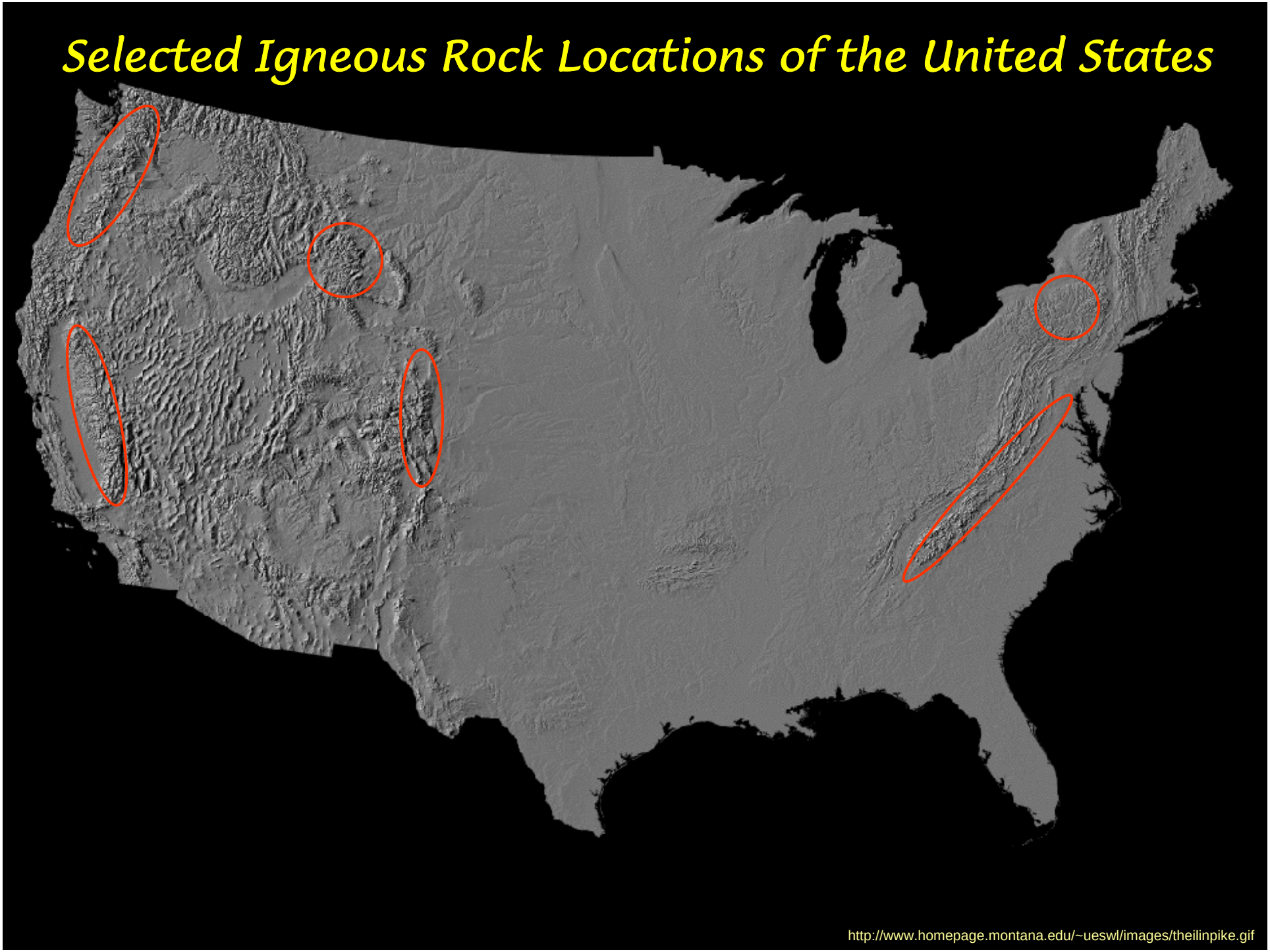
Sedimentary Rock Origins and Classification

Our Core Principle

Minerals and Rocks
(and everything else)
Are Stable
Only Under the Conditions
At Which They Form

Change the Conditions and
They Must Change Also

Selected Igneous Rock Locations of the United States



http://www.homepage.montana.edu/~ueswl/images/theilinpike.gif

Our Core Principle

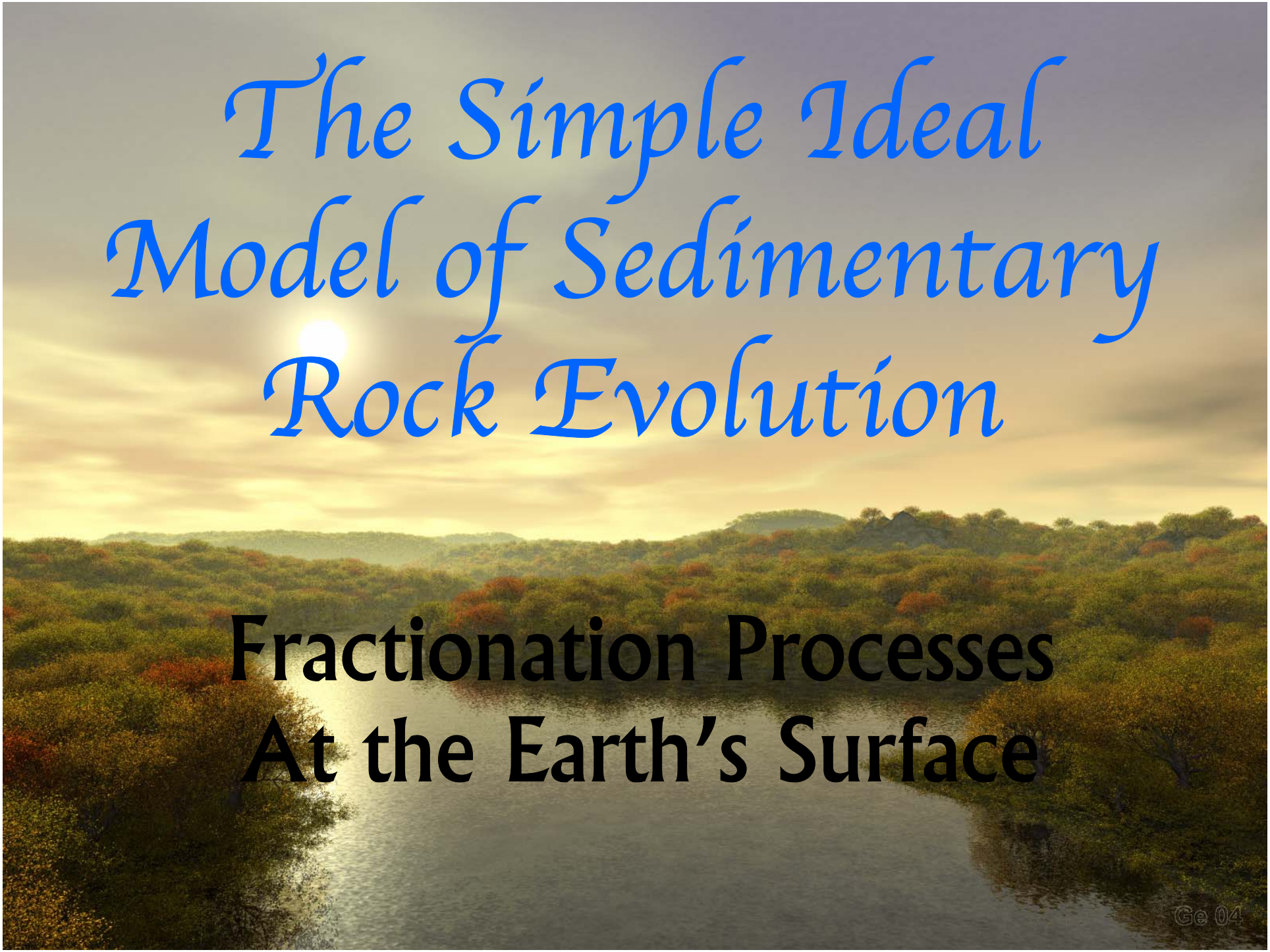
Our Core Principle

With weathering the two major sources of energy are:

Solar → *Heat from the sun*

Heat warms the air and water, setting up different pressures which causes them to move.

Chemical → *Inorganic reactions, of which there are many, many, many – some of which we need to understand*


The Simple Ideal Model of Sedimentary Rock Evolution
Fractionation Processes At the Earth's Surface
Ge 04

The Simple Ideal Model for the Evolution of Sedimentary Rocks

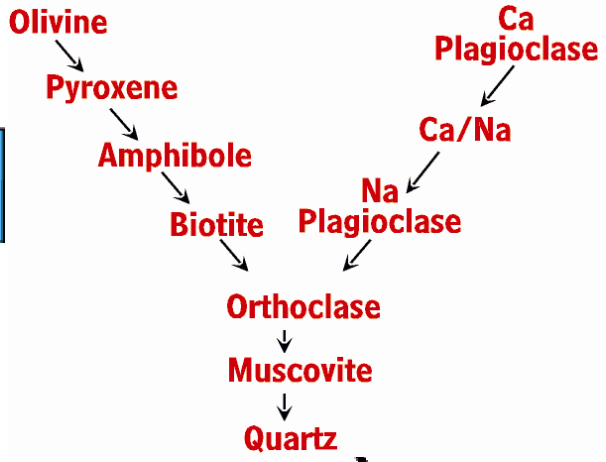
Average Continental Igneous Rock
Granodiorite

Complete Weathering

3 Mixed Weathering Products

Qtz Sand | Clay | Dissol. Calcite

Separation During Transportation



The Simple Ideal Model for the Evolution of Sedimentary Rocks

The Simple Ideal Model for the Evolution of Sedimentary Rocks

http://www.nku.edu/~biosci/CostaRica2003/Punta%20Marenco/Day3/CR%20SanJose%20to%20PM.htm

The Simple Ideal Model for the Evolution of Sedimentary Rocks

wha/photos/elwhamouth.htm

The Simple Ideal Model for the Evolution of Sedimentary Rocks

http://www.serf.tamus.edu/ResearchProjects/TexasInletsOnline/BrazosRiverMouth/Brazos%20River%20Main.htm

The Simple Ideal Model for the Evolution of Sedimentary Rocks

Beach

Near Shelf

Far Shelf

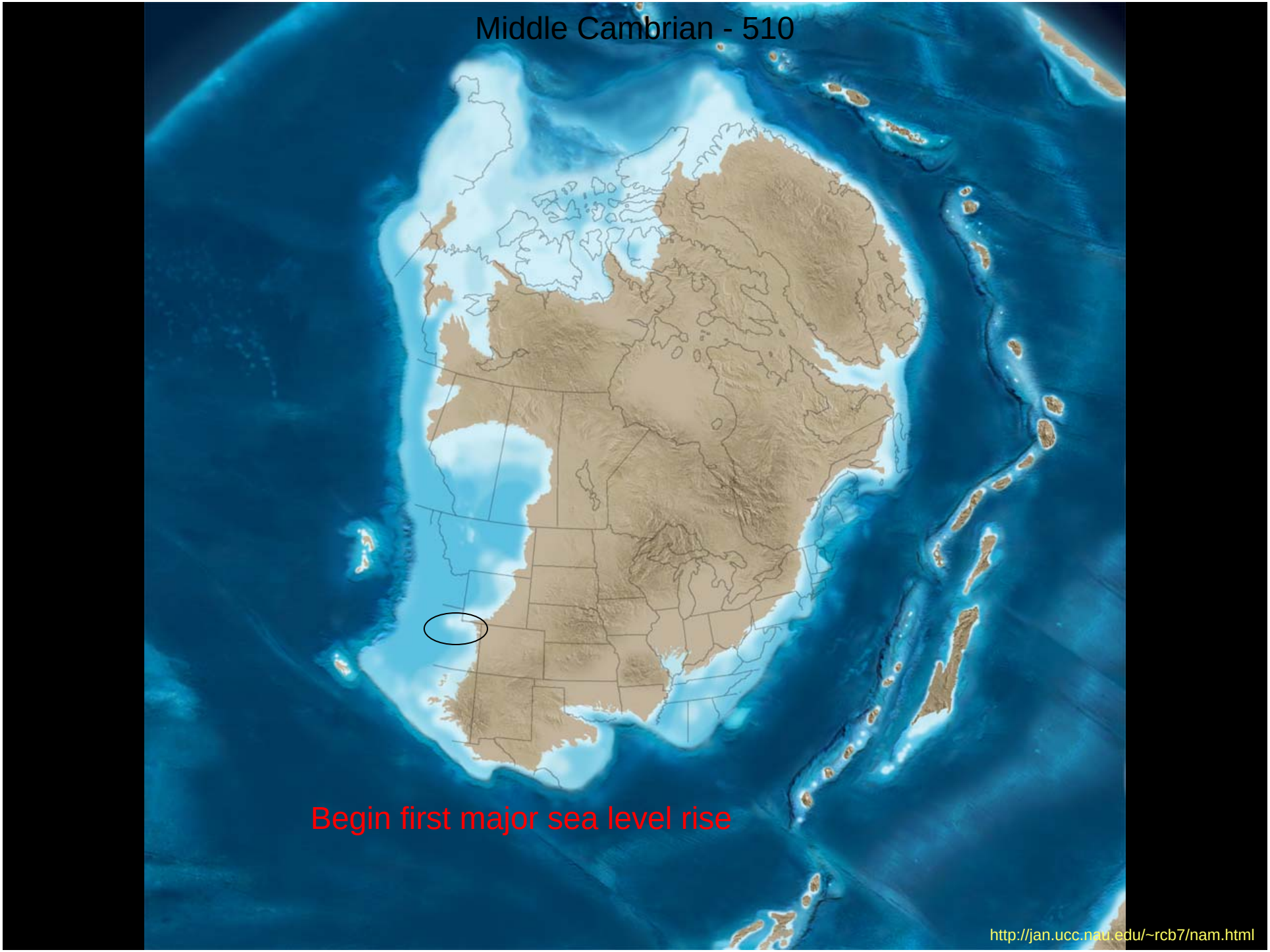
Qtz. Sandstone

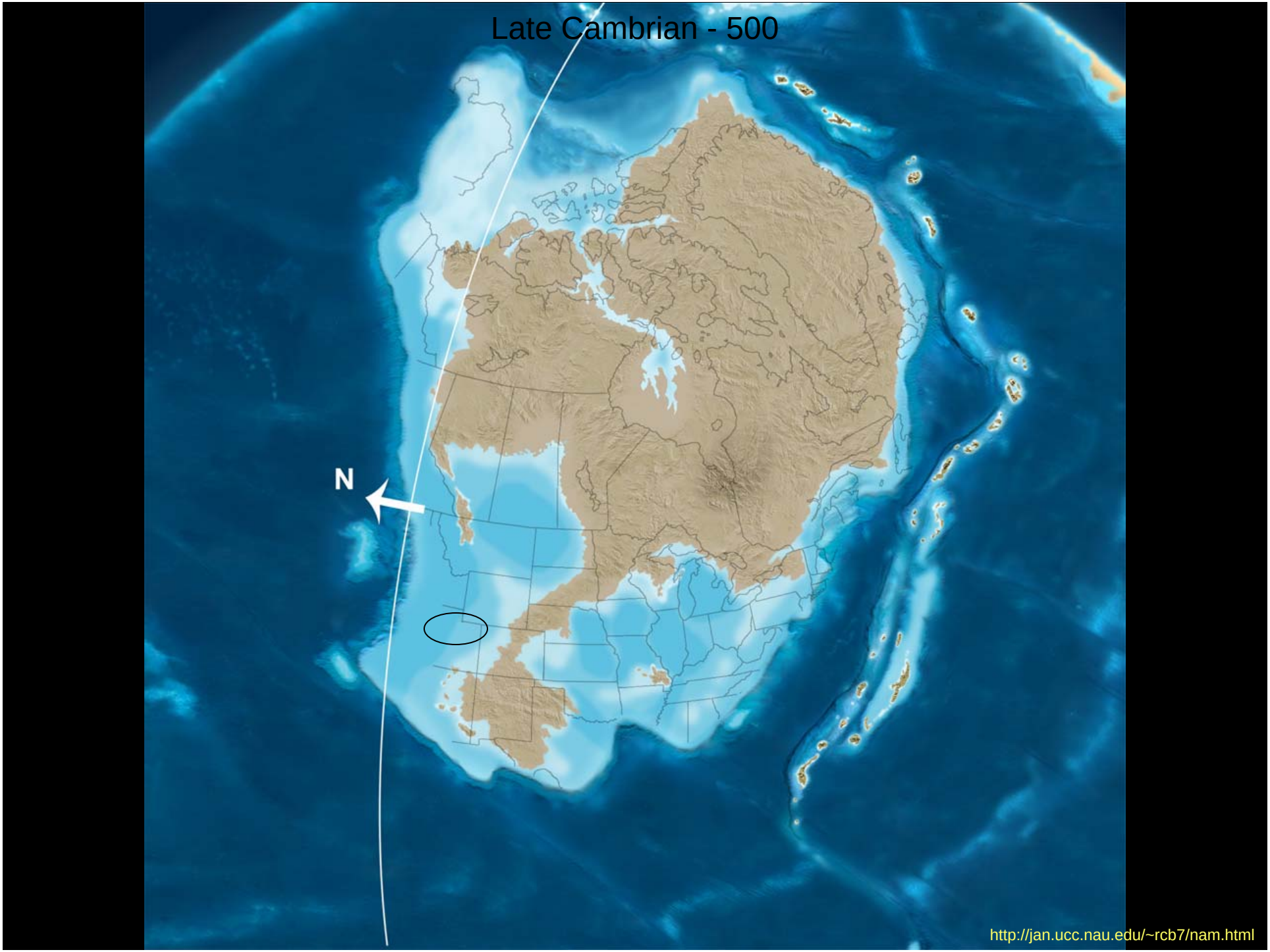
Shale

Limestone

The Simple Ideal Model for the Evolution of Sedimentary Rocks

http://www.serf.tamus.edu/ResearchProjects/TexasInletsOnline/BrazosRiverMouth/Brazos%20River%20Main.htm


