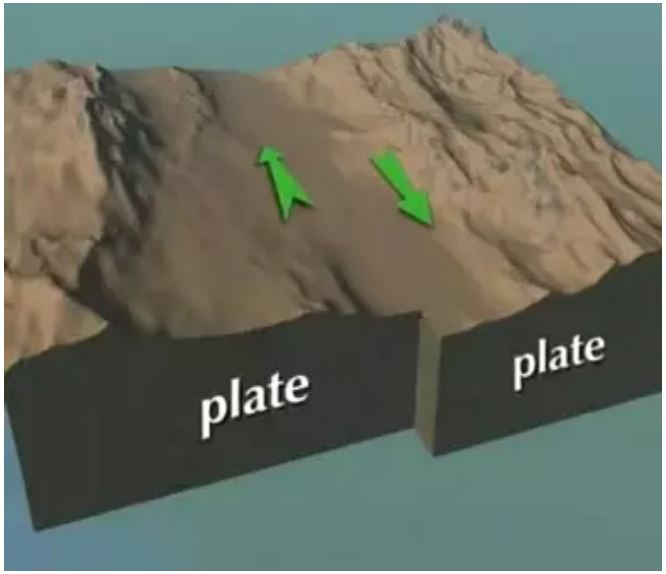
PLATE TECTONICS



Divergent plates (e.g., oceanic ridges)



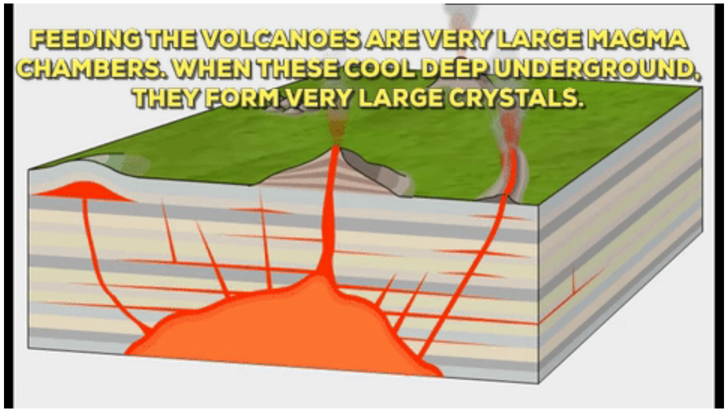
Convergent plates (e.g., subduction zones)

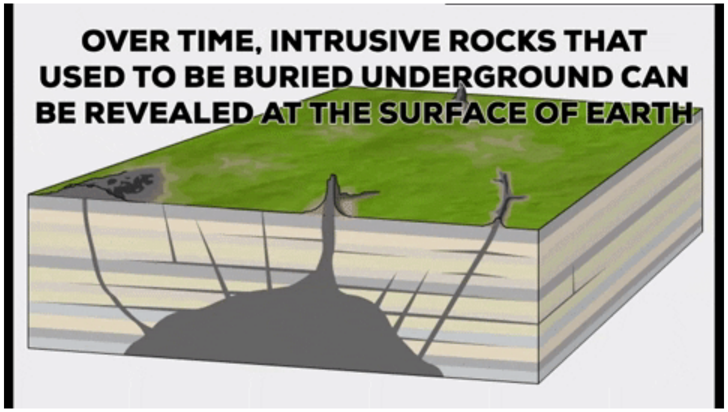


Strike-slip fault

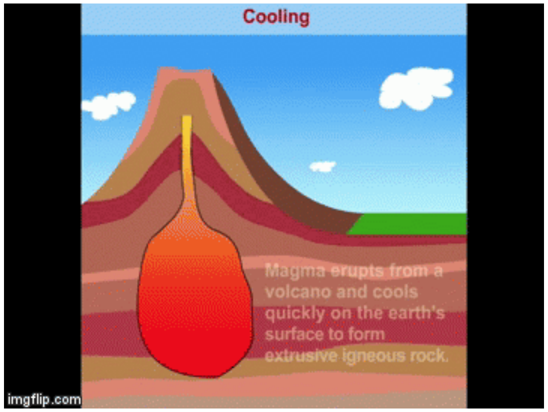
IGNEOUS ROCKS

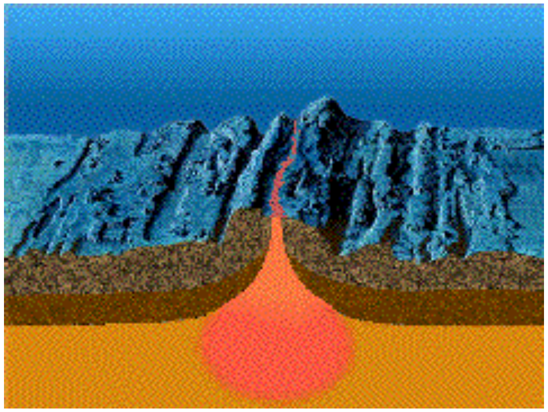
INTRUSIVE





EXTRUSIVE





IGNEOUS ROCKS

Formed by cooling magma/lava, producing crystalization of the rock minerals (mica, feldspar, quartz, etc.).

