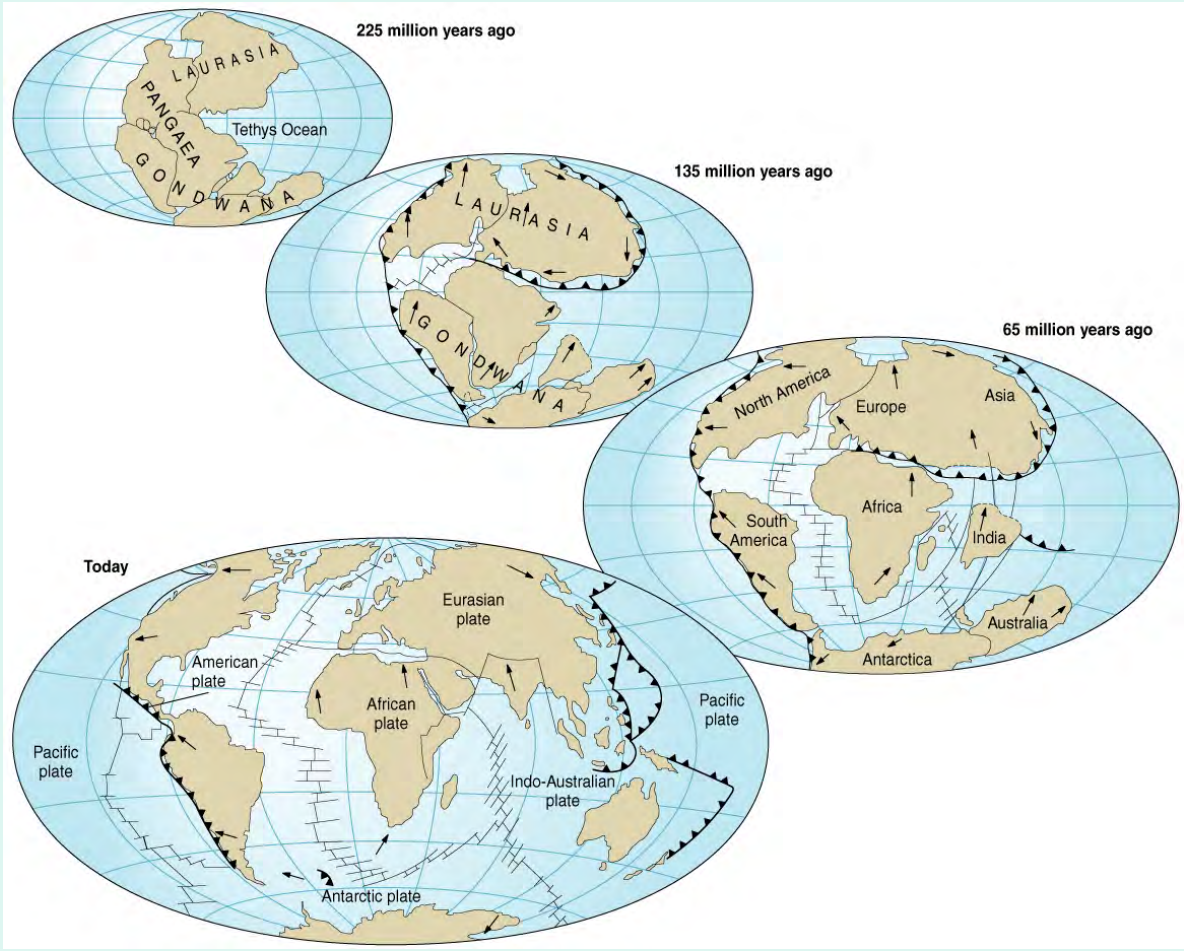

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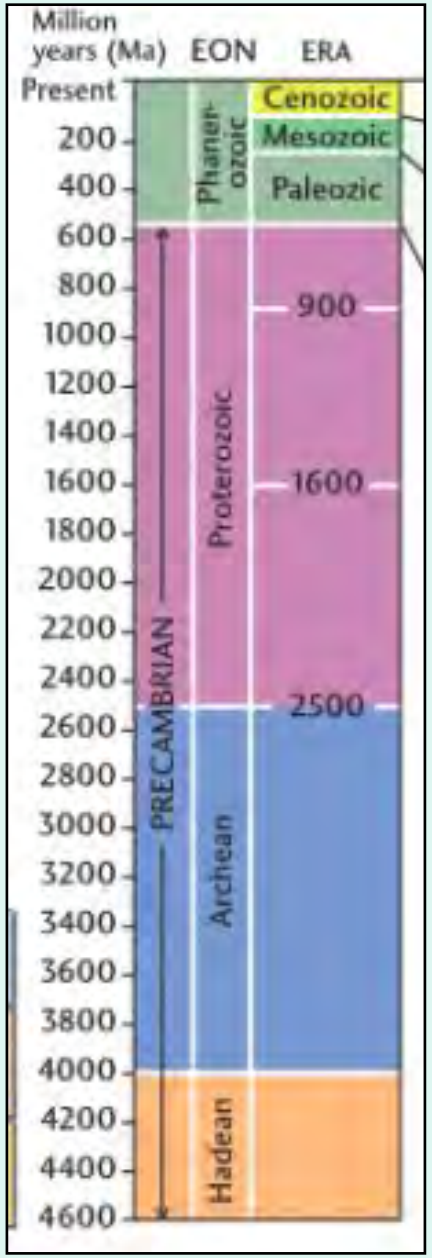
Plate Tectonics (Ch. 1)

Continents in Motion!