Middle Cambrian - 510
Begin first major sea level rise
http://jan.ucc.nau.edu/~rcb7/nam.html


Late Cambrian - 500
N
http://jan.ucc.nau.edu/~rcb7/nam.html


Early Ordovician - 485
Transcontinental Arch
Antietam
http://jan.ucc.nau.edu/~rcb7/nam.html


Weathering
Processes
Ge 04

Weathering

Mechanical Weathering

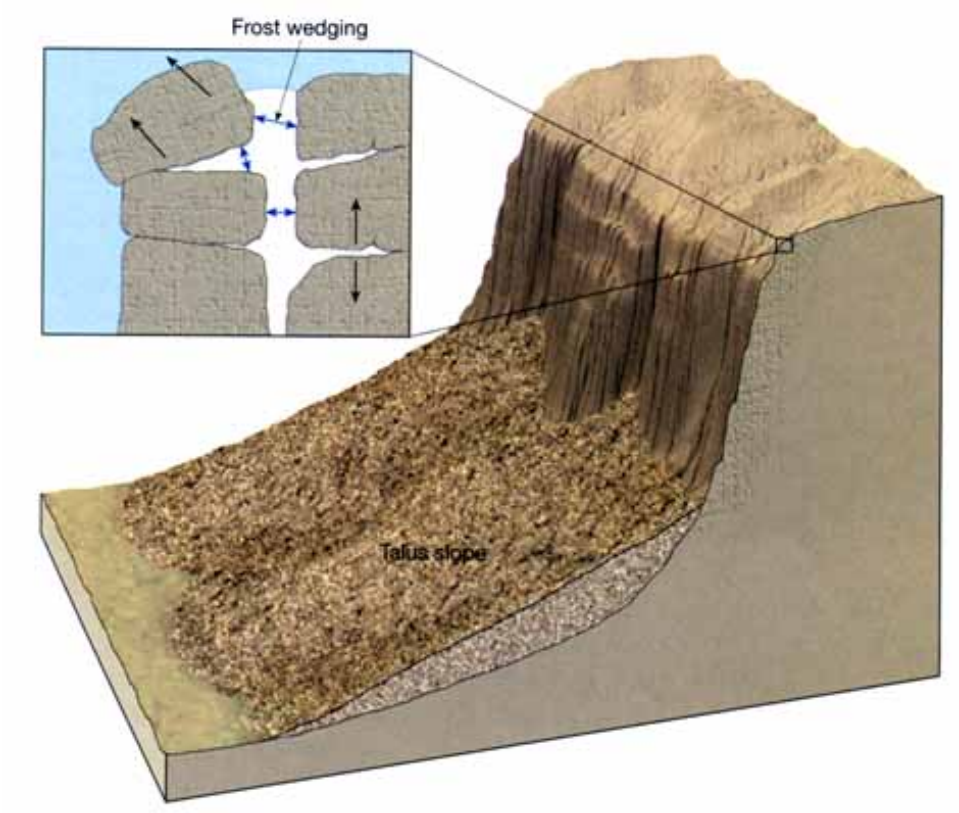
- Making little pieces out of big ones.
- Composition of original rocks does not change.
- Result: lithic fragments

Chemical Weathering

- Original minerals chemically break down.
- Result: formation of new minerals stable at Earth-surface conditions.

Mechanical Weathering

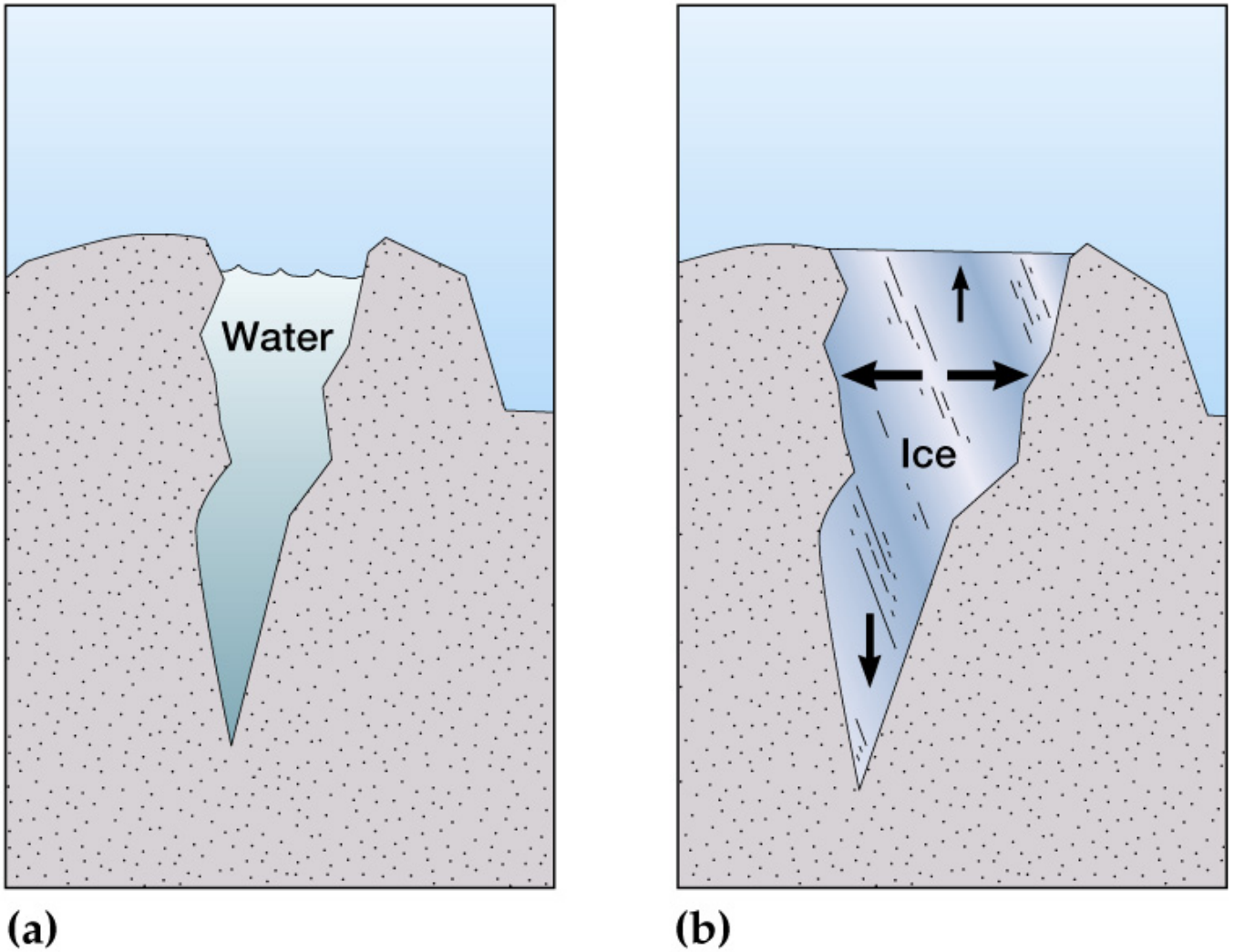
Frost Wedging via Freeze and Thaw



http://faculty.uaeu.ac.ae/~afarrag/physical%20geology/

Mechanical Weathering

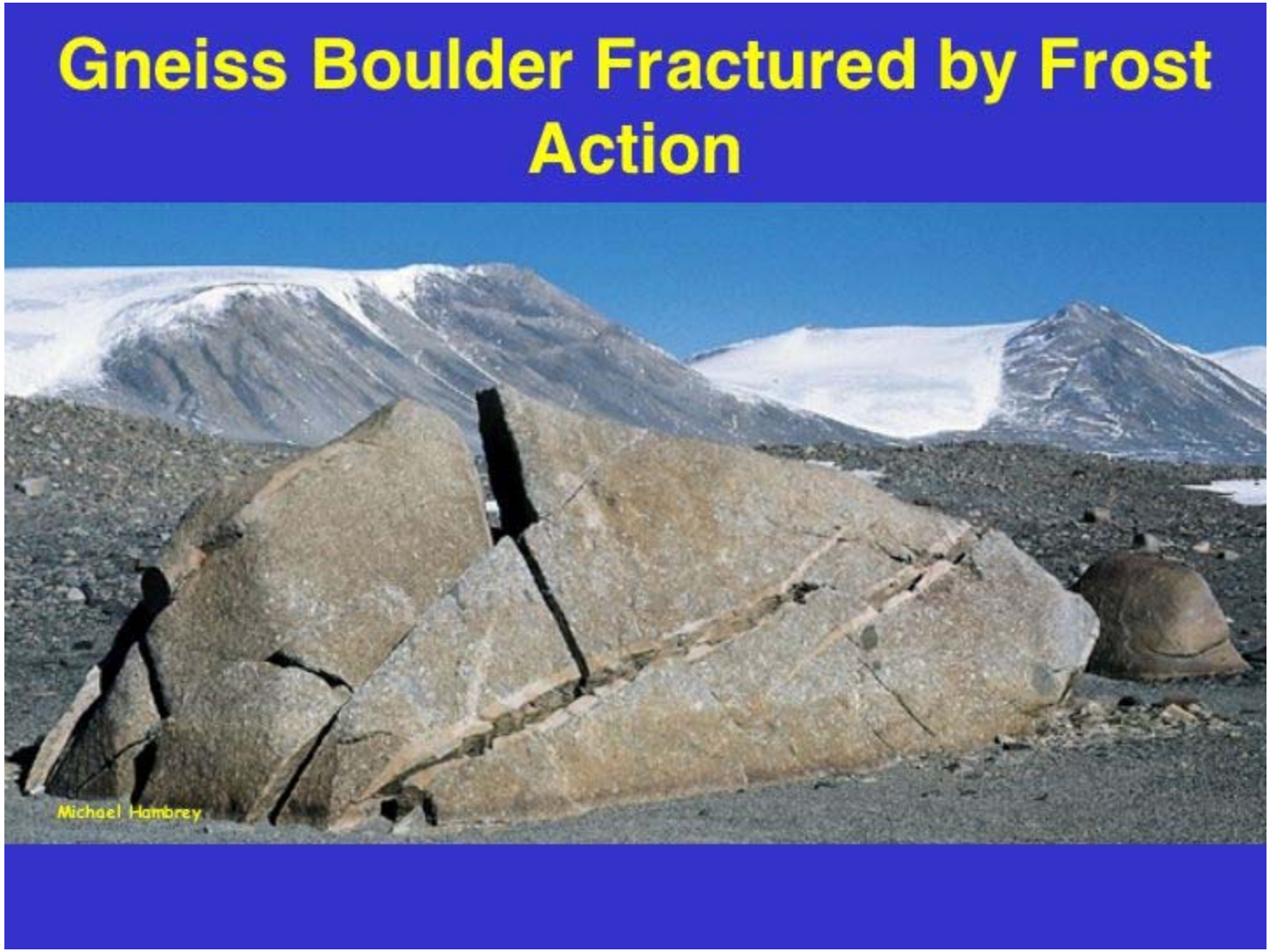
Frost Wedging via Freeze and Thaw



http://www.utexas.edu/depts/grg/hudson/grg301c/hudson_grg_301c/schedule/4_water_geomorph_images/10_weathering/2.htm

Mechanical Weathering

Frost Wedging via Freeze and Thaw



http://www.gly.fsu.edu/%7Esalters/GLY1000/10Weathering_Erosion/Slide27.jpg

Mechanical Weathering

Plant Wedging

http://www3.famille.ne.jp/~kazuo/SR-044.jpg

Mechanical Weathering

Exfoliation

http://www.calstatela.edu/faculty/acolvil/weathering.html

Exfoliation Dome in Yosemite

Weathering

Chemical Weathering

- **Original minerals chemically break down.**
- **Result: formation of new minerals stable at Earth-surface conditions.**

Chemical Weathering
Dissolution

$$CO_2 + H_2O \rightarrow H_2CO_3$$ Carbonic Acid

$$H_2CO_3 \rightarrow H^+ + HCO_3$$

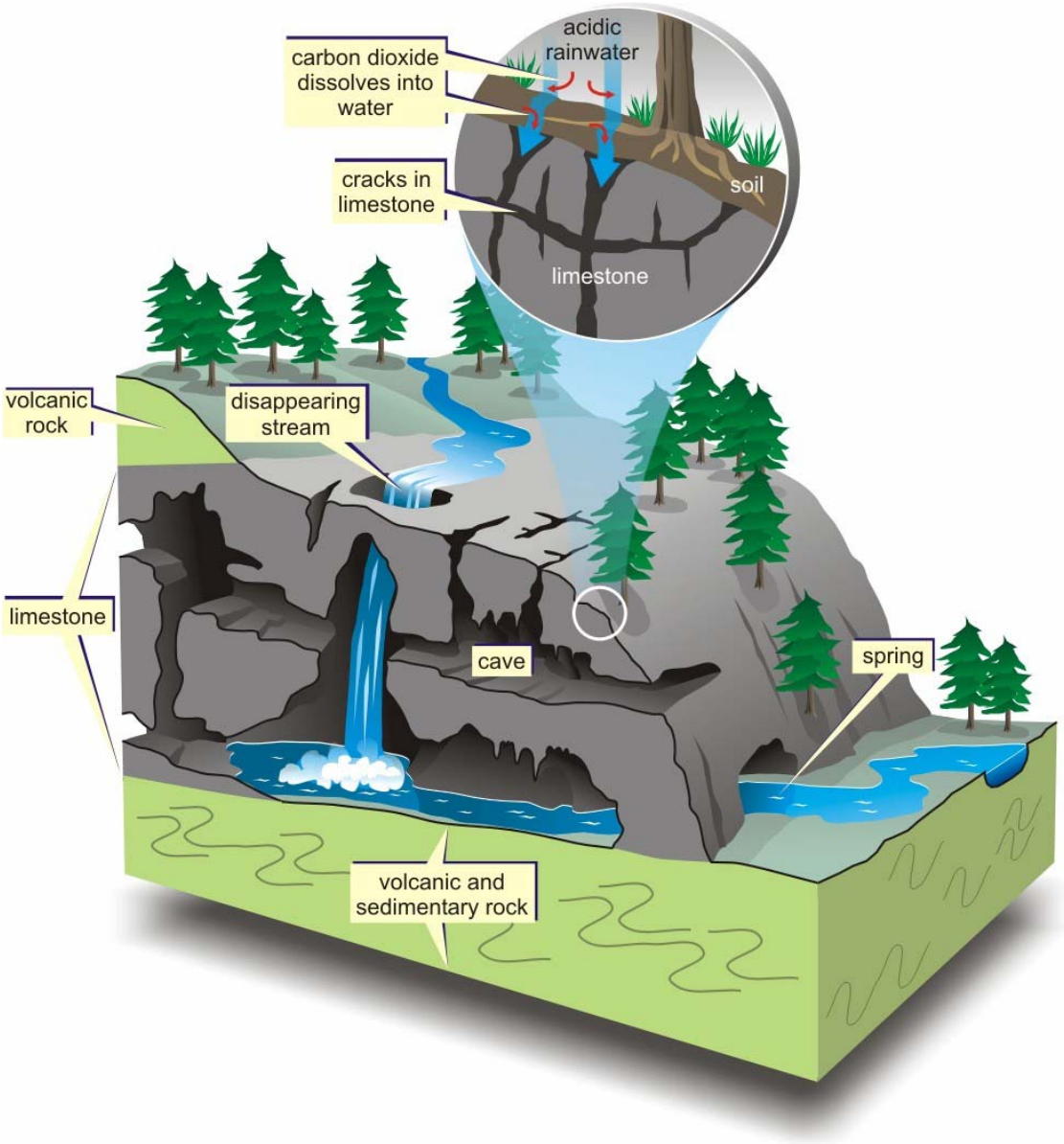
$$CaCO_3 + H^+ \rightarrow Ca^{++} + 2\,HCO_3^-$$