INTRUSIVE

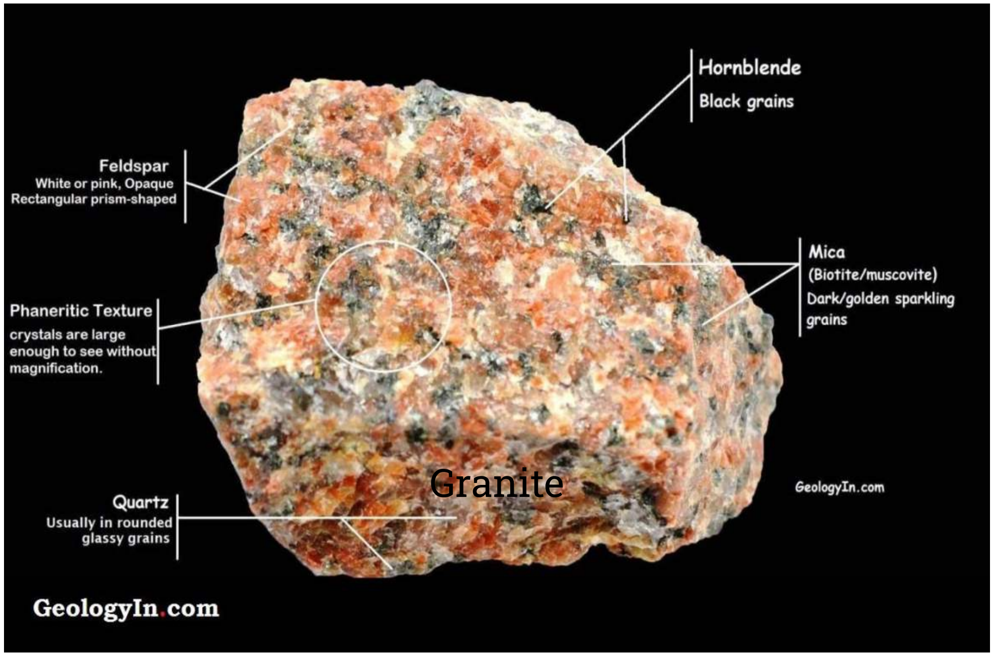
- Formed in the crust's interior.
- Crystalization is slow.
- Minerals form clusters.
- They have grained texture.

EXTRUSIVE

- Formed in the crust's exterior.
- Crystalization is rapid.
- Minerals have no time to form groups.
- They loock uniform in texture and color.

IGNEOUS ROCKS

INTRUSIVE



Granite

EXTRUSIVE

Basalt

WEATHERING

The process of breaking apart or disintegrating rocks to form sediments/soils.

PHYSICAL

- Root wedging.
- Frost wedging.
- Salt wedging.
- Exfoliating.
- Thermal expansion.
- Abrasion.

CHEMICAL

- Hydration.
- Oxydation.
- Dissolution.

WEATHERING

SOILS

Particulate matter desintegrated from rocks.

premierequestrian.com

SOILS

We can subdivide them by particle diameter according to the Unified Soil Classification System (USCS- ASTM D2487):

- Boulders: $d > 300$ mm $\longrightarrow \approx 1$ ft
- Cobbles: $75 < d \leq 300$ mm $\longrightarrow$ 3 in - 1 ft
- Gravels: $4.75 < d \leq 75$ mm $\longrightarrow$ Sieve No.4 - 3 in
- Sands: $0.075 < d \leq 4.75$ mm $\longrightarrow$ Sieve No.200 - Sieve No.4
- Silt: $2 \times 10^{-6} < d \leq 0.075$ mm $\longrightarrow$ Pass sieve No. 200
- Clay: $d \leq 2 \times 10^{-6}$ mm $\longrightarrow$ Pass sieve No. 200

We'll discuss sieve analysis in Module 2.