Minerals (Ch. 2)

The Eons of the Geologic Time Scale



Phanerozoic
0.57 Ga - now

Proterozoic
2.5 - 0.57 Ga

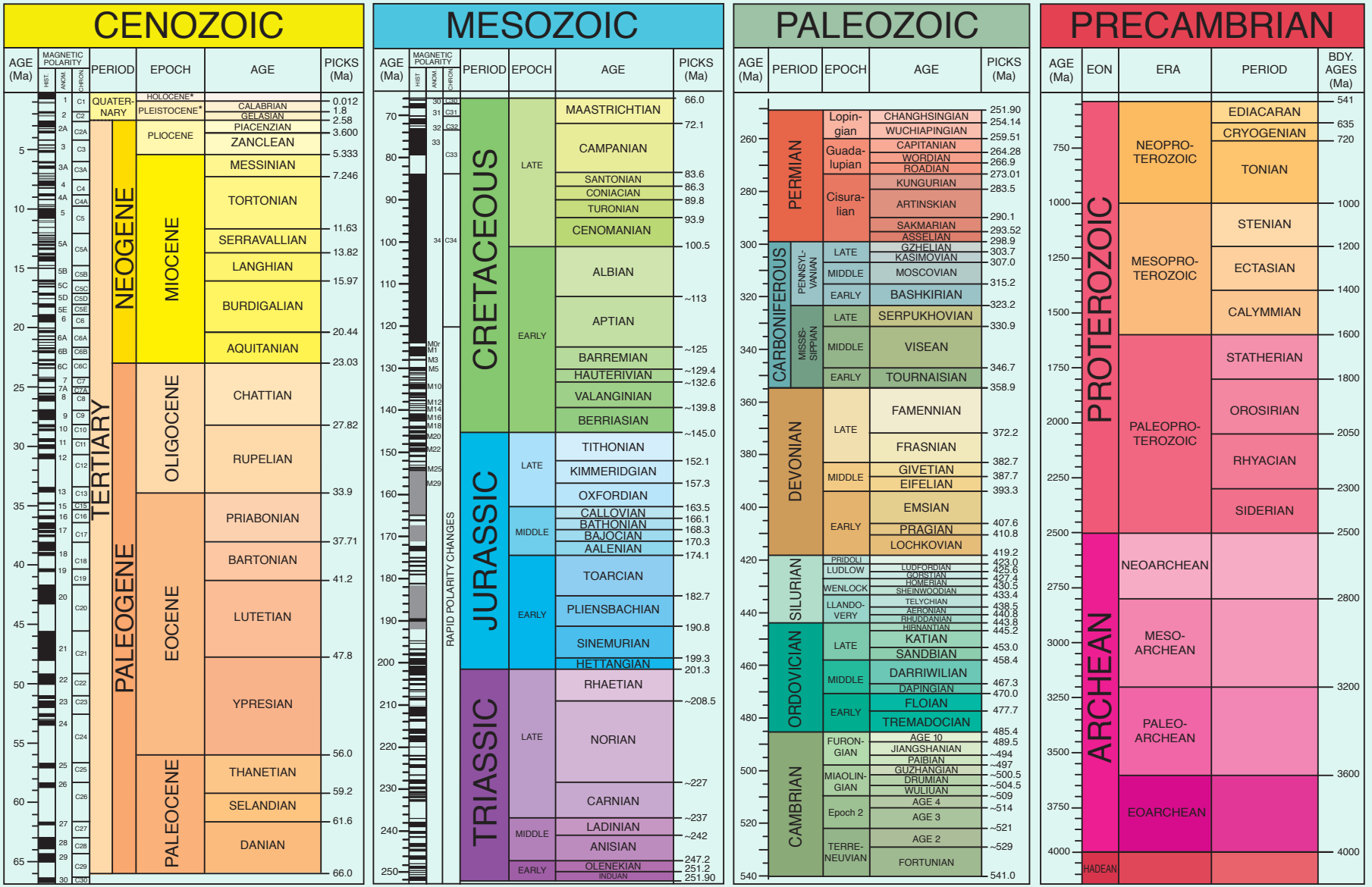
Archean
4.0 - 2.5 Ga

Hadean
4.55 - 4.0 Ga

Ga = billions of years

THE GEOLOGICAL SOCIETY OF AMERICA®

GEOLOGIC TIME SCALE v. 6.0



*The Pleistocene is divided into four ages, but only two are shown here. What is shown as Calabrian is actually three ages: Calabrian from 1.8 to 0.774 Ma, Chibanian from 0.774 to 0.129 Ma, and Late from 0.129 to 0.0117 Ma. The Holocene is divided into three ages: Greenlandian from 0.0117 to 0.0082 Ma, Northgrippian from 0.0082 to 0.0042 Ma, and Meghalayan from 0.0042 to present. The geologic community broadly recognizes the Anthropocene as a proposed new time interval of Earth history, partly coincident with the Holocene. Currently, the Anthropocene has an informal designation, with a proposed age span extending from the present to a beginning point between ca. 15,000 yr B.P. and as recent as 1960 CE.

The Cenozoic, Mesozoic, and Paleozoic are the Eras of the Phanerozoic Eon. Names of units and age boundaries usually follow the Gradstein et al. (2012), Cohen et al. (2012), and Cohen et al. (2013, updated) compilations. Numerical age estimates and picks of boundaries usually follow the Cohen et al. (2013, updated) compilation. The numbered epochs and ages of the Cambrian are provisional. A "~" before a numerical age estimate typically indicates an associated error of ± 0.4 to more than 1.6 Ma.

Walker, J.D., and Geissman, J.W., compilers, 2022, Geologic Time Scale v. 6.0: Geological Society of America, https://doi.org/10.1130/2022.CTS006C. (Walker—University of Kansas; Geissman—University of Texas–Dallas, University of New Mexico.)