Calcite/Limestone — Dissolved Calcium — Bicarbonate Ion

Chemical Weathering
Dissolution of Limestone

HTTP://EDUTEL.MUSENET.ORG:8042/GRAVENET/IMAGES/CLOSI

Chemical Weathering
Dissolution of Limestone



.BC.CA□GEOSCAPE□KARST.HTM

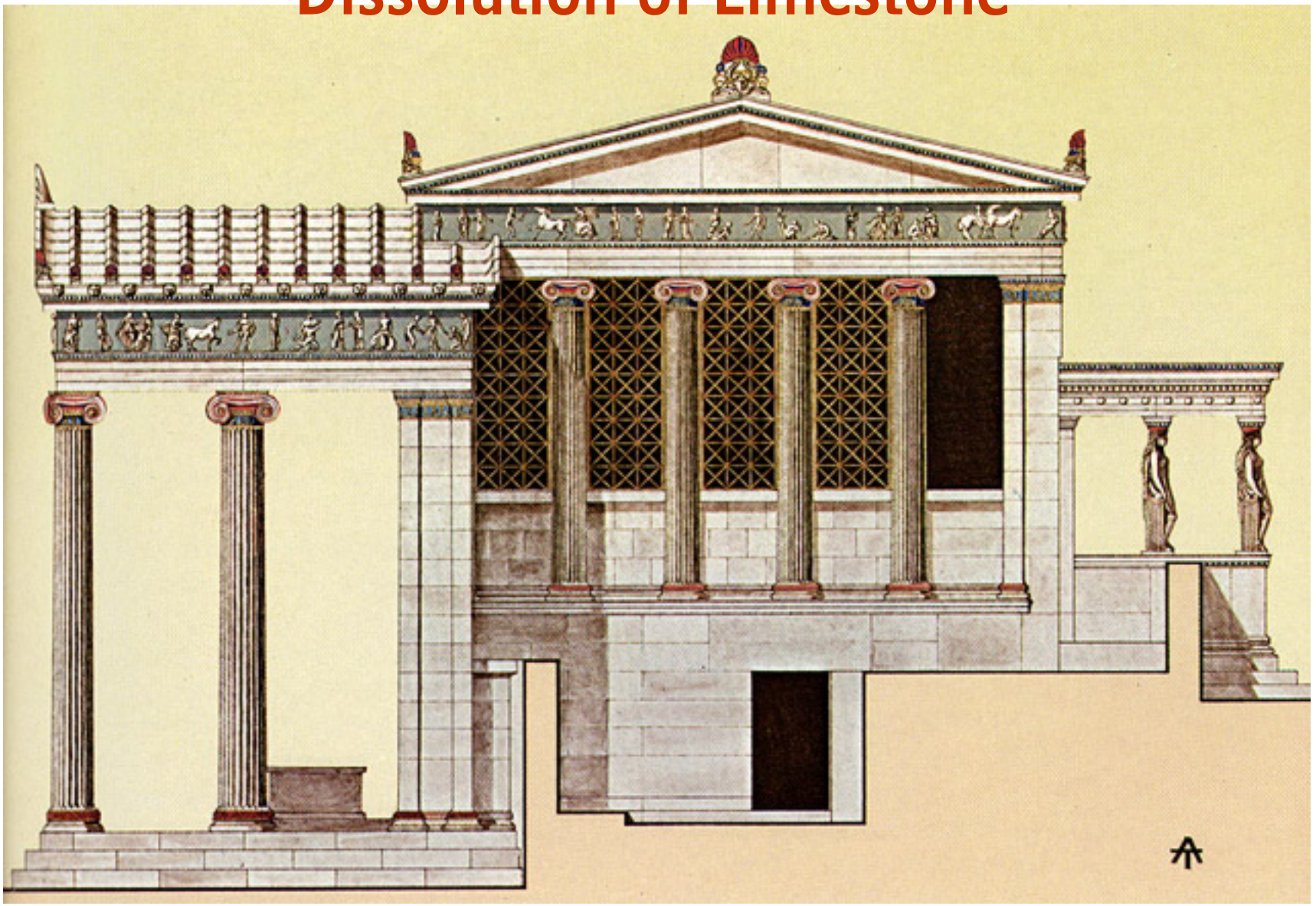
Chemical Weathering
Dissolution of Limestone

http://www.the-spa.com/hanauer/gallery/luray/c

Chemical Weathering
Dissolution of Limestone

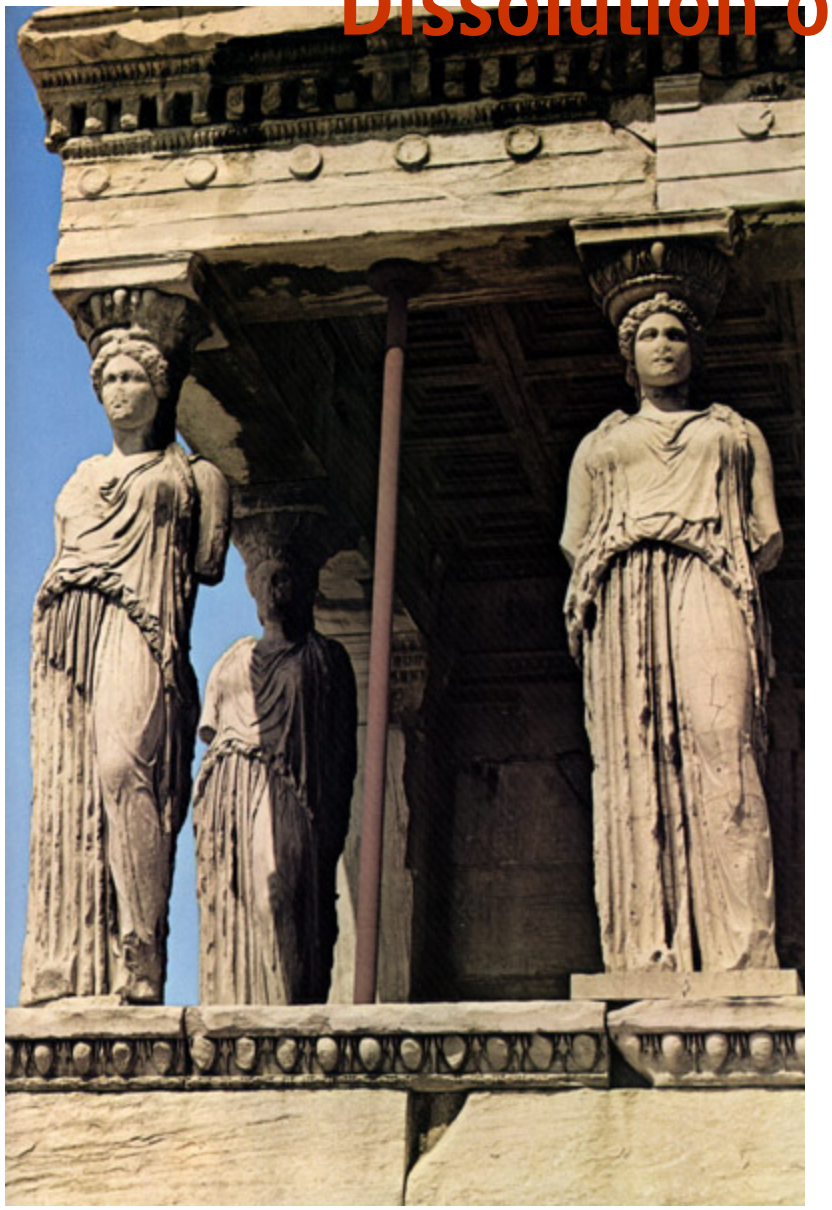
http://firupe.free.fr/Greece/Photo27g/27The_Kai

Chemical Weathering
Dissolution of Limestone



http://www.people.auckland.ac.nz/Frances/Classical%20Art/Classical%20Architect.%20Sc

Chemical Weathering
Dissolution of Limestone



http://www.calvin.edu/academic/clas/pathways/delphi/da

http://www.people.auckland.ac.nz/Frances/Classical%20Art/Classical%20Architect.%20Sculpture/Erechtheion/Karyatids.JPG

Chemical Weathering
Oxidation

$$4\ FeSiO_3 + O_2 + 8\ H_2O \rightarrow 4\ FeO(OH)\cdot n\ H_2O + 4\ SiO_4$$

Pyroxene

Limonite

Goethite

Chemical Weathering

Oxidation

Chemical Weathering

Hydrolysis

$$KAlSi_3O_8 + H_2CO_3 + 12\,H_2O \rightarrow$$

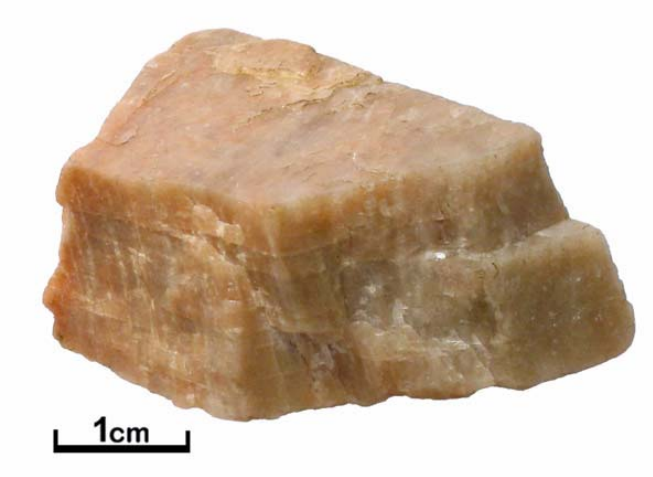
Orthoclase

Dissolved Silica

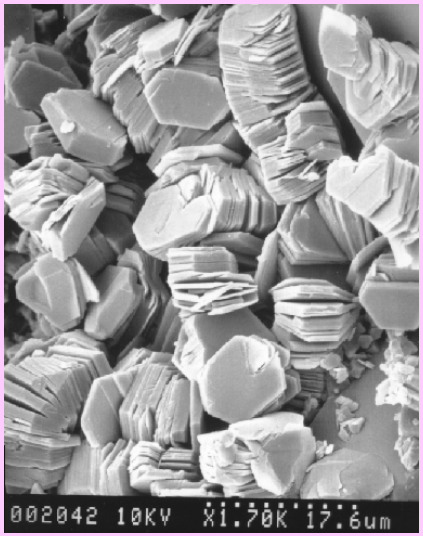
$$2K^+ + 2HCO_3^- + 5H_4SiO^4 +$$

$$+ Al_2Si_2O_5(OH)$$

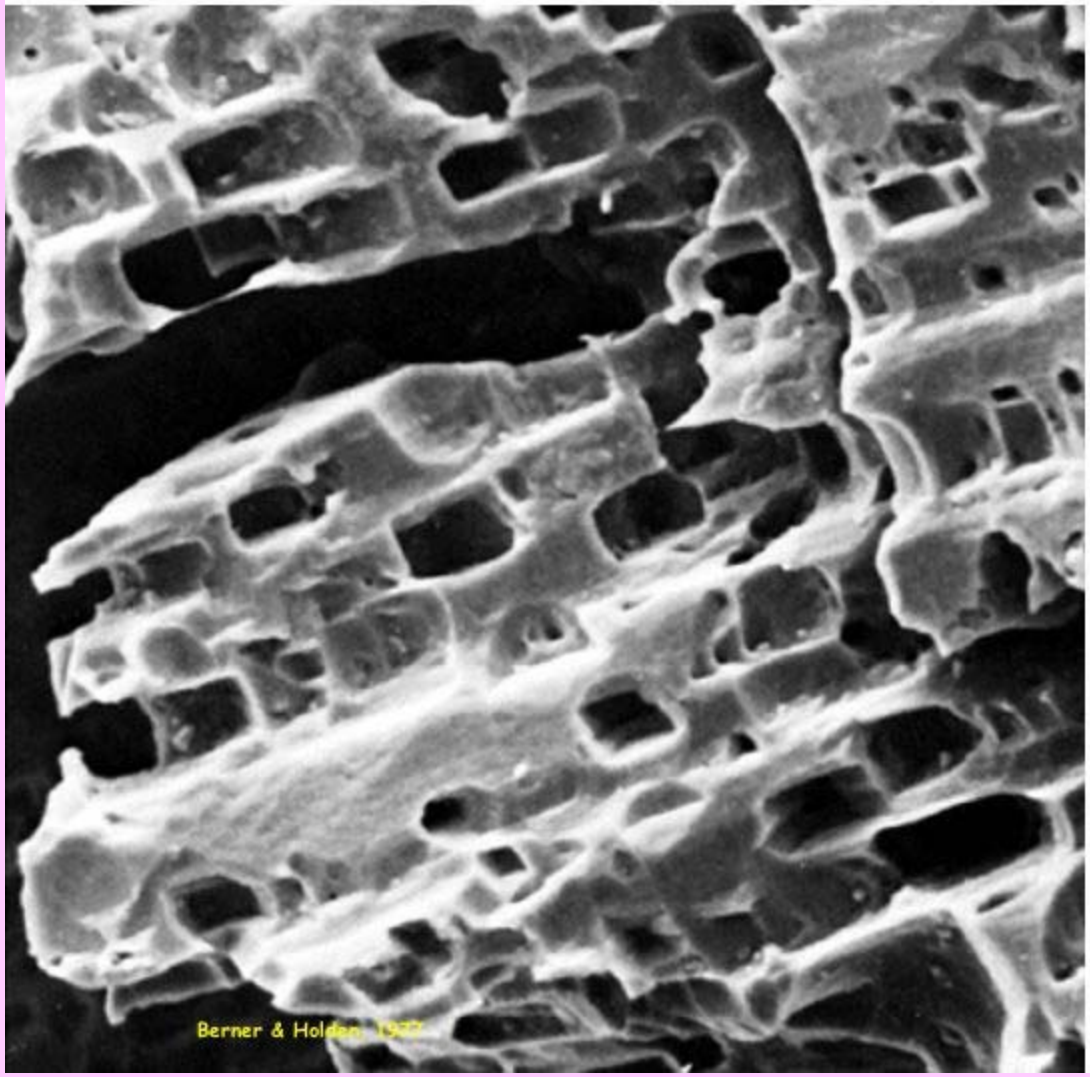
Kaolinite Clay



$KAl_3Si_3O_{10}(OH)$



Chemical Weathering
Hydrolysis



Etched and corroded feldspar in the soil zone

http://faculty.uaeu.ac.ae/~afarrag/physical%20geology/physical5.htm

Chemical Weathering
Hydrolysis

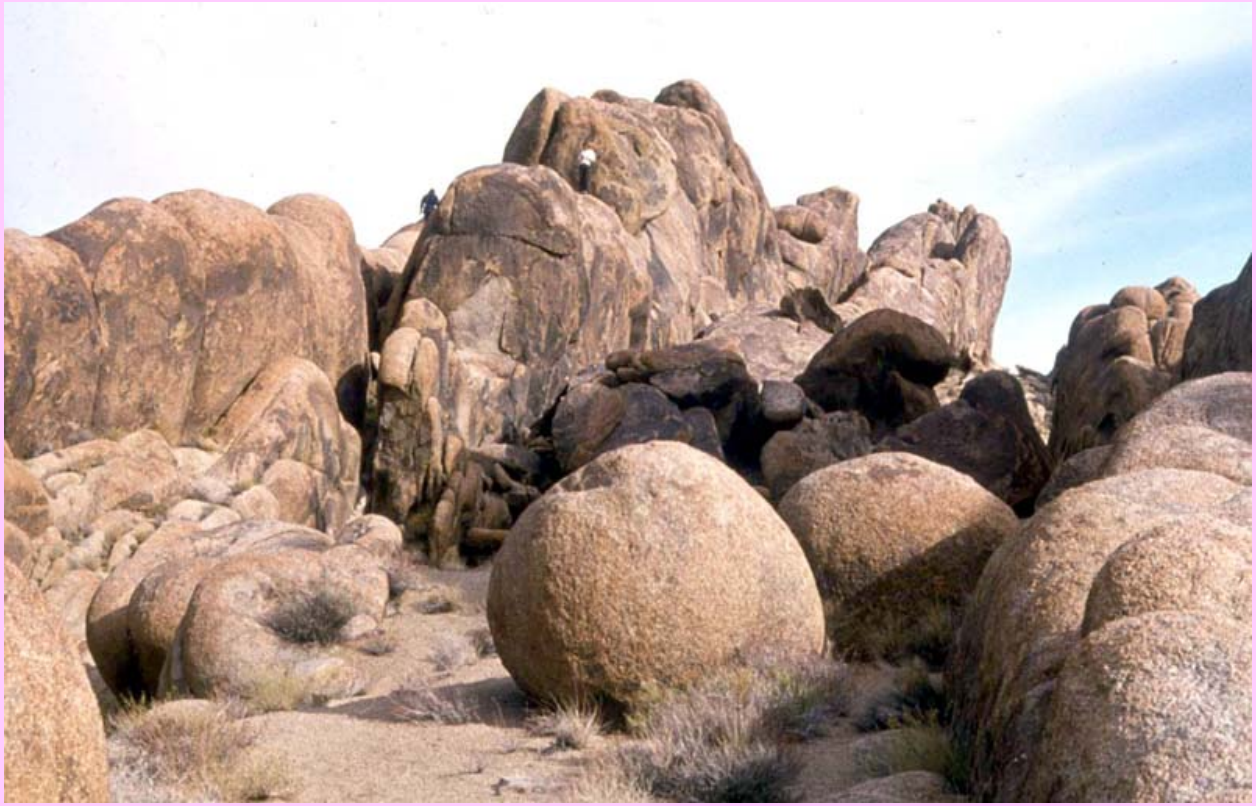
View of the Salisbury Crags sill from the Radical Road. Looking northeast. Spheroidal weathering is best seen in the centre of the image. The field of view is approximately 4 m.

http://www.earthsci.gla.ac.uk/Holyrood7/Images/glacial/spweath.jpg

Chemical Weathering
Hydrolysis

http://epswww.unm.edu/facstaff/gmeyer/eps481/images/corestones.jpg

Chemical Weathering
Hydrolysis



http://www.calstatela.edu/faculty/acolvil/weathering/spheroidal2.jpg

Mobility of Weathering Products

Very Mobile **Ca > Na > Mg > K > Si > Fe > Al** **Immobile**

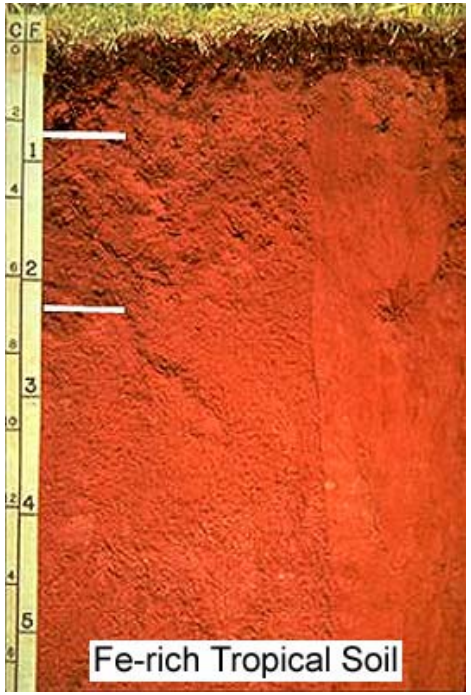
This provides the differences needed for fractionation and evolution to take place.