SEDIMENTARY ROCKS

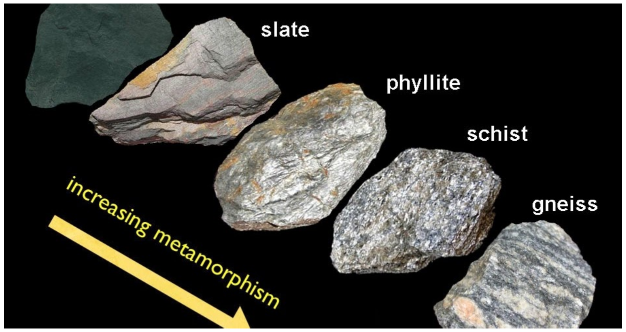
Created by the consolidation or cementation of sediments. Soils are transformed back into rock.

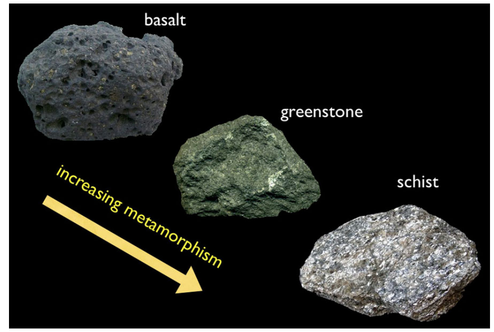
- Clay $\longrightarrow$ Claystone, mudstone, shale
- Silts $\longrightarrow$ Siltstone
- Sand $\longrightarrow$ Sandstone
- Gravel $\longrightarrow$ Conglomerate

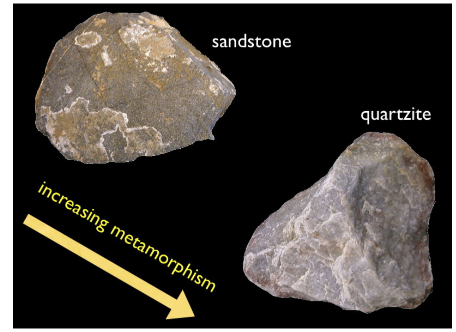

credits.Rhododendrites

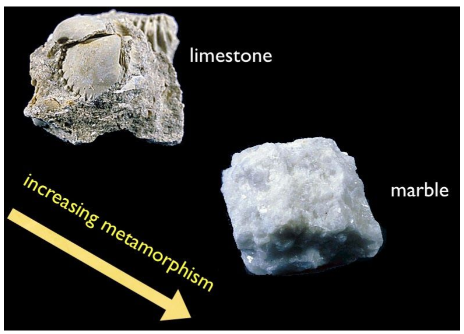
METAMORPHIC ROCKS

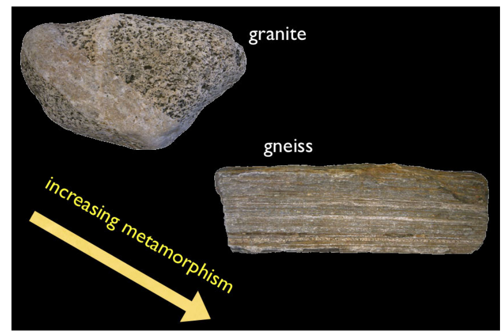
Created by high pressures and/or temperatures.











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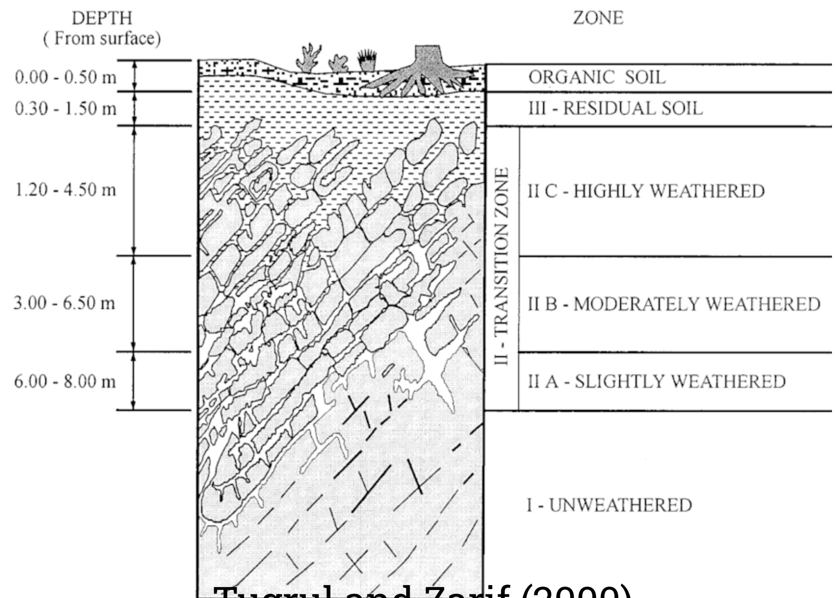
THE GEOLOGICAL CYCLE

Soils can be:

- Residual soils: Soils are formed in situ primarily as a result of chemical reactions.
- Transported soils:Soils are transported from their original source and deposited in a new location.