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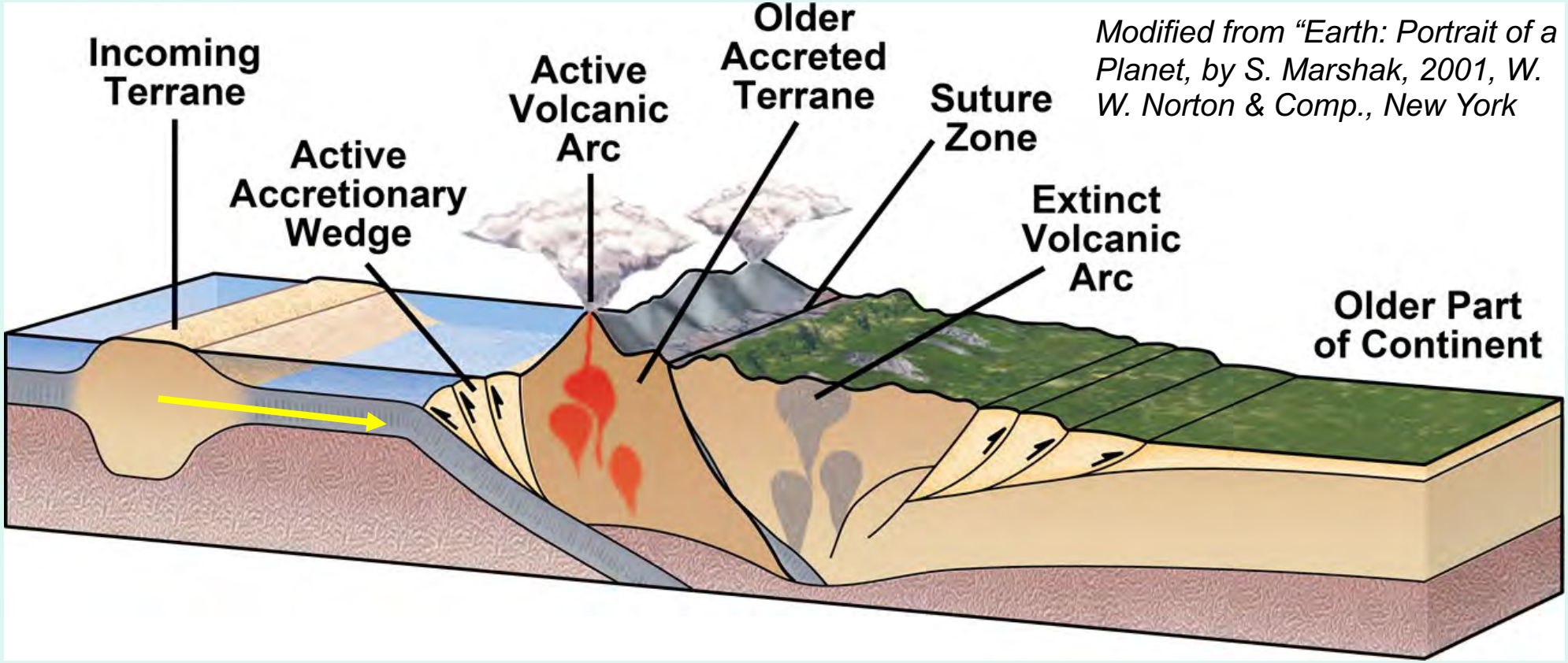
Cohen, K.M., Finney, S.C., Gibbard, P.L., and Fan, J.-X., 2013 (updated), The ICS International Chronostratigraphic Chart: Episodes, v. 36, p. 199–204, http://www.stratigraphy.org/ICSchart/ChronostratChart2021-10.pdf (accessed Sept. 2022).

Gradstein, F.M, Ogg, J.G., Schmitz, M.D., et al., 2012, The Geologic Time Scale 2012: Boston, USA, Elsevier, https://doi.org/10.1016/B978-0-444-59425-9.00004-4.

How Continents Grow by Accretion

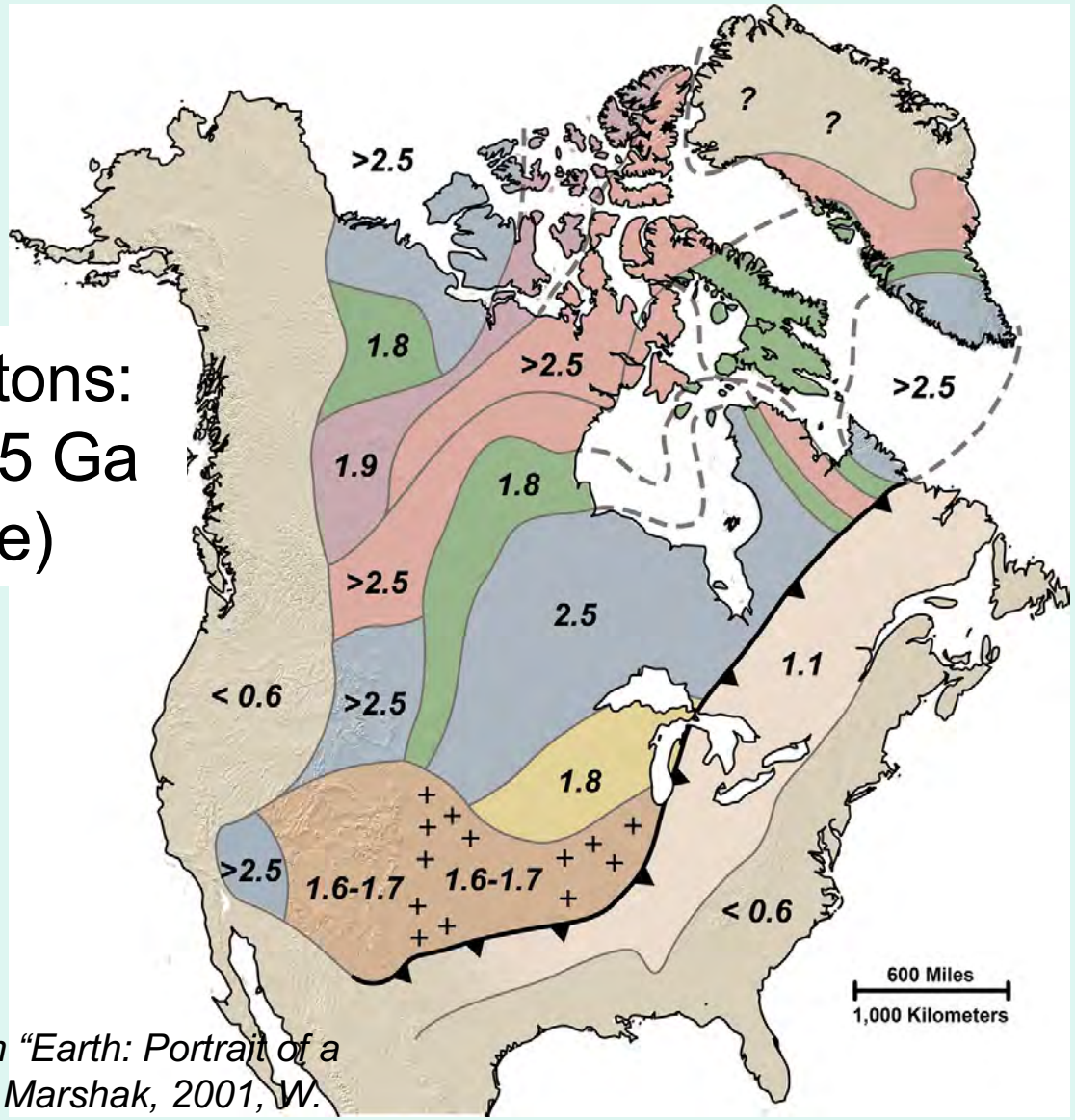


Modified from "Earth: Portrait of a Planet, by S. Marshak, 2001, W. W. Norton & Comp., New York