Mobility of Weathering Products

A Chemical Fractionation Process

Very Mobile **Ca > Na > Mg > K > Si > Fe > Al** **Immobile**

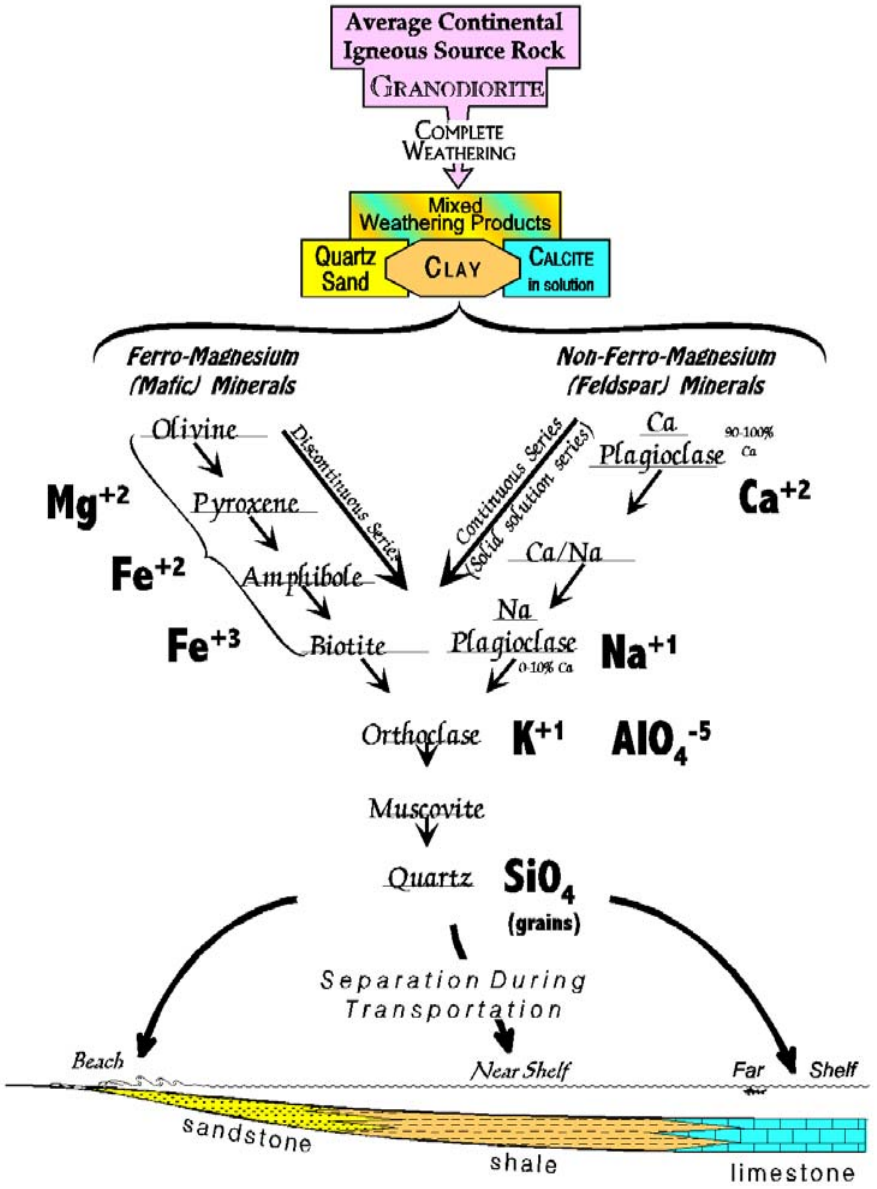
Bauxite



Laterite Soil

The Fractionation of Sedimentary Rocks Through Weathering and Transportation

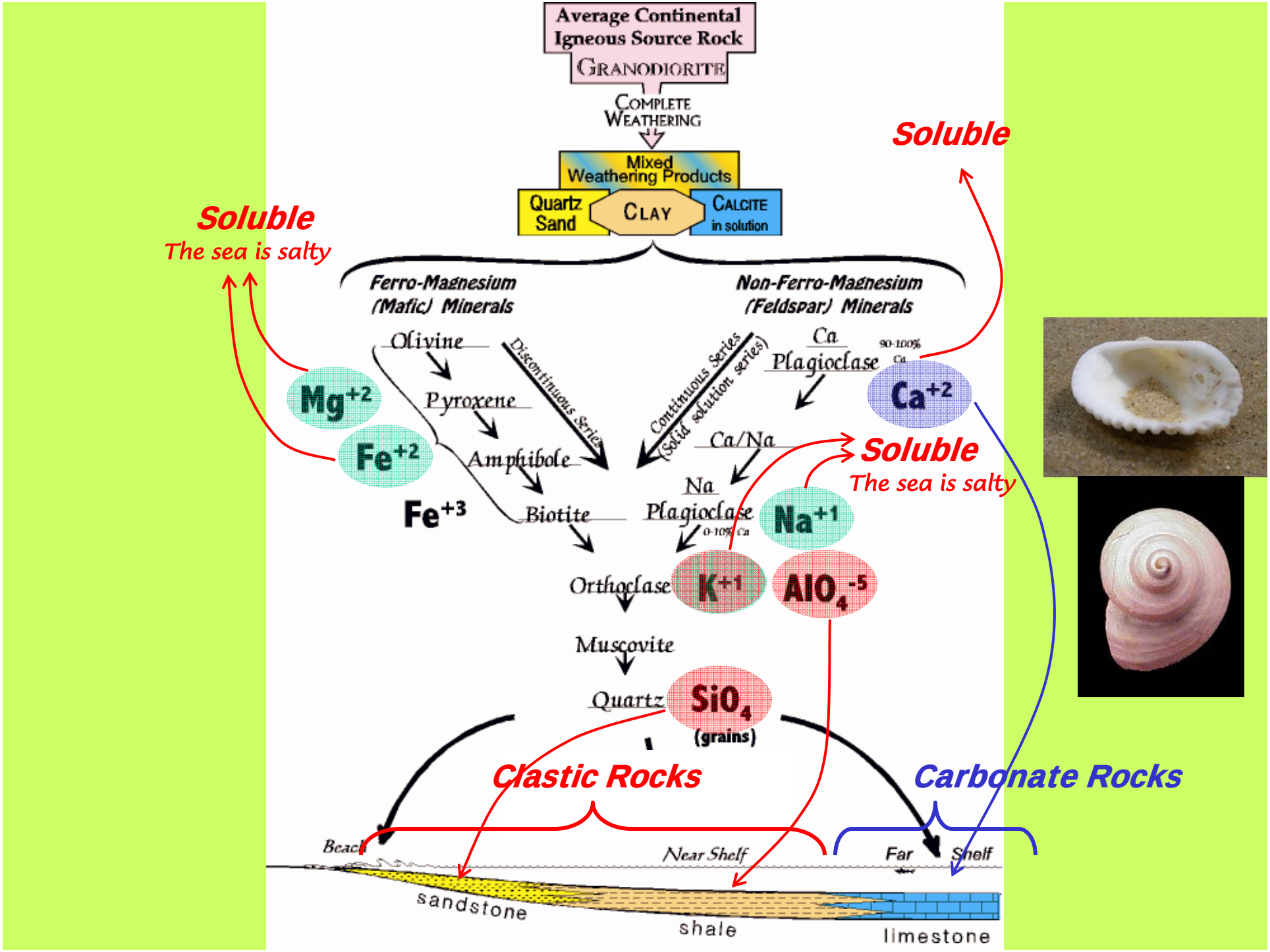
Basic Question: Compared to the igneous rocks they started as, is the composition of a clastic sedimentary rock higher on the reactions series, lower on the reactions series, or at the same place?



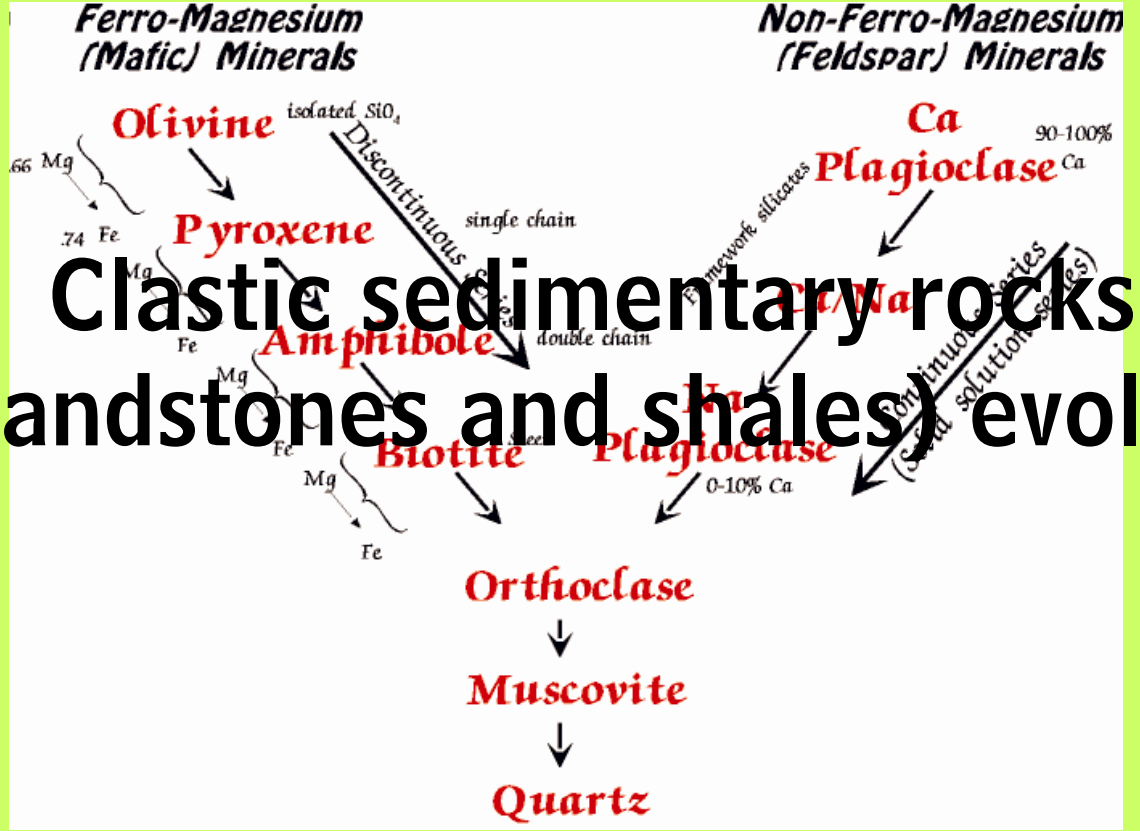
The Fractionation of Sedimentary Rocks

Through Weathering and Transportation

Basic Question: Compared to the igneous rocks they started as, is the composition of a clastic sedimentary rock higher on the reaction series, lower on the reaction series, or at the same place?


Average Continental Igneous Source Rock
GRANODIORITE
COMPLETE WEATHERING
Mixed Weathering Products
Quartz Sand
CLAY
CALCITE in solution
Soluble
The sea is salty
Soluble
Ferro-Magnesium (Mafic) Minerals
Non-Ferro-Magnesium (Feldspar) Minerals
Olivine
Pyroxene
Amphibole
Biotite
Discontinuous Series
Continuous Series (Solid solution series)
Ca Plagioclase
90-100% Ca
Ca/Na
Na Plagioclase
0-10% Ca
Orthoclase
Muscovite
Quartz
Mg+2
Fe+2
Fe+3
Ca+2
Na+1
K+1
AlO4-5
SiO4
(grains)
Soluble
The sea is salty
Clastic Rocks
Carbonate Rocks
Beach
Near Shelf
Far Shelf
sandstone
shale
limestone

Basic Question: compared to the igneous rocks they started as, is the composition of a clastic sedimentary rocks higher on the reaction series, lower on the reaction series, or at the same place?



Clastic sedimentary rocks (sandstones and shales) evolve.


Fates of
Weathering
Products
Ge 04

The Simple Ideal Model for the Evolution of Sedimentary Rocks

Average Continental Igneous Rock

Granodiorite

Complete Weathering

Mixed Weathering Products

Qtz Sand

Clay

Calcite

Separation During Transportation

Beach

Near Shelf

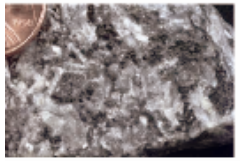
Far Shelf

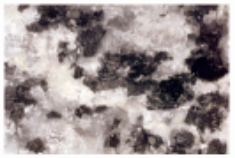
Sandstone

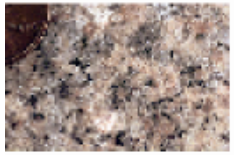
Shale

Limestone

Igneous Rocks, Their Weathering Products and Evolution

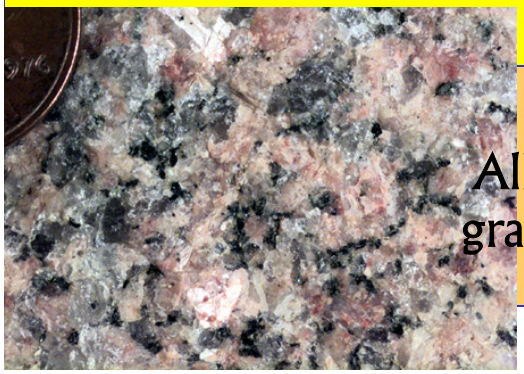






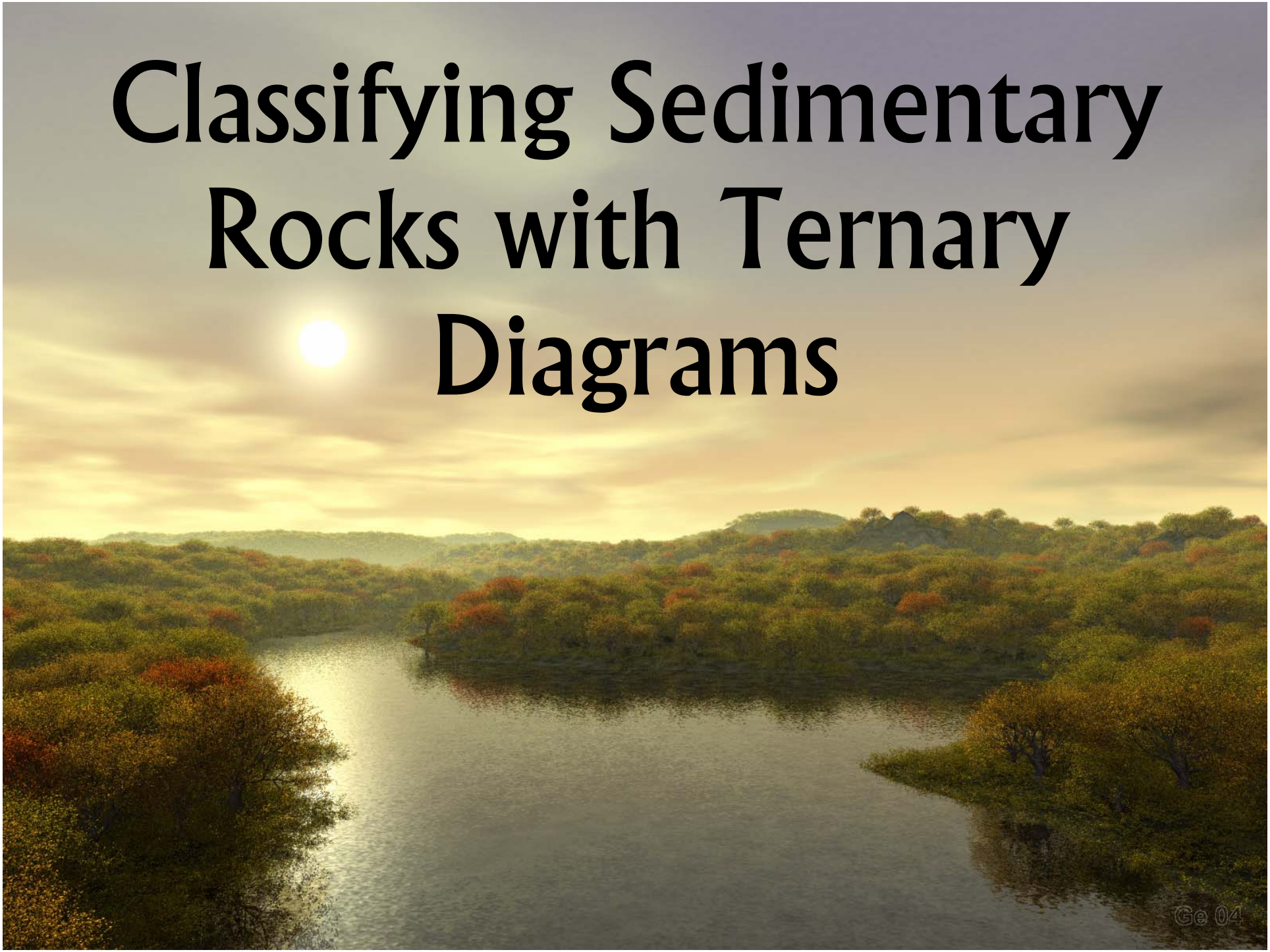
Rock	Mineral	Specimen	Cation	Weathering Product	Specimens	Sedimentary Outcome
Gabbro	Olivine		Fe, Mg	Hematite/ Limonite		Stains (yellow, brown, red)
	Pyroxene					
	Ca Plagioclase		Ca	$CaCO_3$		Limestone
				$CaSO_4$		Gypsum
Diorite	Amphibole		Fe, Mg	Hematite/ Limonite		Stains (yellow, brown, red)
	Na Plagioclasse		Na	NaCl halite		Rock Salt
Alkali-granite	Orthoclase		K	Kaolinite		Clay (shale)
	Quartz		Quartz	Quartz		Sand grains