RESIDUAL SOILS

- Forms in place due to chemical processes.
- The properties of residual soils depend on the parenting rock and climate.
- In depth, the distribution is heterogeneous.
- Particle size assortment with depth.
- Difficult to characterize.



Tugrul and Zarif (2000)
(Modified from Deere and Patton 1971)

hkss.cedd.gov.hk

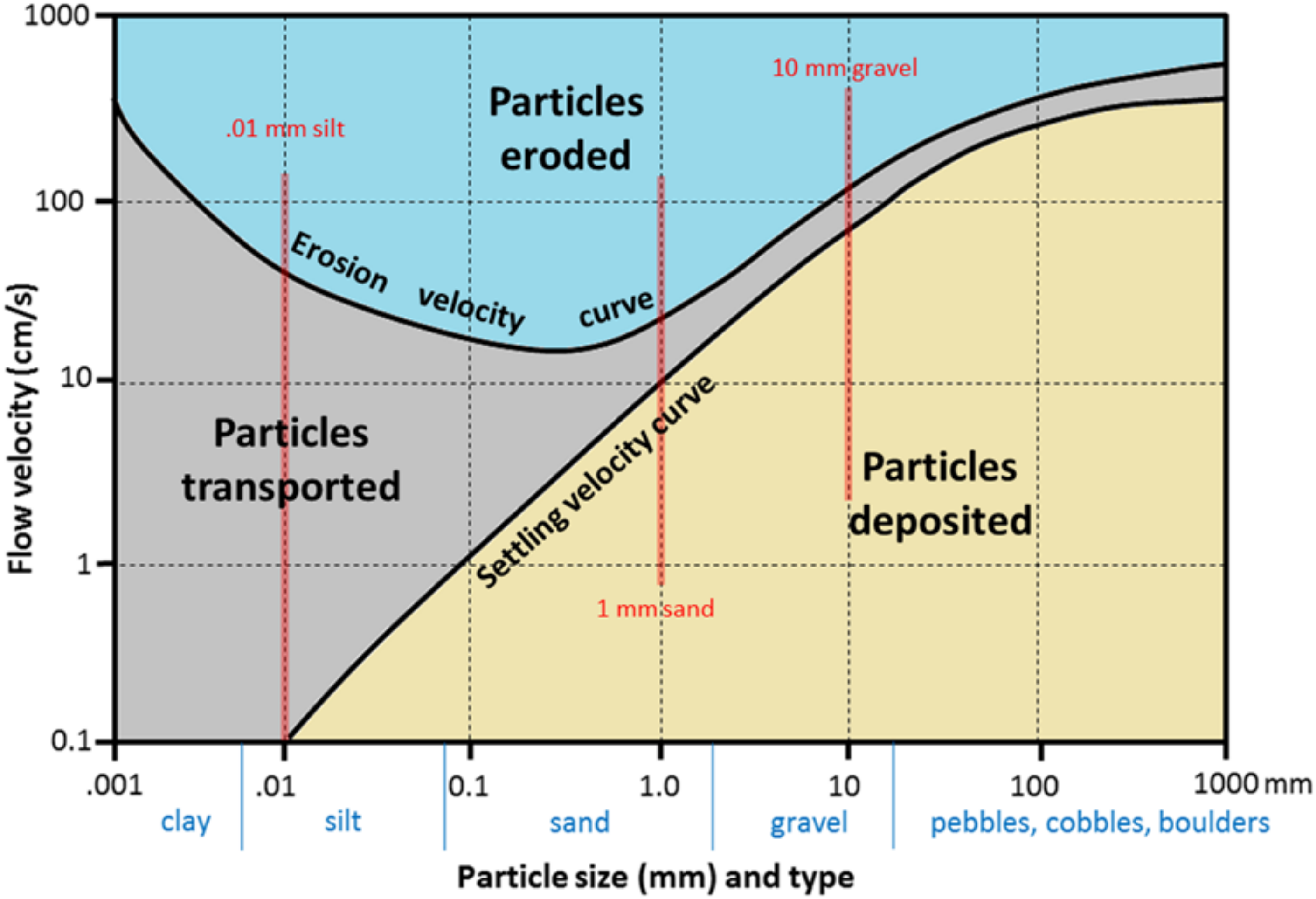
TRANSPORTED SOILS

How are soils transported?