Moving plates carry small fragments of continental material that collide with, and are thus added to, older continental masses

Assembly of a Continent

Cratons:
> 2.5 Ga
(blue)



Modified from "Earth: Portrait of a Planet, by S. Marshak, 2001, W. W. Norton & Comp., New York

Orogens: Growth by addition of small continental masses along margins of **cratons**

Note that cratons may also include older orogens

The Atmosphere

-first atmosphere H, He;
swept away by solar wind

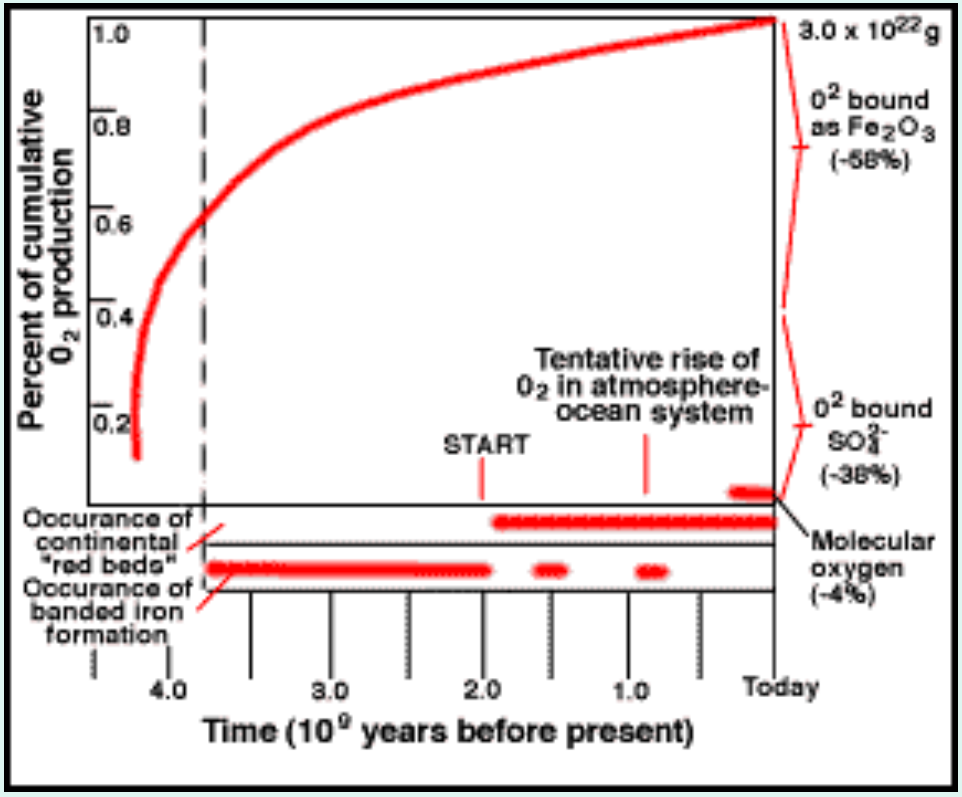
-volcanism --> H_2O, CO_2, H, S
- second atmosphere!

-Earth cools enough that condensed H_2O pools, forms lakes, oceans – *removes* H_2O

- *CO_2 removed* by photosynthesis, carbonate rocks

-eventually N, O dominate atmosphere (organic activity)

-but no free O_2 for first 2.5 billion years of Earth history



www.globalchange.umich.edu

Where We Are At……

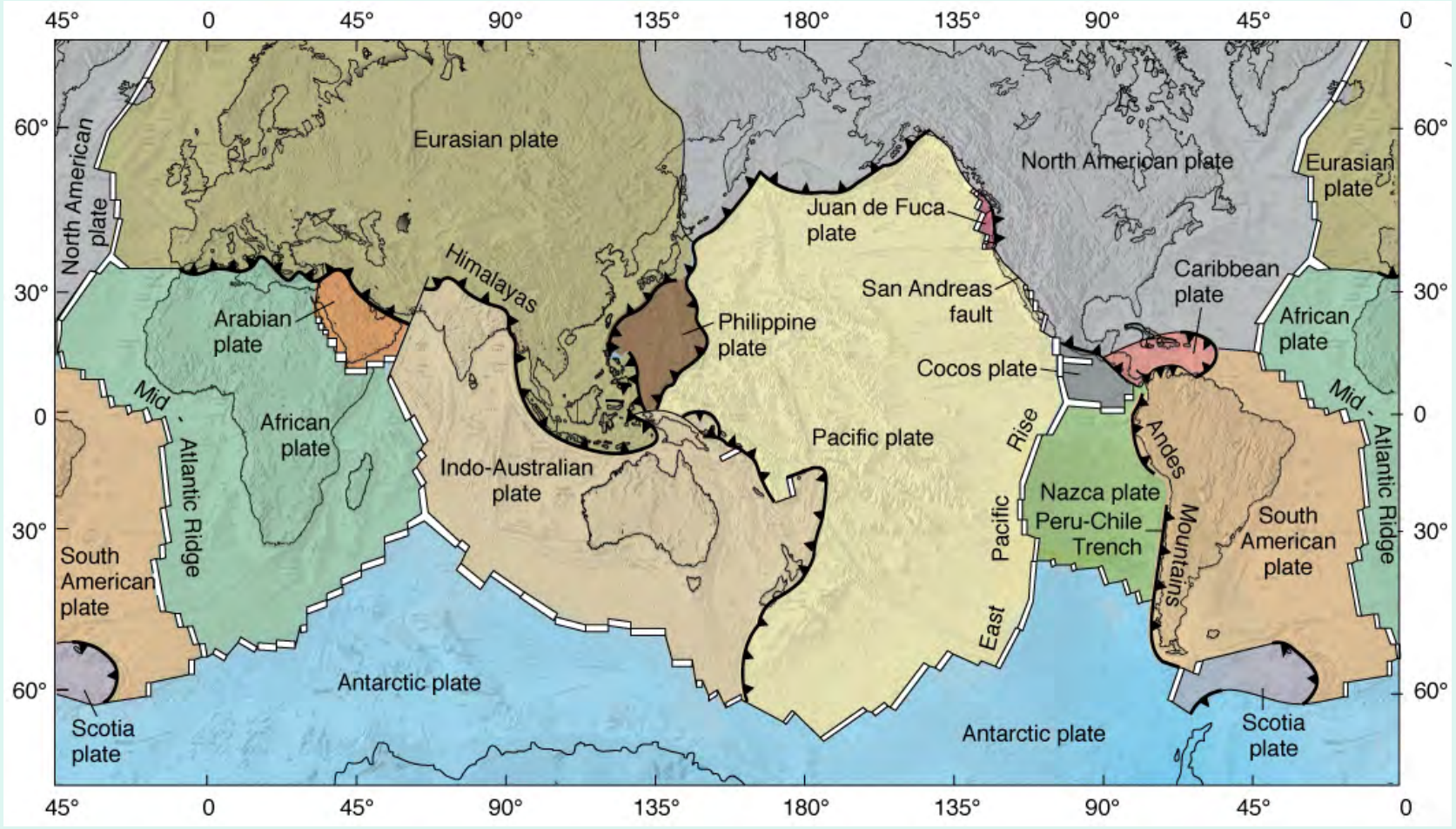
-Earth formation 4.6 Ga; Moon at 4.5 Ga; earliest continent formation at 4.4 Ga (Ga = billion years)