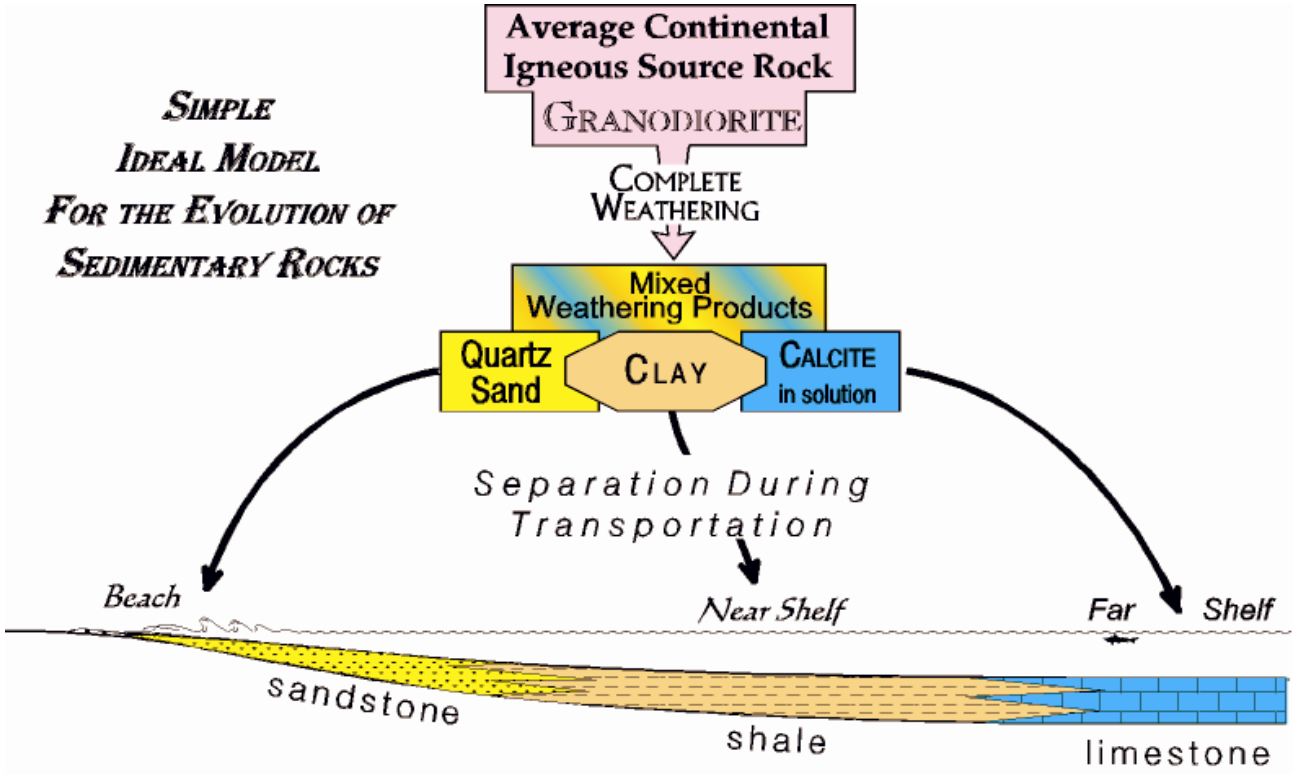
Weathering of Igneous Rocks



Rock	Mineral	Cation	Weathering Produce	Sedimentary Outcome
Gabbro	Olivine	Fe Mg	Hematite/ Limonite	Stains (yellow, brown, red)
	Pyroxene			
	Ca plagioclase	Ca	$CaCO_3$ calcite	Limestone
			$CaSO_4$ gypsum	Gypsum
Diroite	Amphibole	Fe Mg	Hematite/ Limonite	Stains (yellow, brown, red)
	Na plagioclase	Na	NACl halite	Rock Salt
Alkali granite	Orthoclase	K	Kaolinite	Clay/ Shale
	Quartz	Quartz	Quartz	Sand grains

Classifying Sedimentary Rocks with Ternary Diagrams

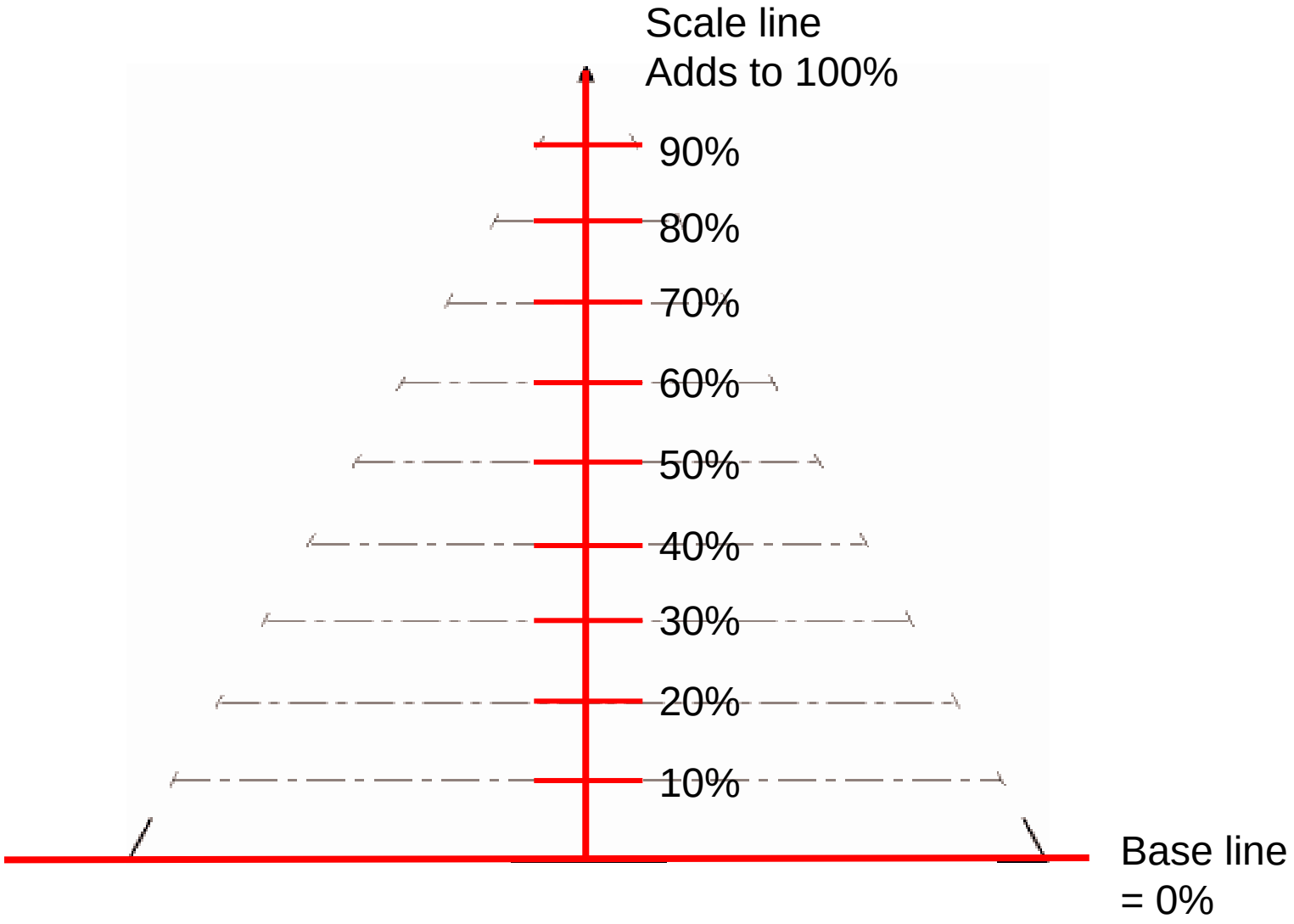




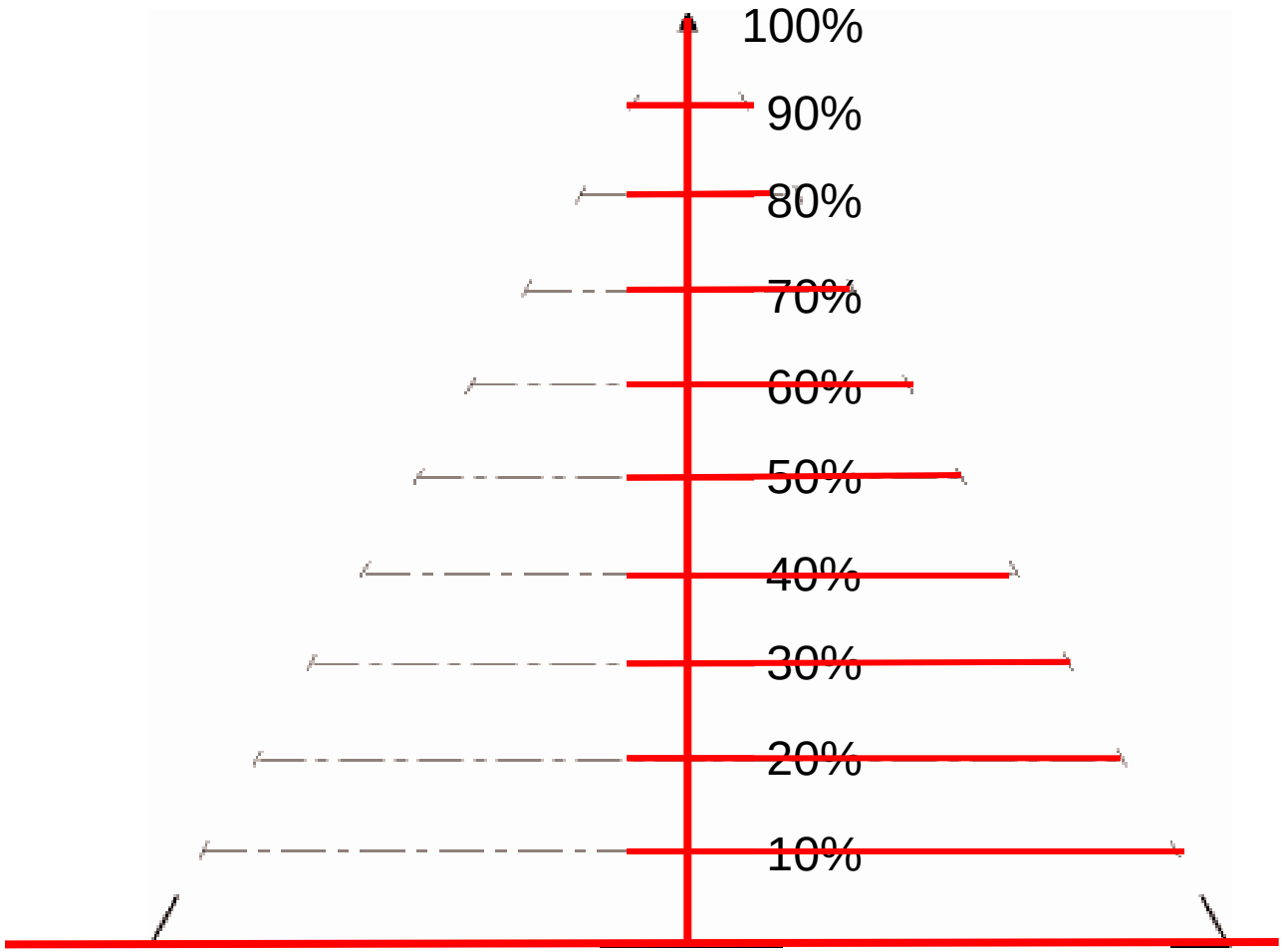
The Simple Ideal Model for sedimentary rocks results in three end members: quartz sand, clay, and calcite in solution.

Things show up in threes a lot when we look at the Earth, and many classifications are based on threes – that is a triangular (or ternary) diagram.

