GEOG203 – Environmental Systems

Soils & Biogeochemistry

Physical & chemical weathering Processes and Controls

Instructor: Julie Turgeon
julie.turgeon@mcgill.ca
BH 318
TA: Dolly Kothawala
dolly.kothawala@mcgill.ca

Weathering is any of the chemical or mechanical processes by which rocks exposed to the weather undergo changes in character and break down to produce soil material.

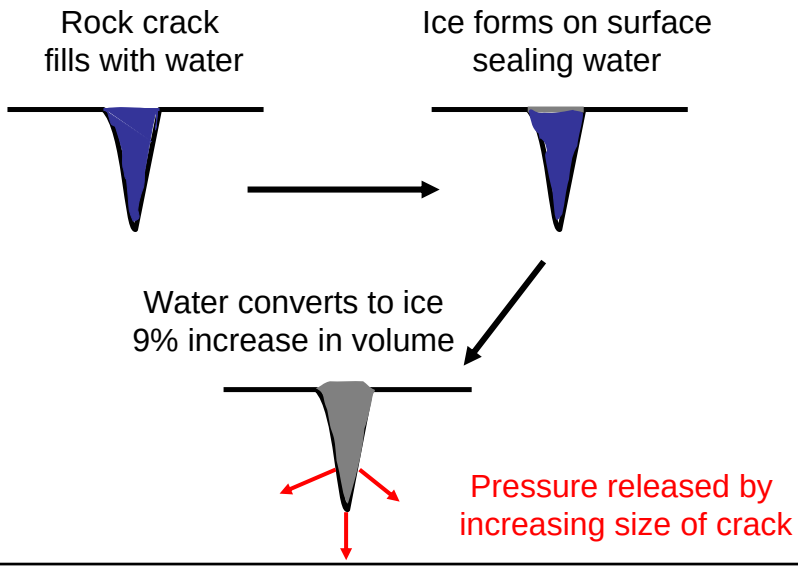
Two major types of weathering processes:

- **Physical weathering** – physical disintegration of rocks and minerals, decreasing particle size and increasing surface area.
- **Chemical weathering** – chemical transformation of minerals into new products.

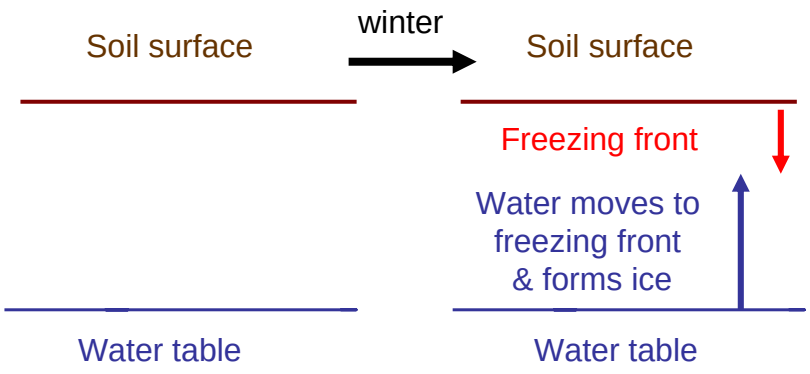
Physical Weathering Processes

Freeze-thaw - caused by increase in volume of 9% when water freezes and, more importantly, movement of water to freezing front. Requires freeze-thaw cycles in climate.

Freeze-thaw weathering: traditional explanation



More likely reason for freeze-thaw weathering



Physical Weathering Processes

Thermal changes – variations in temperature lead to differential rates of expansion and contraction amongst minerals. Require variable thermal regime. Occurs on rock surfaces exposed to strong sunlight (e.g. deserts) and fires burning in soil.

Wetting/drying – some minerals such as clays increase volume when wetted

Physical Weathering Processes

Biological – plant root penetration, earthworm churning of soil.

Salt weathering – formation and growth of salt crystals in arid/semi-arid environments.

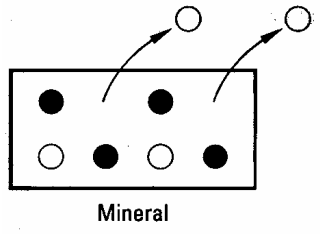
Pressure release - when igneous rocks exposed at surface.

Chemical weathering processes

Direct solution – dissolution of soluble salts.

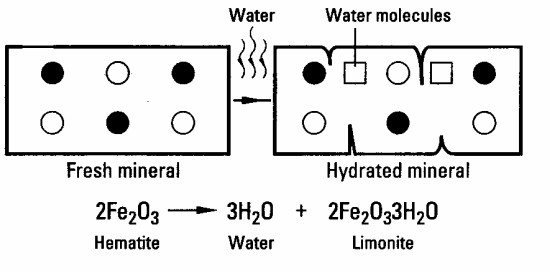
Hydration – absorption of water.

Direct solution – dissolution of soluble salts.



e.g. Na and K
Cl and SO_4

Hydration – absorption of water.



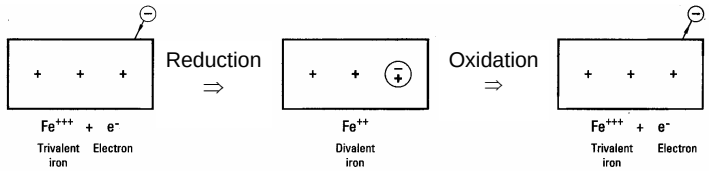
e.g.
hematite to limonite
or
anhydrite to gypsum

Chemical Weathering Processes

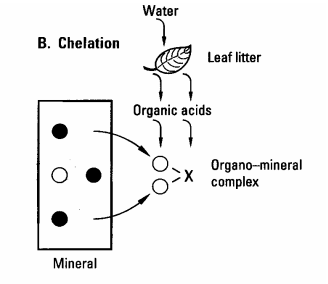
Oxidation – reduction – change in valency of element such as Fe ($Fe^{2+} \Leftrightarrow Fe^{3+}$).