-Major continent formation during Archean (4.0-2.5 Ga), but growth continued via continent-continent collisions and other processes (e.g., volcanism)

Questions:

Why do continents collide?
Why do we have earthquakes?
Why do we have volcanoes?
Has the Earth always looked as it does now, or is it constantly changing?

Plate Tectonics: Lithospheric Plates



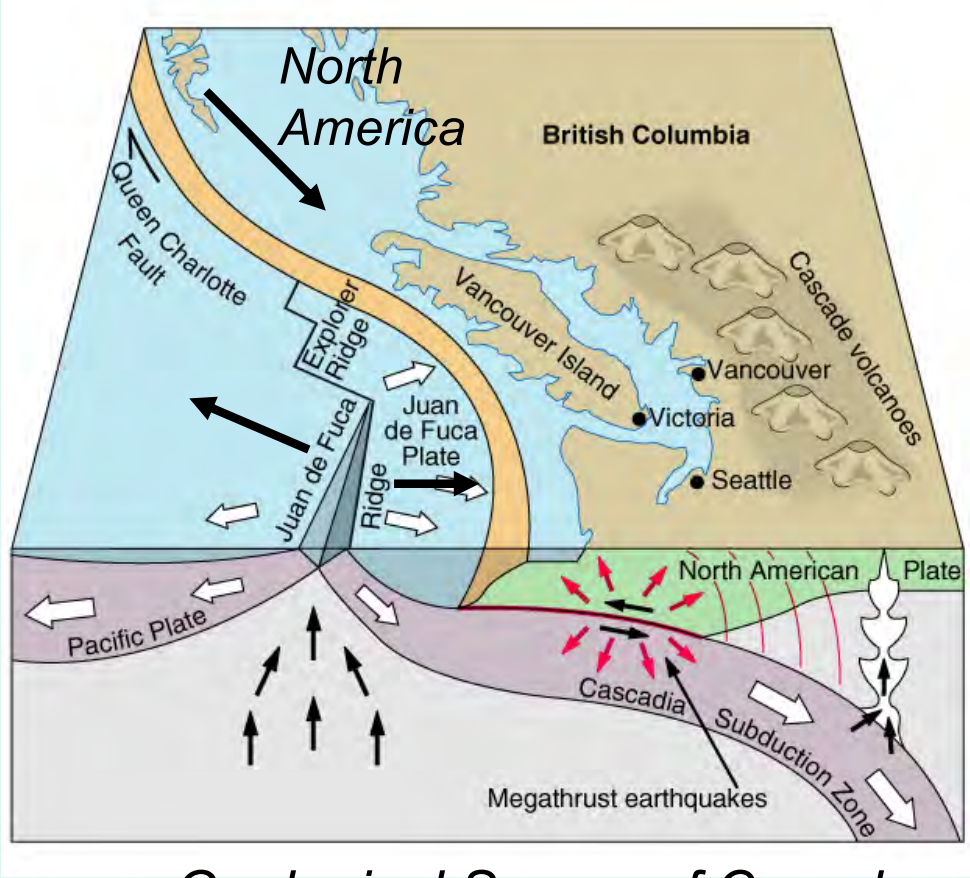
Plates = crust plus uppermost mantle (solid)