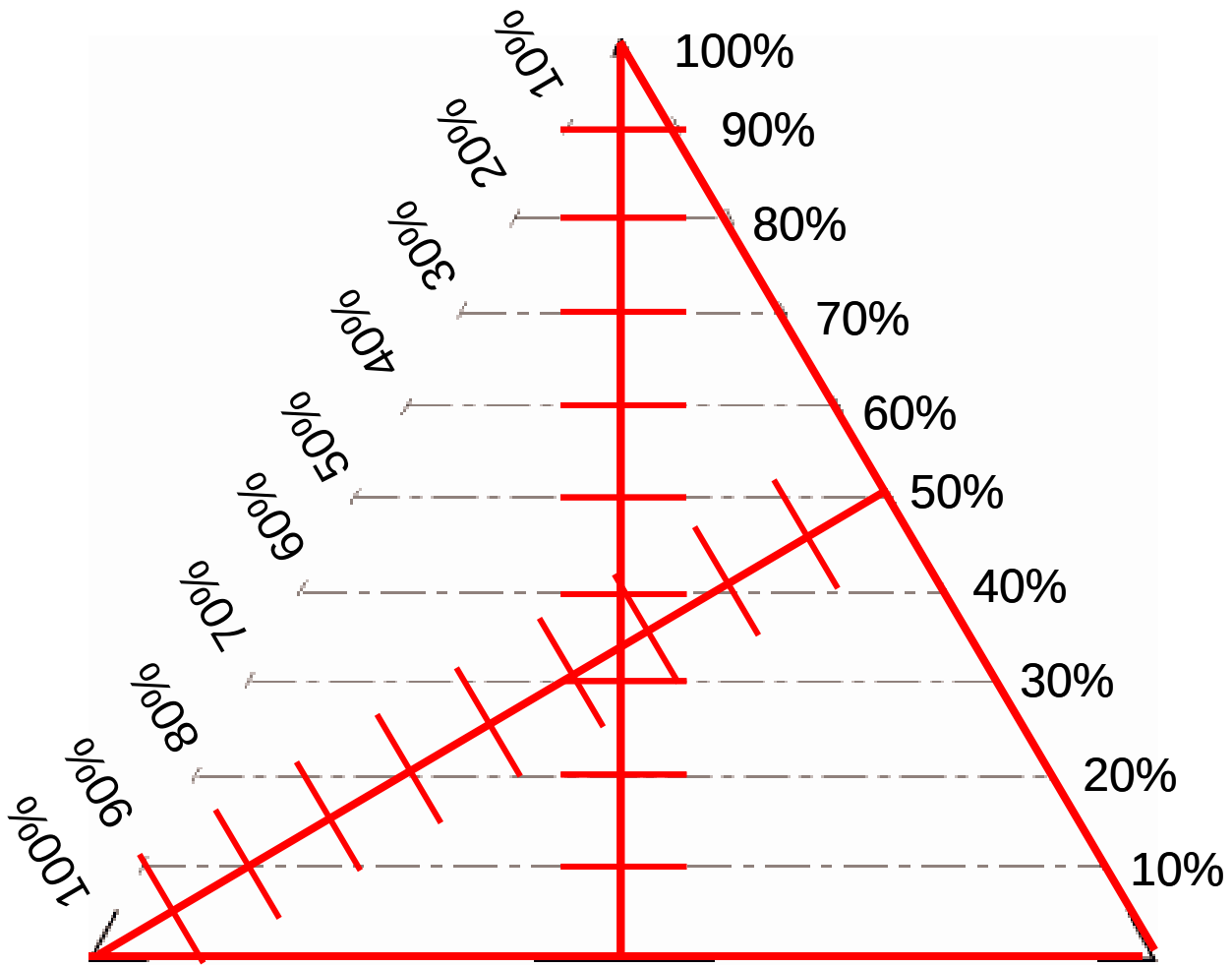
Reading Ternary Diagrams



Reading Ternary Diagrams

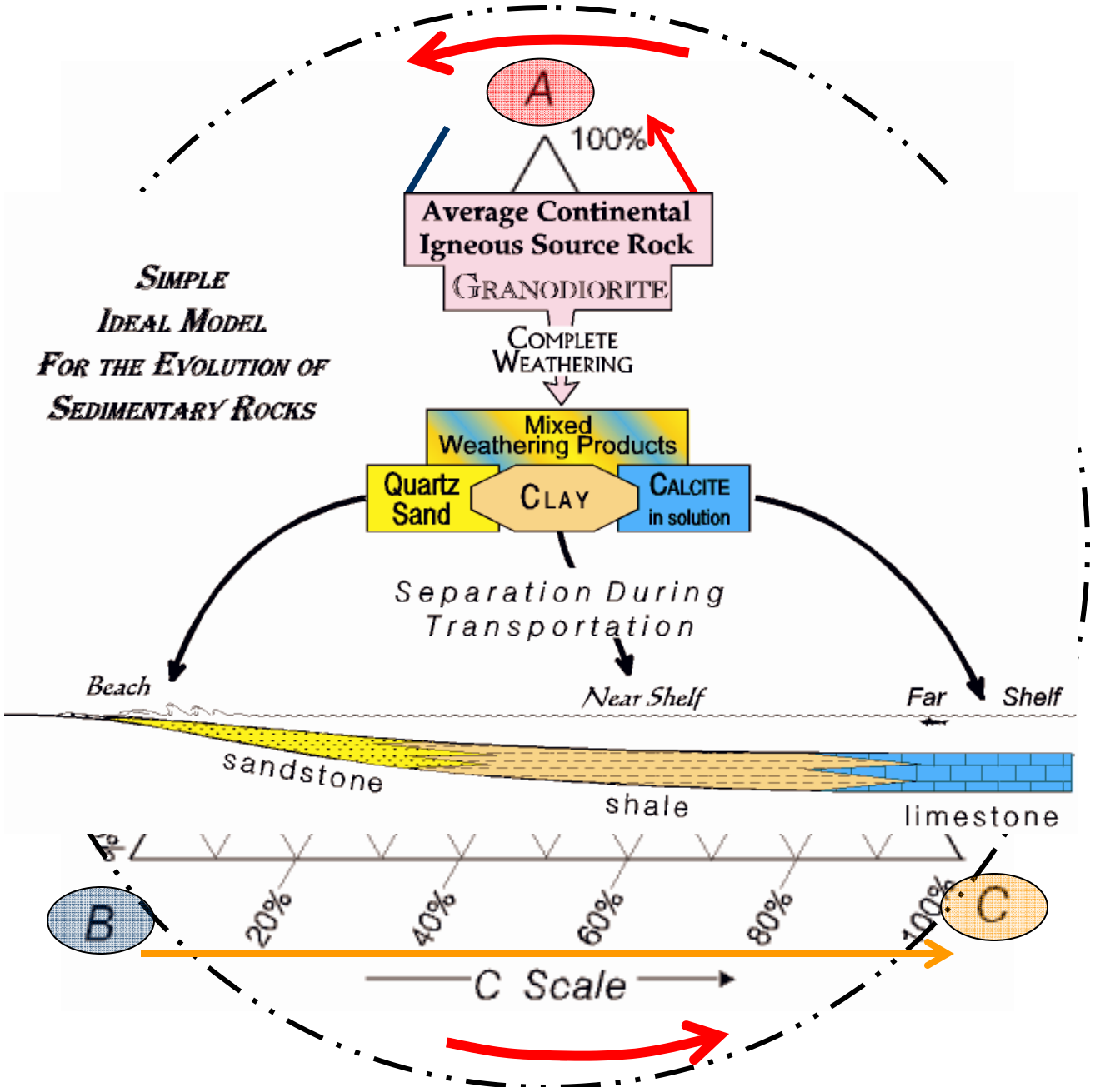


Reading Ternary Diagrams



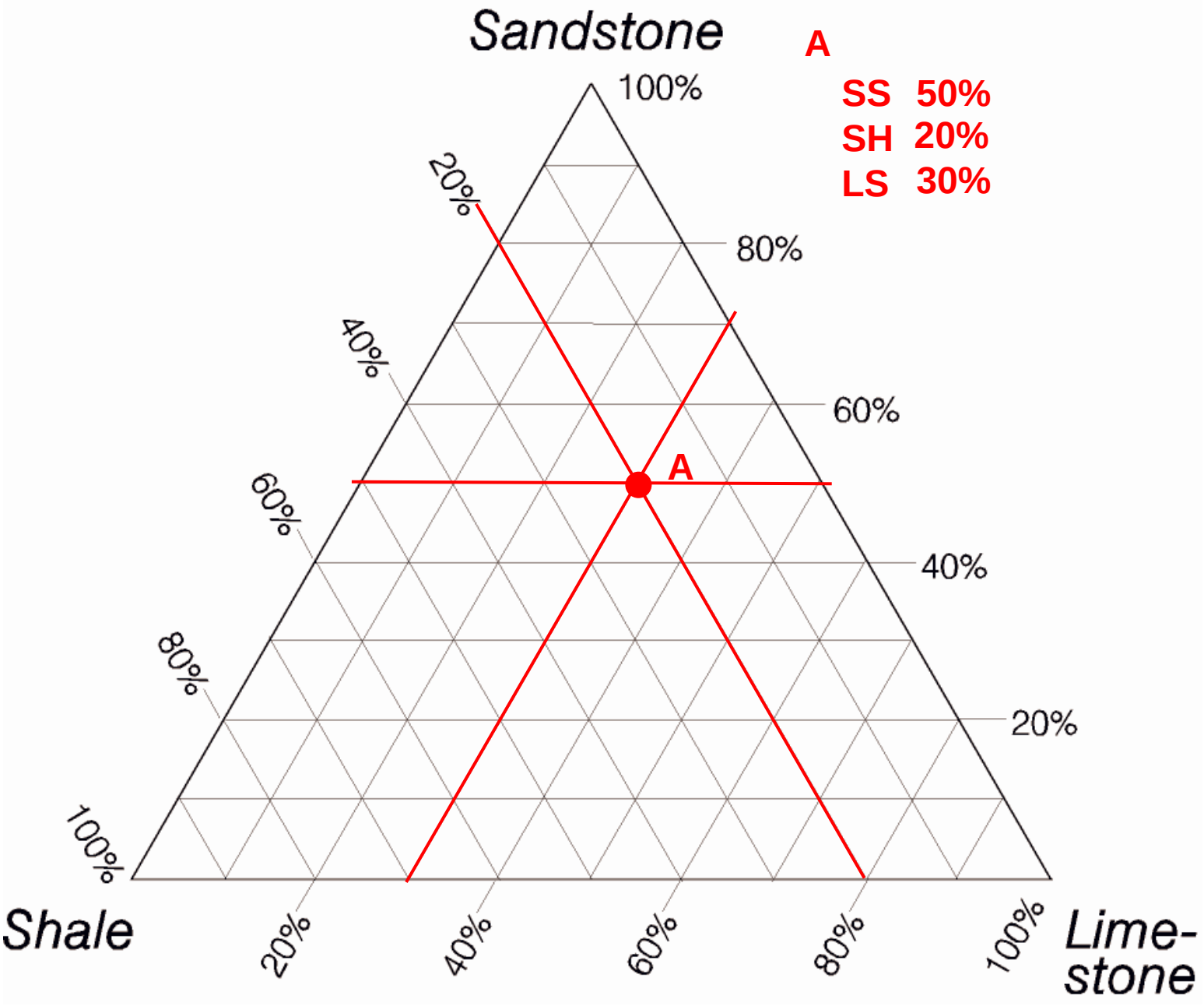
Reading Ternary Diagrams

P 131

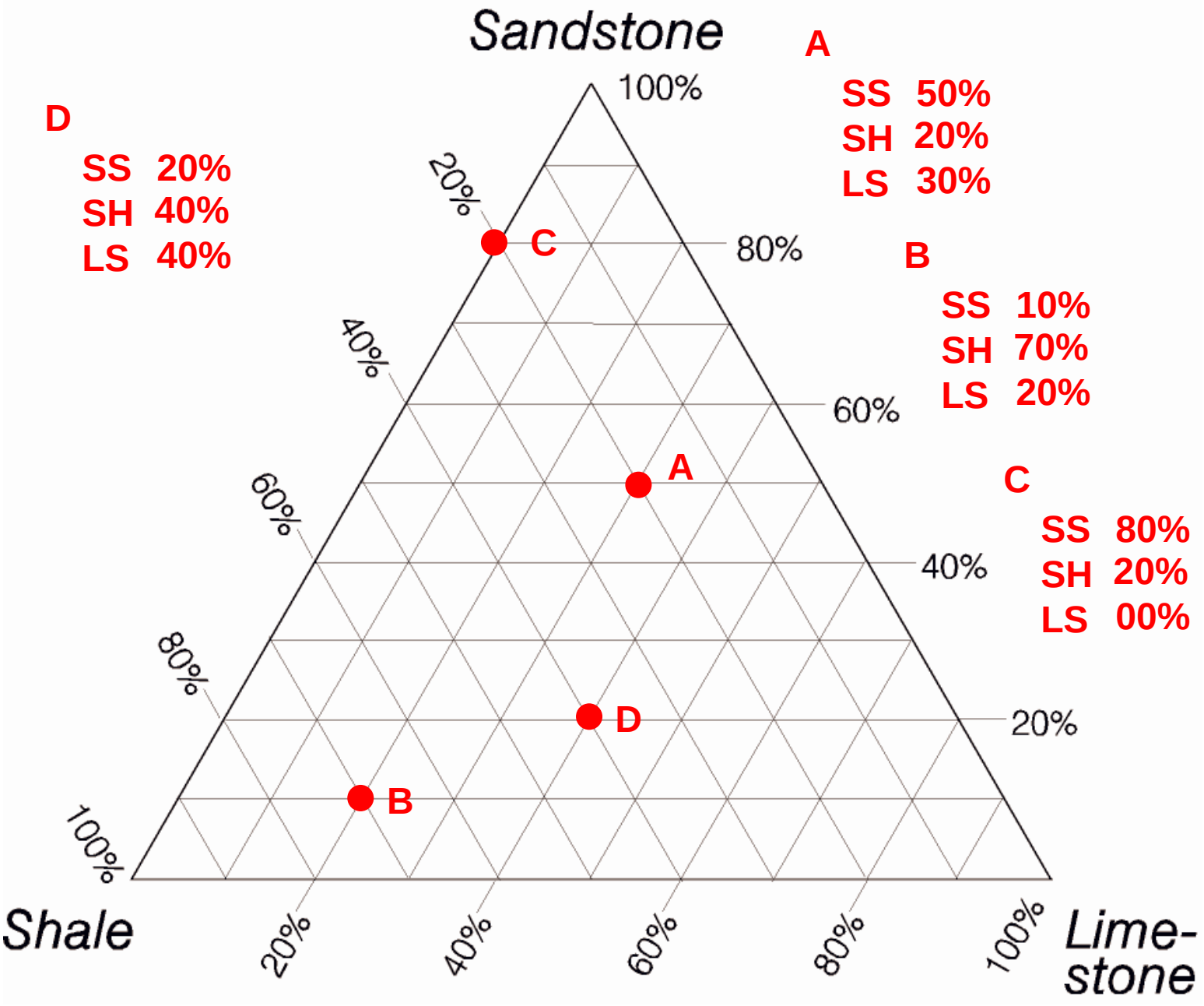


SIMPLE IDEAL MODEL FOR THE EVOLUTION OF SEDIMENTARY ROCKS

Reading Ternary Diagrams



Reading Ternary Diagrams



Naming Sedimentary Rocks

A

SS 50%
SH 20%
LS 30%

Shaley-limey Sandstone

B

SS 10%
SH 70%
LS 20%

Sandy-limey Shale

C

SS 80%
SH 20%
LS 00%

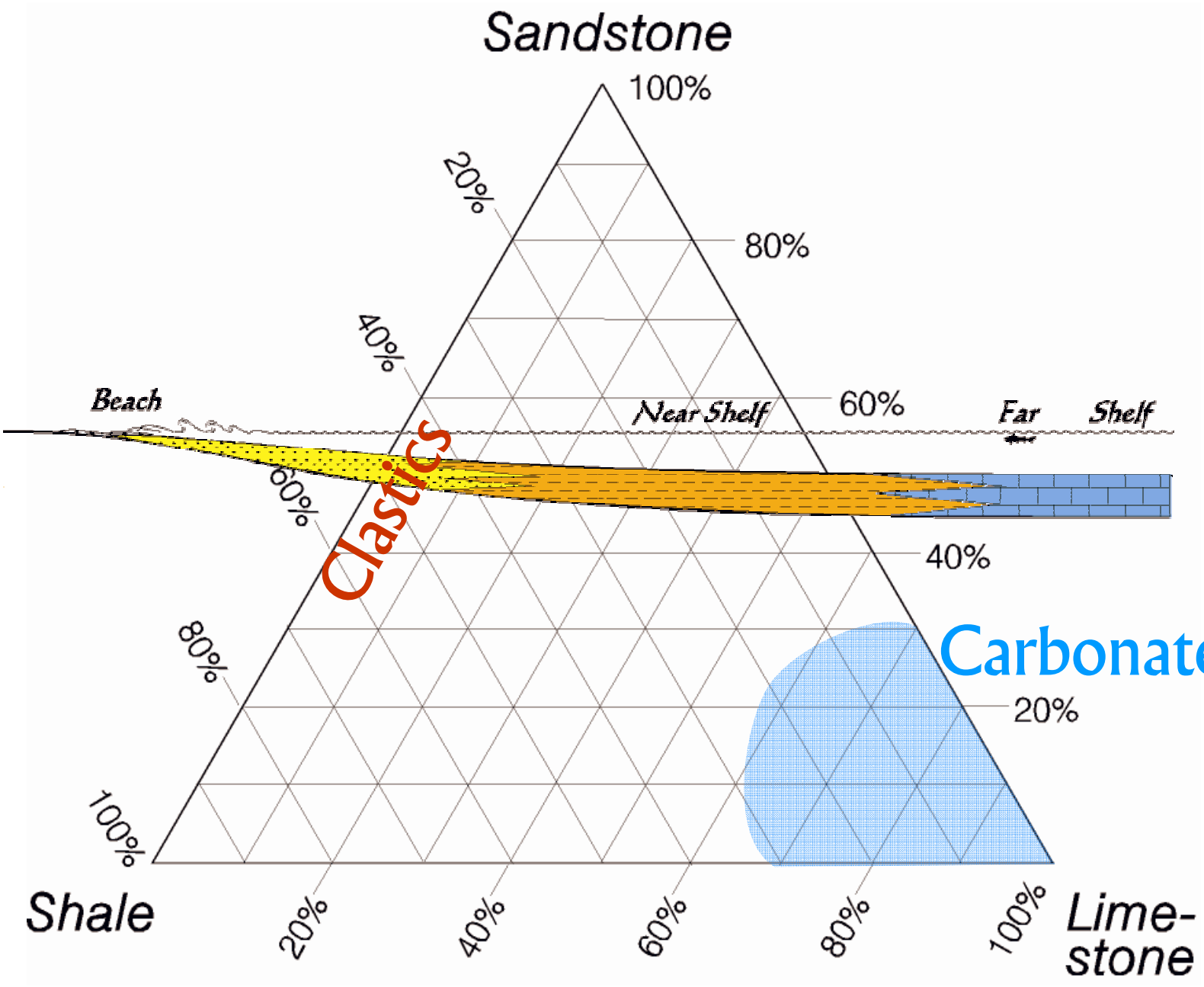
Shaley Sandstone

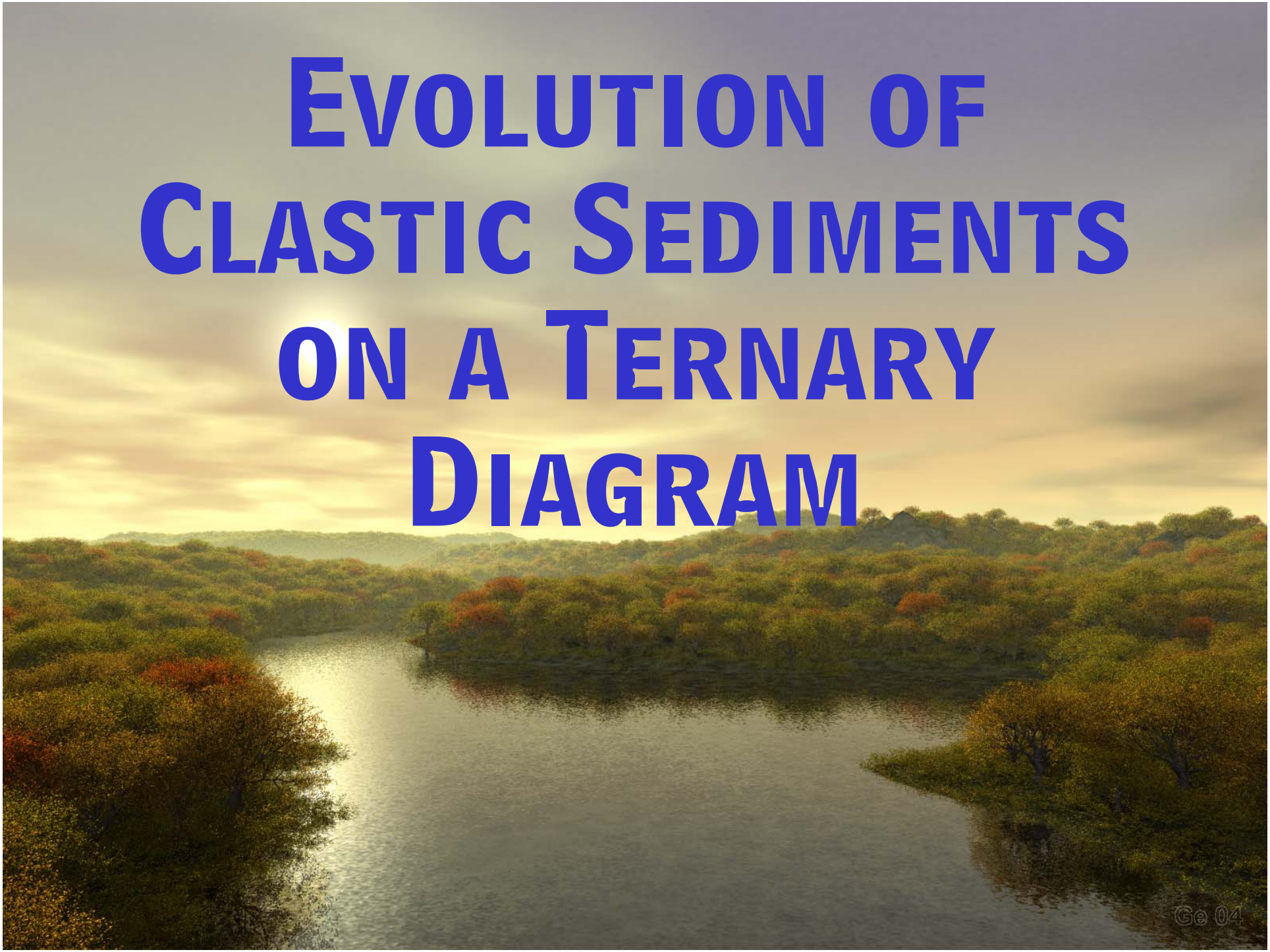
D

SS 20%
SH 40%
LS 40%

Sandy-shaley Limestone

Sedimentary Rock Classification




Evolution of
Clastic Sediments
on a Ternary
Diagram
Ge 04

Sediment Evolution on a Ternary Diagram

1

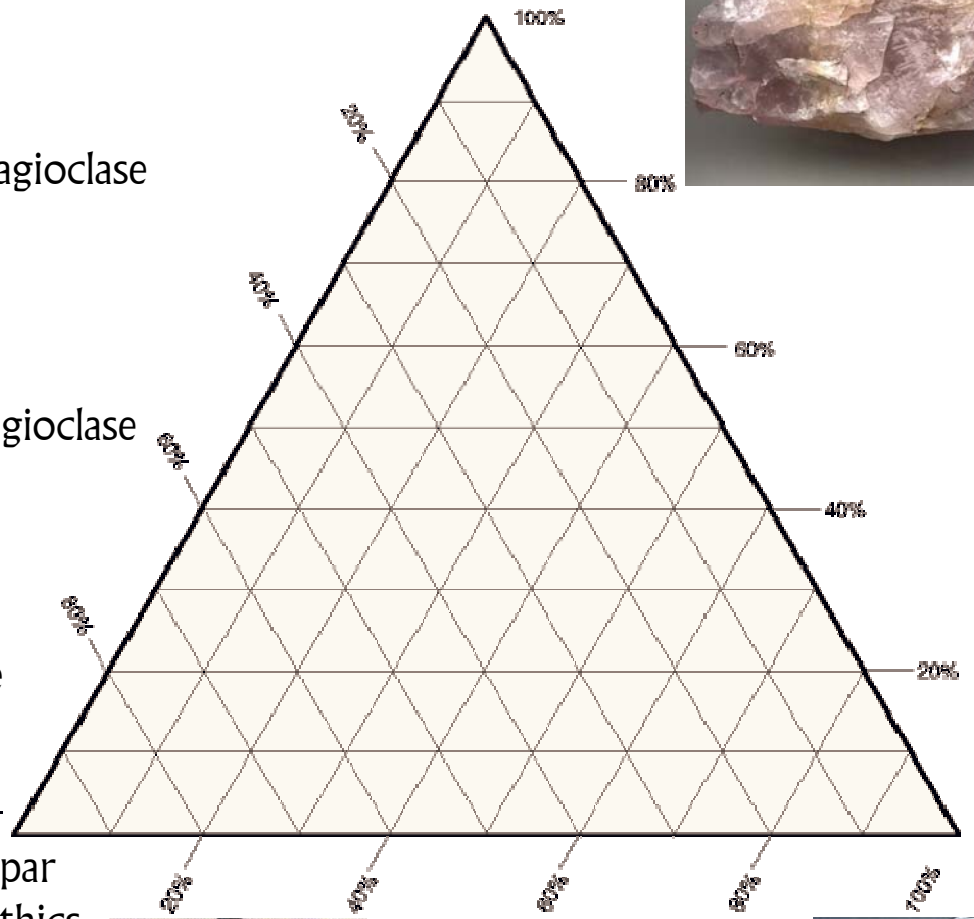
The Q, FL, and M Axes

Quartz

Ca Plagioclase

Na Plagioclase

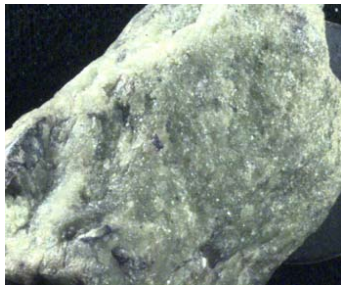
Orthoclase



Clay (matrix)
(shale)