- Running water $\longrightarrow$ Alluvial soils.
- Tide/wave dominated water $\longrightarrow$ Coastal-estuarine sediments.
- Deposition in lakes $\longrightarrow$ Lacustrine soils.
- Deposition in the ocean $\longrightarrow$ Marine soils.
- Glaciers $\longrightarrow$ Glacial soils, morraine deposits.
- Wind-blow deposition $\longrightarrow$ Aeolian soils.
- Gravity, rockfall, landslide $\longrightarrow$ Colluvial soils.

ALLUVIAL DEPOSITS

Hjulström (1935) erosion curve. Figure taken from Earle (2019)



ALLUVIAL DEPOSITS

- They can be extremely complex due to stream alignment changes, floods, droughts, etc.
- Particles are usually rounded.
- Usually uniform gradation (soil particles have similar size).
- Tey will often consist of coarse-sized material.

COASTAL/ESTUARINE SOILS

Beaches

Credits: Acadia National Park

- They are governed by wave currents across and along the shoreline.
- They are usually made of uniform sand and, rarely, gravel.
- Sediments migrate very rapidly and are deposited and acreed constantly.
- Infiltration-exfiltration processes in the beach face regulate the erosion rate.
- The beach profile responds quickly to sea level rise.
- Influenced by on-shore activities.

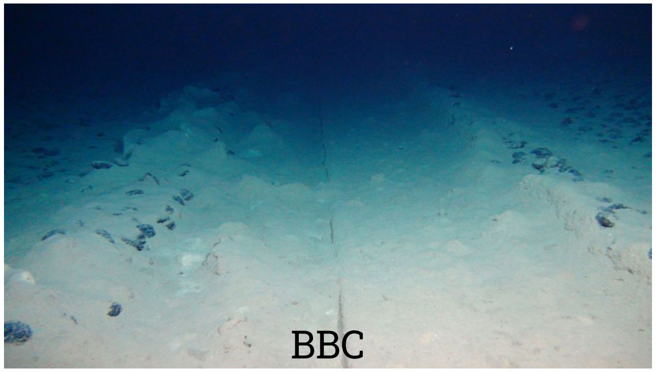
Estuarine soils

Credits rzotelli

- They are influenced by wave and tide dominated currents.
- Due to flow reversal, sand, silt, and clay deposits are possible.
- In tide-dominated flooded areas, fine soils (silts and clay) are common.
- In wave-dominated areas, sand is more common.

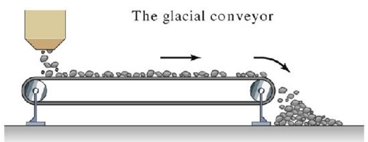
LACUSTRINE/MARINE SOILS

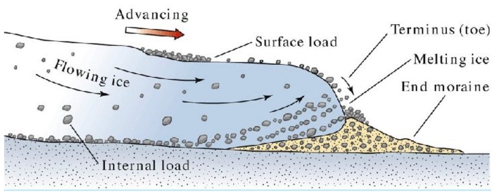
- They are depossited at very low flow velocities.
- Usually they are made of fine soils and/or organic matter.
- In lacustrine deposits, perios of flood and droughts influence the particle size and organinc content.
- There is a significant difference between lacustrine and marine soils. The chemistry of clay particles in marine sediments is influenced by salt water.



GLACIAL DEPOSITS

- They are extremely complex.
- These deposits can be found all around the world, not just near the poles.
- Variety of mixed particle sizes. From clay to boulders.
- Made of angular clasts.





AEOLIAN SOILS

Sand dunes:

- Predominantly rounded sand-sized particles.
- Common in arid regions and some coastal areas.
- Different morphologies.
- Travel pretty quicky.

Loess:

- Accumulation of wind-blown fine sediments (silt).
- Homogeneous, highly porous, non-stratified deposits.
- Collapsible deposit upon saturation.

COLLUVIAL DEPOSITS

- Remainder of landslides and rockfall.
- Heterogeneous deposits.
- Mixed particle size.
- Indicate a zone of instability.