Plate Boundaries

Divergent: ***new plate***

Convergent: ***destroy plate***

Transform: ***plates slide***



Geological Survey of Canada

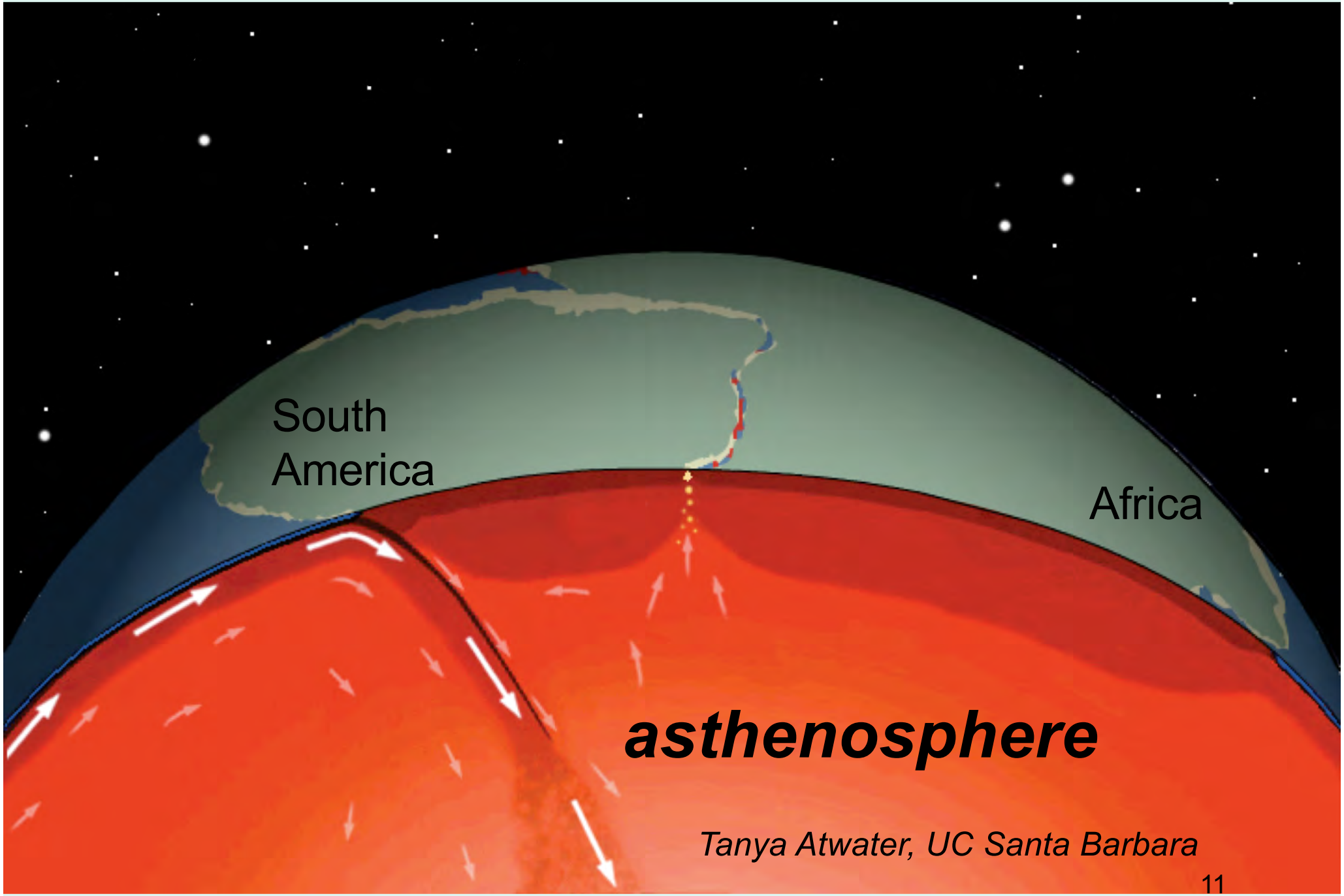

South
America
Africa
asthenosphere
Tanya Atwater, UC Santa Barbara

Plate Tectonics

- Earth's surface divided into ~13 lithospheric plates, in motion

- Plates include lithospheric mantle (solid), crust (solid)

- Plates underlain by upper mantle *asthenosphere* (hot, plastic, convects)

- Three kinds of plate boundaries: divergent, convergent, transform

- Volcanoes, earthquakes commonly associated with plate boundaries

- *More to come as course progresses!*

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Minerals: The Building Blocks!

Chapter 2

Carletonite

Minerals Learning Outcomes

- Know the definition of a mineral
- Know the structure of the silicon tetrahedron
- Know the five silicate minerals groups: isolated, single chain, double chain, sheet, framework
- Know what physical properties distinguish minerals
- Understand that Earth shells have different composition, minerals
- Know the three kinds of feldspar minerals

What is a mineral?

-Naturally occurring

-Inorganic

-Homogeneous solid

-Ordered atomic arrangement (crystal structure)

-Specific (fixed) chemical composition

What is a rock?

Answer - an aggregate of minerals!

Wikipedia

How Many Minerals?

Almost 4000!

How many do YOU need to know?

About 25! *(phew….)*

What is NOT a mineral?

Bone - Ca-phosphate (apatite) is ORGANIC

Seashell - Ca-carbonate (calcite) is ORGANIC

Opal - SiO_2 (quartz) is NOT CRYSTALLINE

Tree resin - ORGANIC

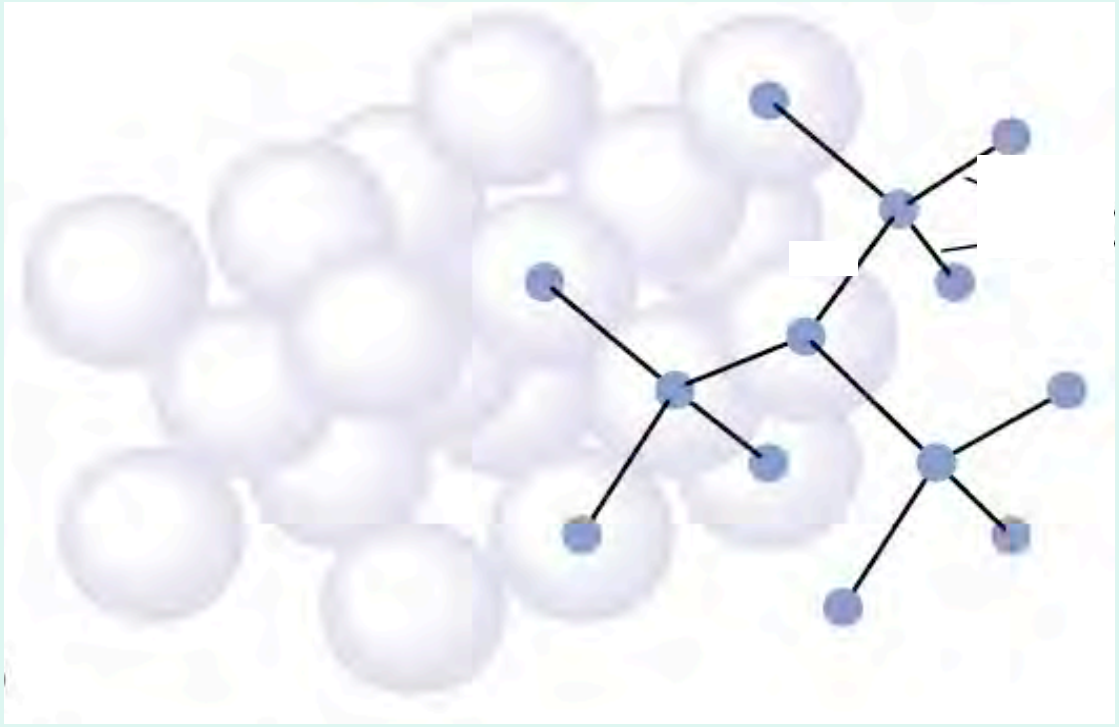
Volcanic glass - NOT FIXED COMPOSITION, NOT CRYSTALLINE