Feldspar

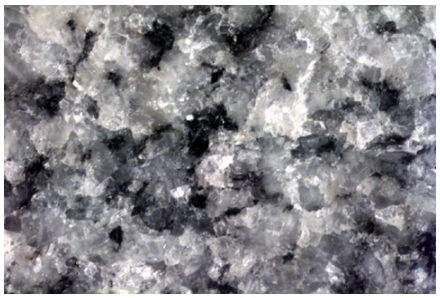
Lithics



Sediment Evolution on a Ternary Diagram

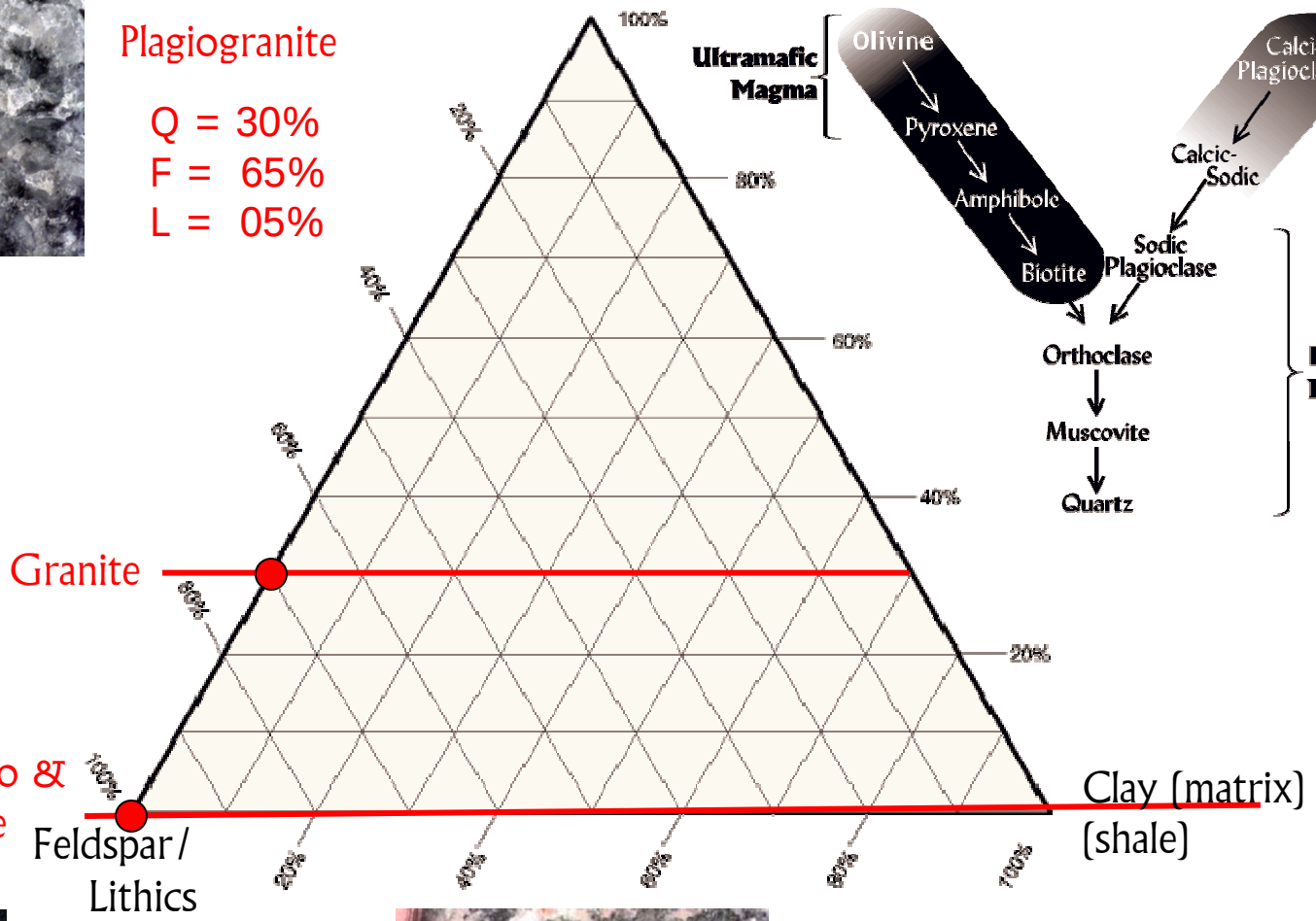
Igneous Rock Composition

2



Plagiogranite

Q = 30%
F = 65%
L = 05%



Gabbro

Q = 00%
F = 45%
L = 55%

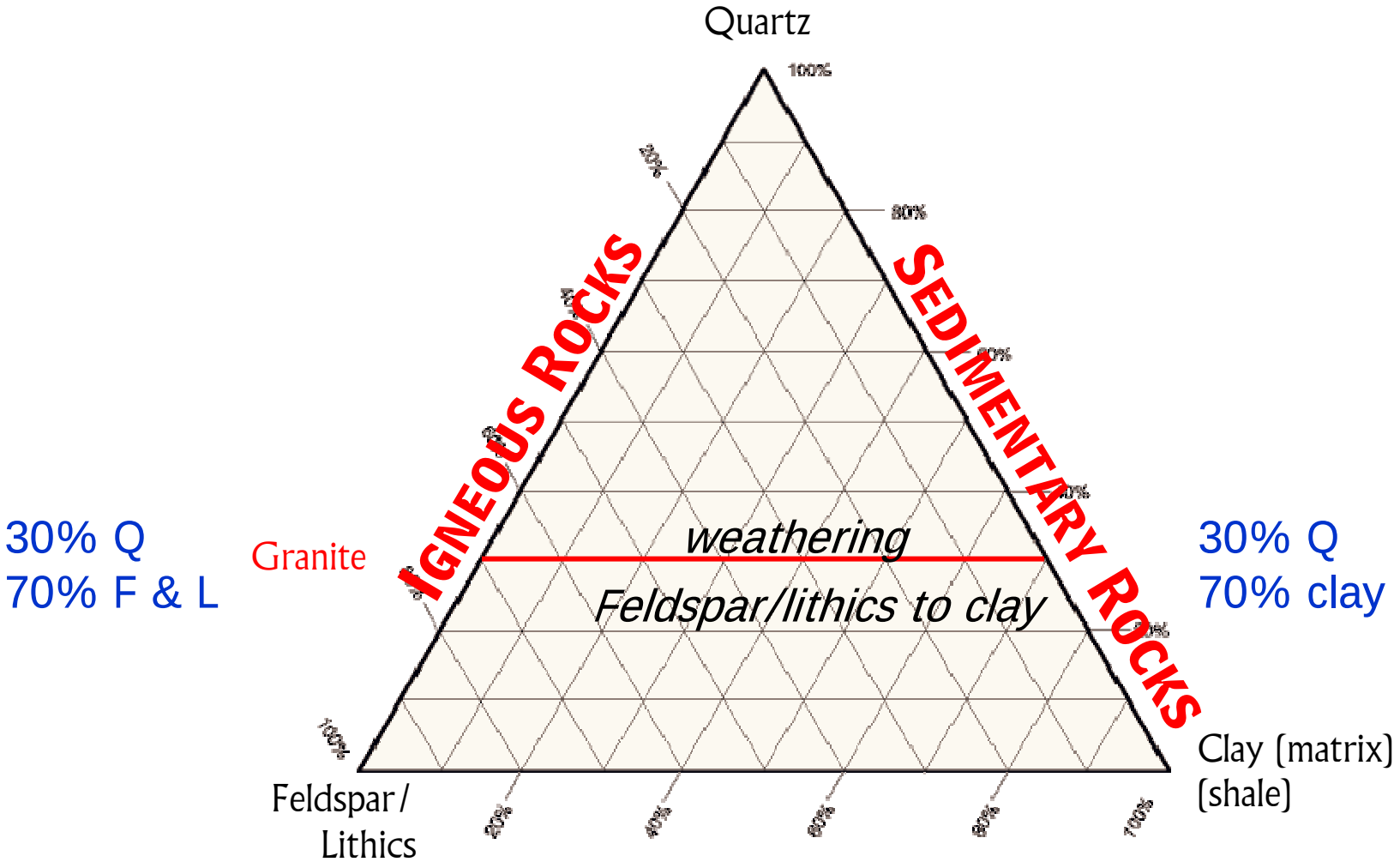
Syenite

Q = 00%
F = 80%
L = 20%

Sediment Evolution on a Ternary Diagram

3

Weathering



Sediment Evolution on a Ternary Diagram

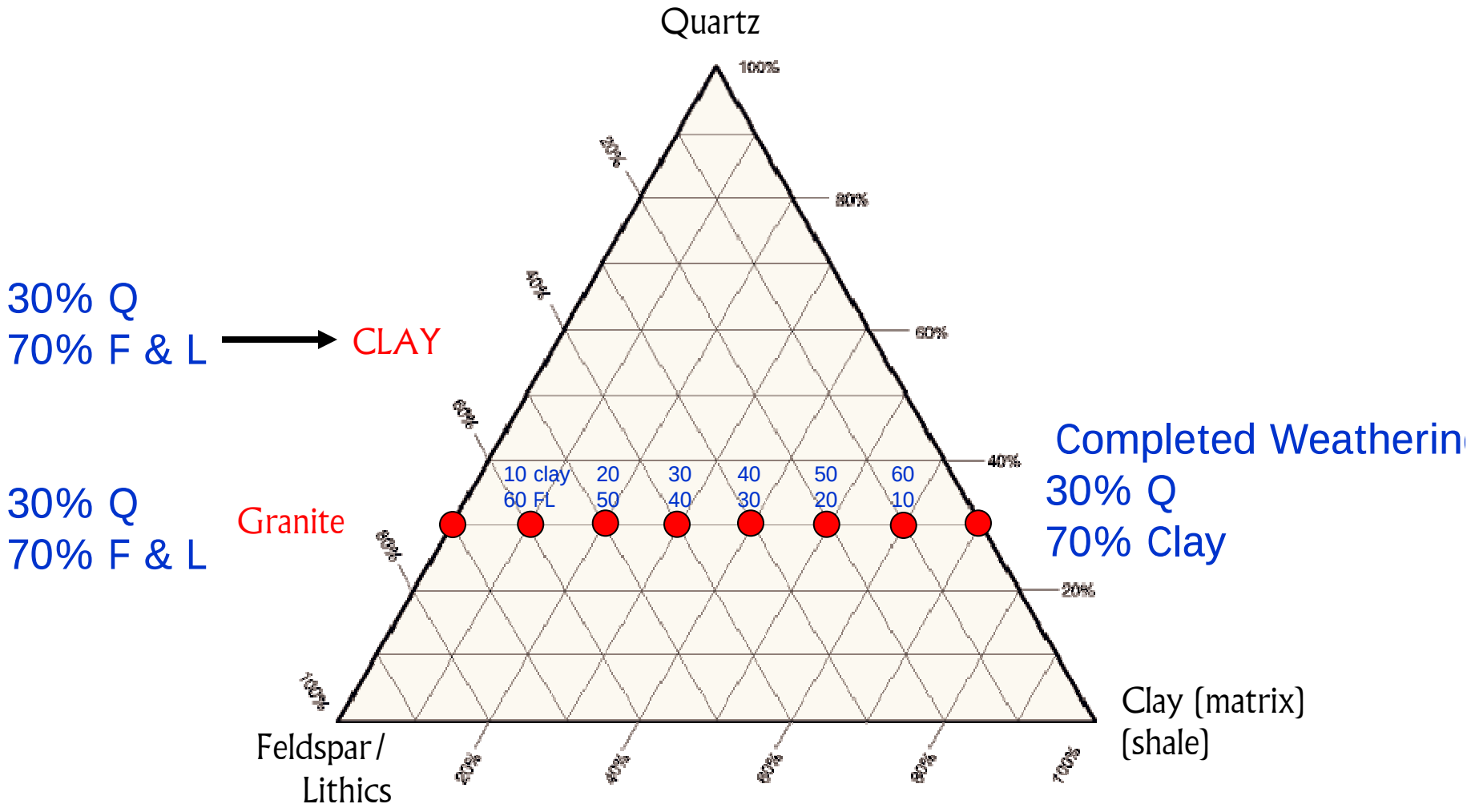
4

Sorting

Sediment Evolution on a Ternary Diagram

Step by Step Weathering

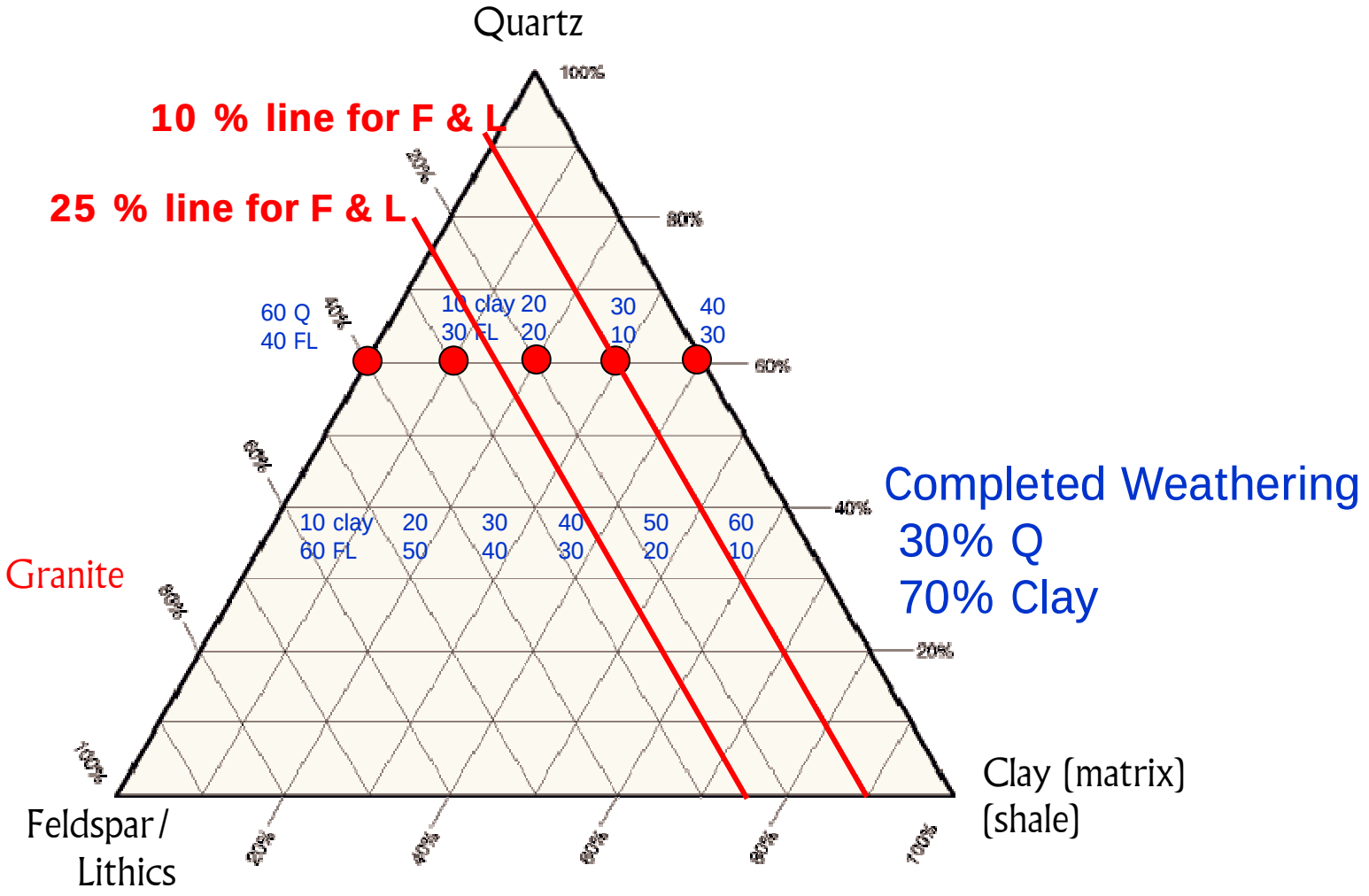
5



Sediment Evolution on a Ternary Diagram

Step by Step Weathering

6

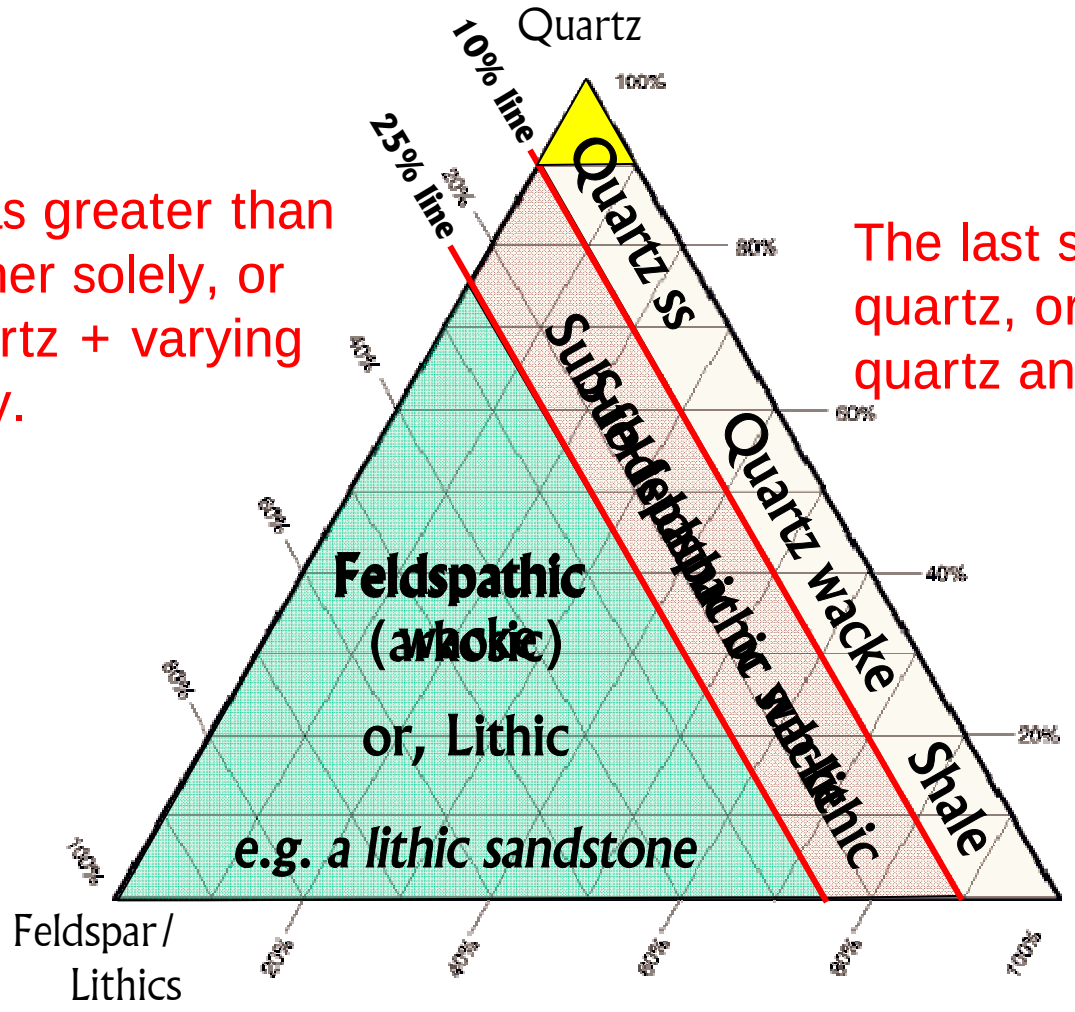


Sediment Evolution on a Ternary Diagram

7

Naming the Rocks

This triangle has greater than 25% F & L, either solely, or mixed with quartz + varying amounts of clay.



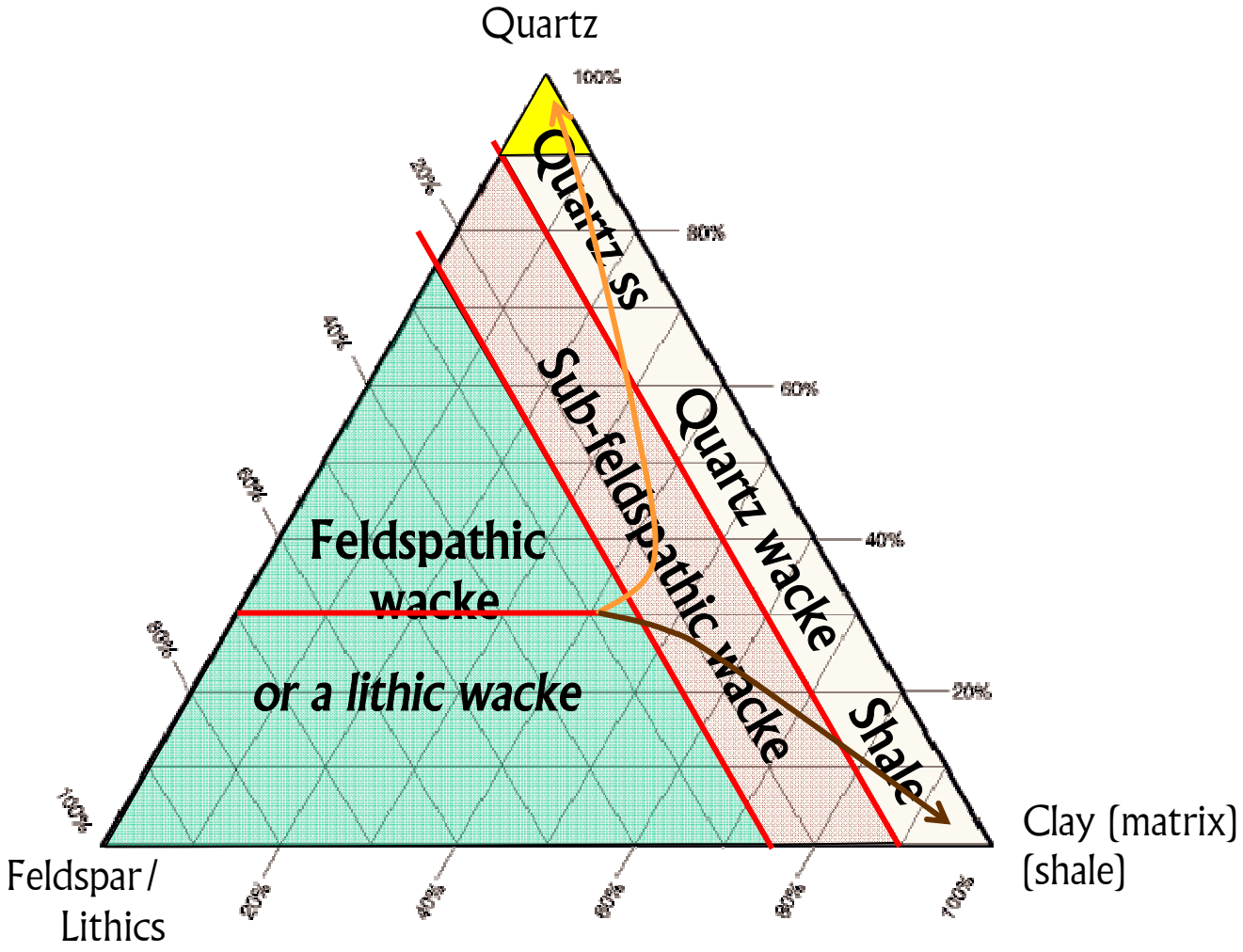
The last sliver has mostly quartz, or clay, or mixed quartz and clay.

This area is approaching the end of weathering; F & L are down to between 10 and 25%.