Chelation – reaction of normally insoluble elements with complex organic compounds produced by the decomposition of organic matter, e.g. Fe, Al.

Oxidation – reduction – change in valency of element such as Fe ($Fe^{2+} \Leftrightarrow Fe^{3+}$)



Chelation – reaction of normally insoluble elements (e.g. Fe, Al) with complex organic compounds produced by the decomposition of organic matter.



Chemical Weathering Processes

Carbonation – reaction of carbonic acid (H_2CO_3 produced by dissolution of CO_2) with carbonates

$CaCO3 + H_2CO_3 \Rightarrow Ca(HCO_3)_2$

insoluble soluble

Hydrolysis – reaction of H+ ion with cation in mineral:

$H^+ + KAlSi_3O_8 \Rightarrow H_4SiO_4$ soluble silicic acid

insoluble clay mineral

Carbonation – reaction of carbonic acid (H_2CO_3 produced by dissolution of CO_2) with carbonates

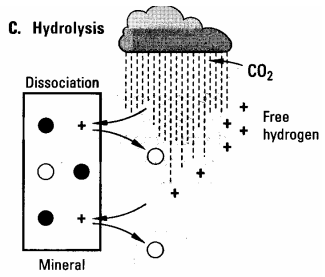
$CaCO3 + H_2CO_3 \Rightarrow Ca(HCO_3)_2$

insoluble soluble

Hydrolysis – reaction of H+ ion with cation in mineral:

$H^+ + KAlSi_3O_8 \Rightarrow H_4SiO_4$ soluble silicic acid K^+

insoluble clay mineral



H^+ from CO_2 dissolution in water acid rain

Rates of weathering

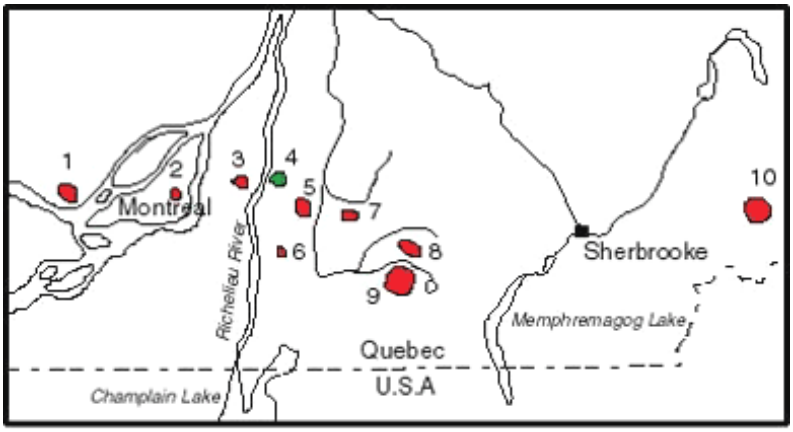
Dependent on strength and resistance of rocks and minerals.

Strength of rocks generally:

igneous > metamorphic > sedimentary

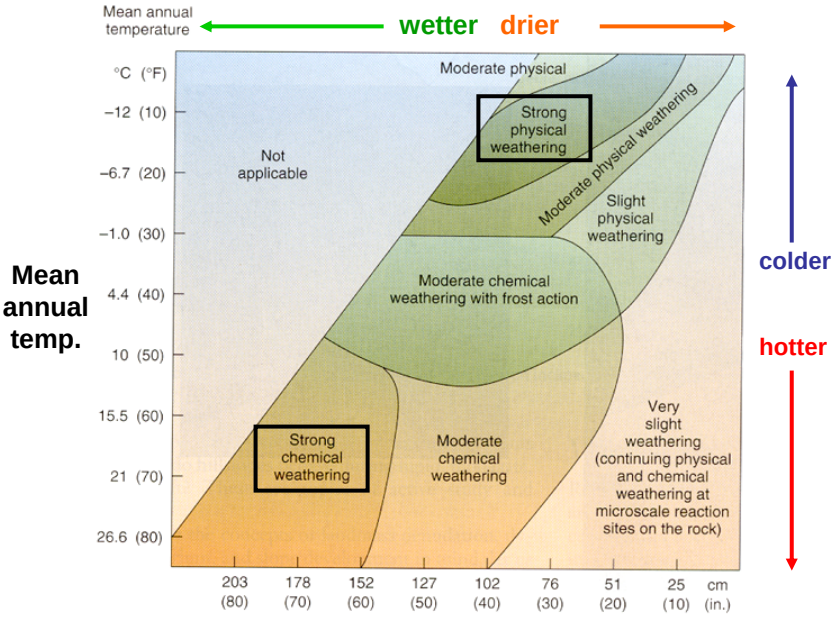
An example…

The Monteregian Hills, southern Quebec



1. Oka
2. Mont Royal
3. Mont Saint-Bruno
4. Mont Saint-Hilaire
5. Mont Rougemont
6. Mont Saint-Grégoire
7. Mont Yamaska
8. Mont Shefford
9. Mont Brome
10. Mont Mégantic

Climate and weathering (from Christopherson)



Stability or resistance of minerals to chemical weathering

Least resistant

Soluble salts (e.g. Na and K chlorides and sulphates)
Carbonates ($CaMg(CO_3)_2$
Ferromagnesian minerals:
olivine
pyroxene
amphibole
Mica (Fe-Mg rich igneous minerals)
Feldspars (aluminosilicates)
Clay minerals (Si-Al sheets):
montmorillonite
kaolinite
Quartz (igneous mineral with no Fe-Mg)
Fe and Al oxides and hydroxides

Most resistant