Minerals Built from Atoms: Elements

Element	Continental Crust
Oxygen (O)	**46.6%**
Silicon (Si)	27.7%
Aluminium (Al)	8.1%
Iron (Fe)	5.0%
Calcium (Ca)	3.6%
Sodium (Na)	2.8%
Potassium (K)	2.6%
Magnesium (Mg)	2.1%
Others	1.7%

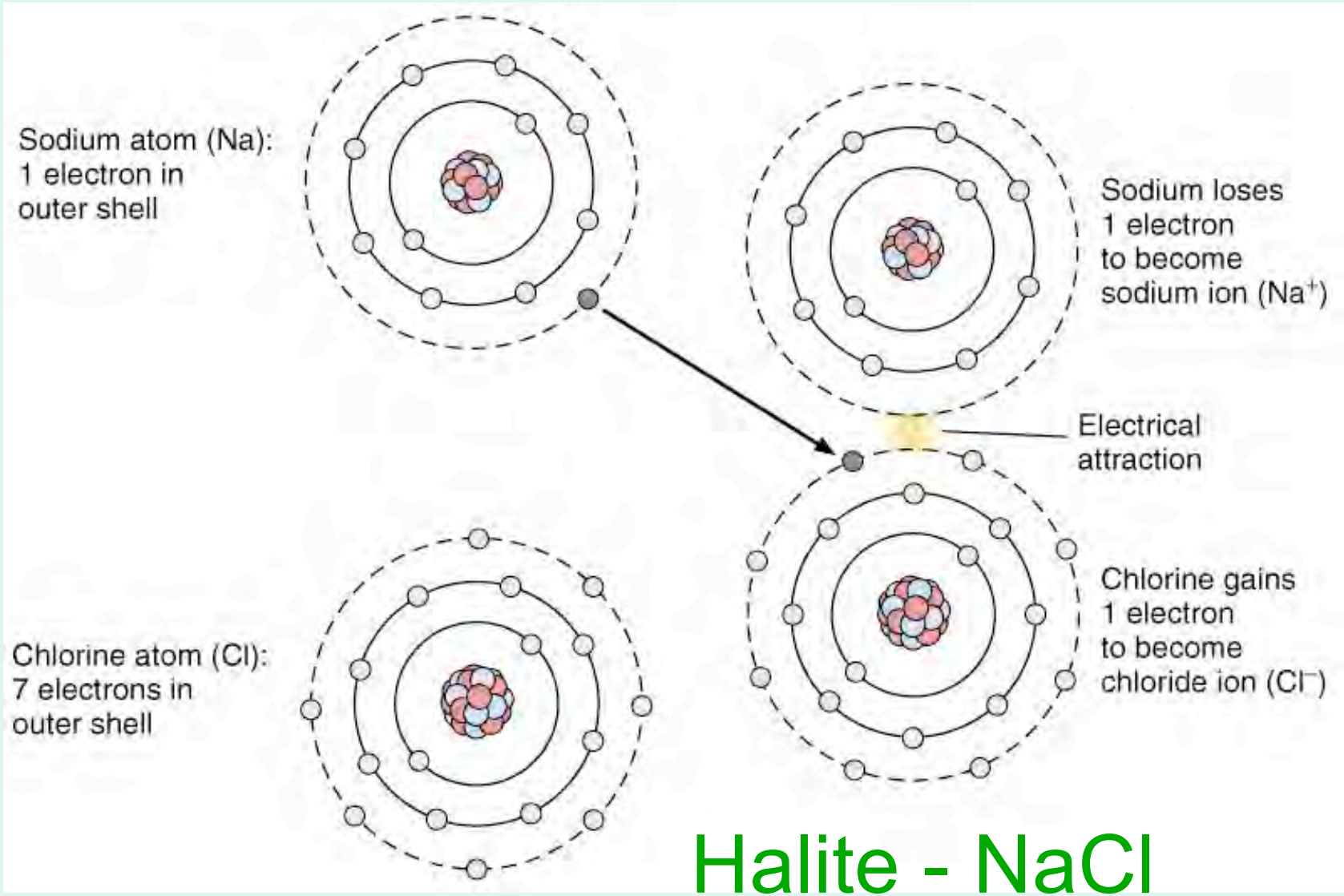