Sediment Evolution on a Ternary Diagram

Clastics and Carbonates

8

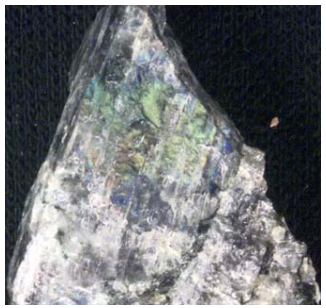


Sediment Evolution on a Ternary Diagram

Carbonates and Evaporates

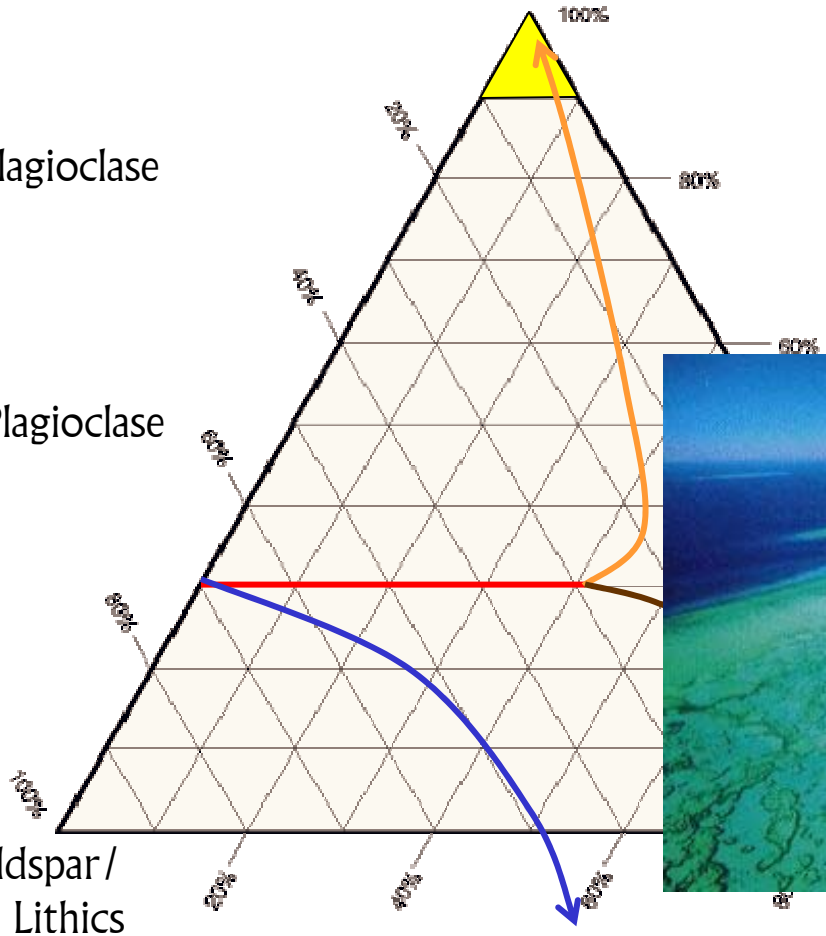
9

Quartz



Ca Plagioclase

Na Plagioclase



Feldspar / Lithics

Ca / Na leaves the diagram

Limestone

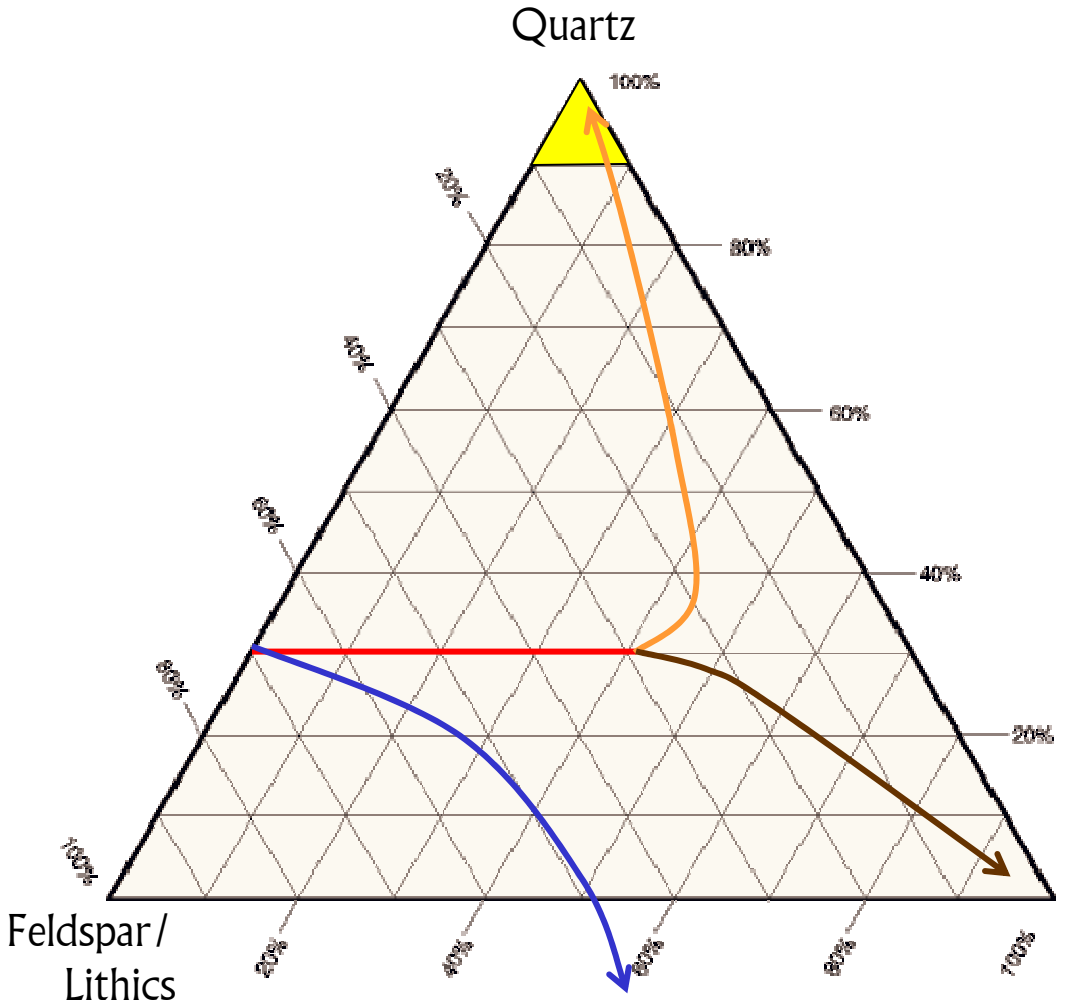
Gypsum

Rock Salt

Sediment Evolution on a Ternary Diagram

Clastics and Carbonates

10



Clastic Rocks

Carbonate/ Evaporate

Dead Sea


Mediterranean Sea
Sea of Galilee
SYRIA
Jordan R.
JORDAN
Kallia
Khirbat Qumran
Dead Sea
Sodom and Gomorrah
ISRAEL
EGYPT

Dead Sea

Salt concentrations are so high that people can float in the water without effort.

http://www.galilcol.ac.il/ecards.asp

Salt crusts on the edge of the Dead Sea

http://www.galilcol.ac.il/ecards.asp

http://www.trekearth.com/gallery/Africa/Tunisia/South/photo78623.htm

Great Salt Lake, Utah

http://www.life.umd.edu/emeritus/reveal/pbio/biome/lec35f1.html

http://members.tripod.com/bradleyvw/