
610-280 Environmental Chemistry

Rachel Caruso

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Soil: Components

- Definition and formation
- Soil composition and texture
 - Inorganic component
 - Clay mineral types
 - Sand, silt

Rachel Caruso, Room 276, rcaruso@unimelb.edu.au

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References

- V. P. Evangelou, Environmental Soil and Water Chemistry
- Wright, J. Environmental Chemistry, 2003

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What is soil?

- N. C. Brady, The Nature and Properties of Soils

“ Soil ... a collection of natural bodies which has been synthesised in profile form from a variable mixture of broken and weathered minerals and decaying organic matter, which covers the earth in a thin layer, and which supplies, when containing the proper amounts of air and water, mechanical support and sustenance for plants”

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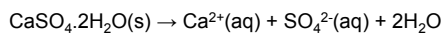
Formation of soil

- Pedogenesis
- 5 main categories of variables that influence the formation of soil:
 - Parent material
 - Climate
 - Organisms
 - Topography
 - Time
- Weathering (physical and chemical)

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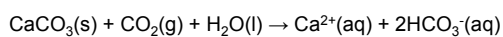
Chemical weathering

- Dissolution:

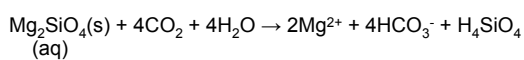


In the presence of CO_2 and water - which form acidic solution $\text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \leftrightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})$

Calcium carbonate



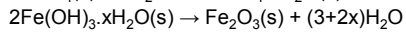
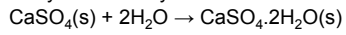
Forsterite



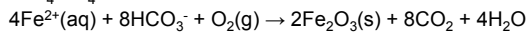
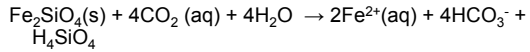
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Chemical weathering

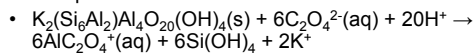
- Hydration/dehydration



- Oxidation



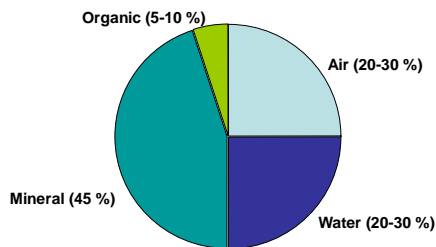
- Complexation



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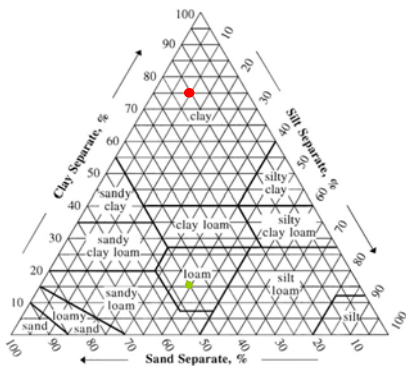
Soil composition

- The four main constituents of soil:



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Classification of Soil Texture



Wikipedia

Classification of soil texture

	International Soil Science Society
Gravel	> 2 mm
Coarse sand	0.2 to 2 mm
Fine sand	0.02 to 0.2 mm
Silt	0.002 to 0.02 mm
Clay	< 0.002 mm

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Inorganic minerals of soil

- Size of soil mineral particle varies from clay sized to gravel and rocks
- Two classifications
 - Primary minerals - chemical composition and structure obtained during crystallization of molten lava (eg. SiO_2 - quartz)
 - Secondary minerals – have altered from the original structure and chemical composition by weathering (eg. Clay minerals)

Element	Percent
O	46.5
Si	27.6
Al	8.1
Fe	5.1
Ca	3.6
Na	2.8
K	2.6
Mg	2.1
others	1.6

Evangelou

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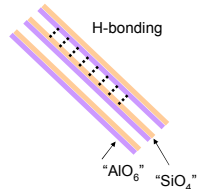
Clay minerals

- Mainly secondary silicates and aluminosilicates
- Small size
 - spaces between particles small, poor drainage
 - act as colloids in water
- High plasticity index
- Layered structures labelled 1:1, 2:1 and 2:2 according to arrangement of two different sheet structures (one sheet consists of tetrahedral units, each Si shares one O atom with second sheet which consists of octahedral units).

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1:1 Clay

- Pairs of sheets are held together by hydrogen bonding (stops insertion of H_2O or ions between sheets)
- Does not expand when wet
- Eg. Kaolin group
 - kaolinite

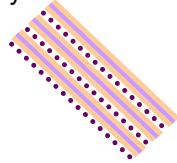


http://www.soils.wisc.edu/virtual_museum/kaolinite/index.html

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2:1 Expanding Clay

- Three sheets "t-o-t" comprising a layer
- Layers separated by an interlayer metal cation
- Expanding
- Eg. Smectite group
 - montmorillonite



http://www.soils.wisc.edu/virtual_museum/soil_smectite/index.html

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2:1 Non-expanding clay

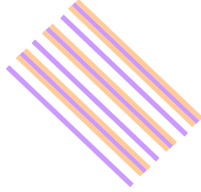
- Three sheets "t-o-t" comprising a layer
- Non-expanding
- High negative charge, interlayer K^+ tightly held and therefore not exchangeable
- Eg. Illite, mica

http://www.soils.wisc.edu/virtual_museum/muscovite/index.html

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2:2 clay

- Two repeating layers - a 2:1 “t-o-t” and a discrete “o” layer
- No significant expansion
- Eg. Chlorite



http://www.soils.wisc.edu/virtual_museum/chlorite/index.html

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Substitution

- Leads to variation in composition:
 - Al^{3+} may replace some Si^{4+} in tetrahedral sheets (resulting in net negative charge)
 - Al^{3+} in octahedral sheets may be replaced by Mg^{2+} , Zn^{2+} , Fe^{3+} or Fe^{2+} ions (sometimes resulting in net negative charge)
- Charge normally balanced by attachment of univalent or divalent ions: Na^+ , K^+ , Ca^{2+} .

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Comparison between clay types

Mineral	Kaolinite (1:1)	Smectite (2:1 expanding)	Mica (2:1 non-expanding)	Chlorite (2:2)
Size (μm)	0.1-1	0.01-0.1	0.1-2.0	
SA (m^2g^{-1})	10-20	600-800	70-120	70-150
Internal surface	none	very high	medium	
External surface	low	high	medium	
Swelling capacity	low	high	medium	
Cation exchange capacity ($cmolkg^{-1}$)	1-10 (pH dependent)	80-120	20-40	10-40

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Sand

- Mainly quartz
- Large particle size – large spaces between particles, easy passage of water
- Particles do not carry charge
- Particles do not show marked physical activity
- Considered the skeleton of soil



Wikipedia

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Silt

- Mainly quartz and some silicates
- Particles do not carry charge
- Particles do not show marked physical activity
- Considered the skeleton of soil

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In summary

Soil: Components

- Defined soil and looked at its formation
- Composition of soil, texture classifications
- Determined texture from ternary phase diagram
 - Inorganic component of soil
 - Comparison of clays
 - Sand, silt

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