Atomic Bonding

Geometric arrangement of atoms --> crystal lattice - defines a mineral



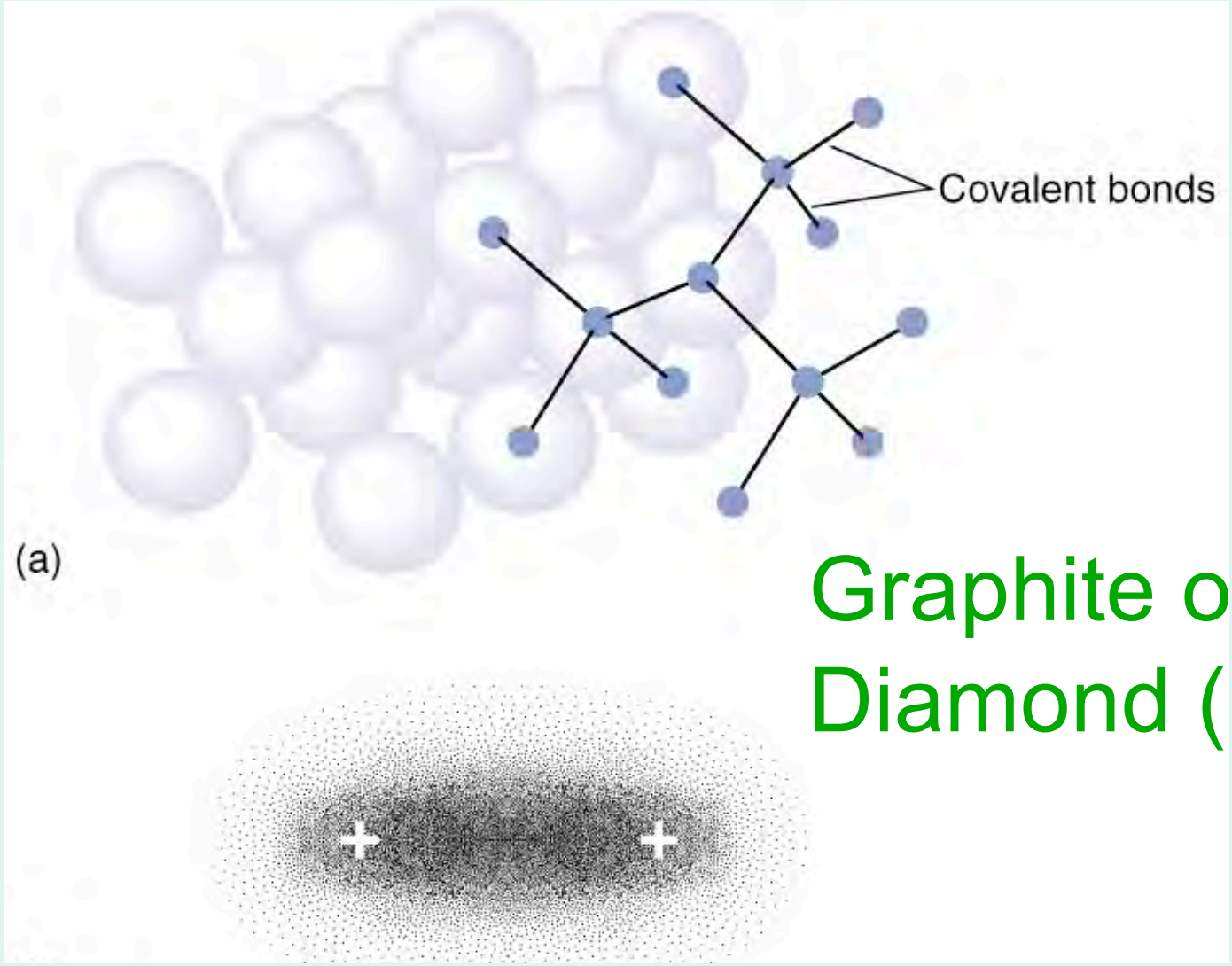
Mineral properties reflect bond type, strength

Ionic



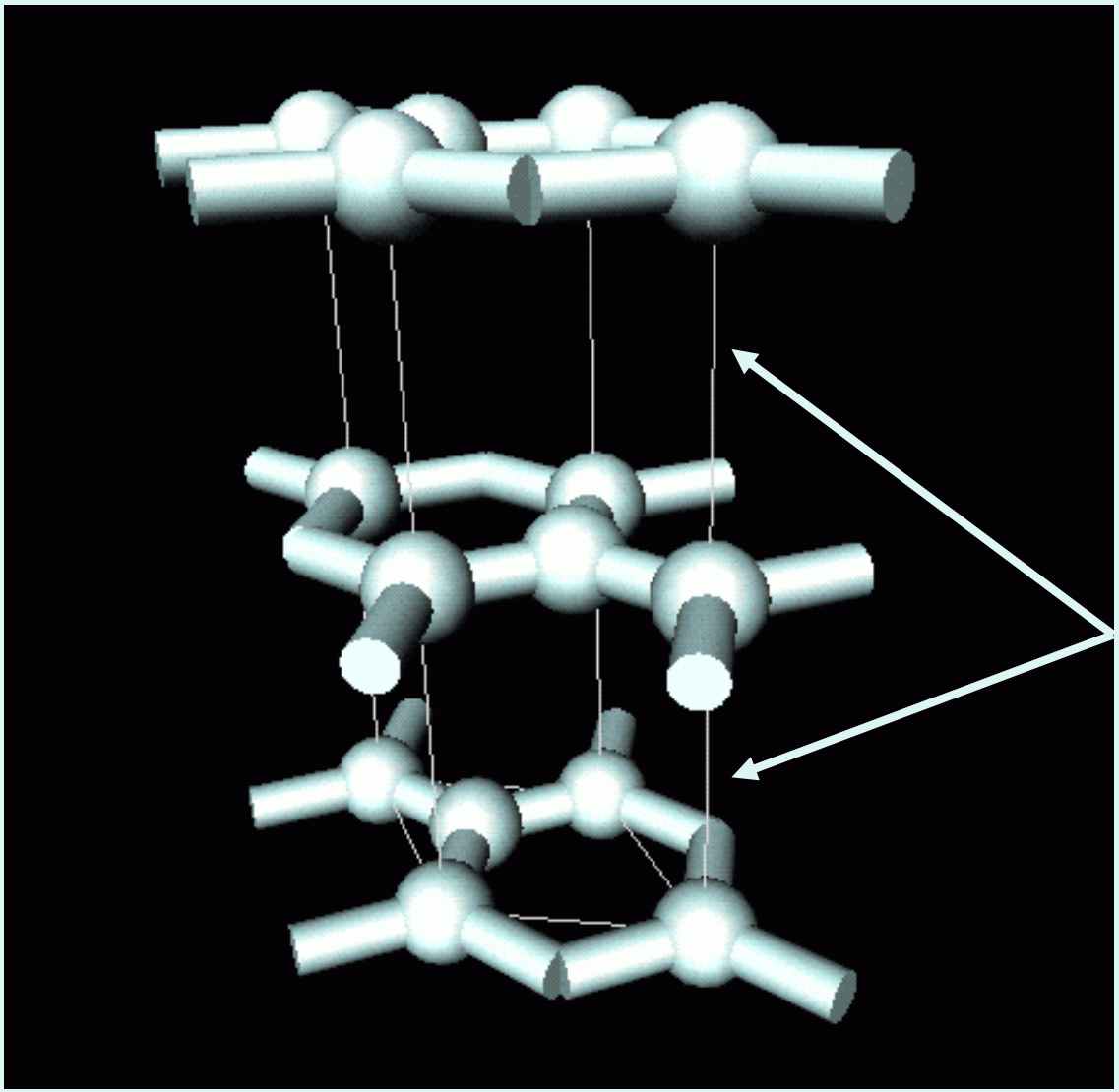
Halite - NaCl

Covalent



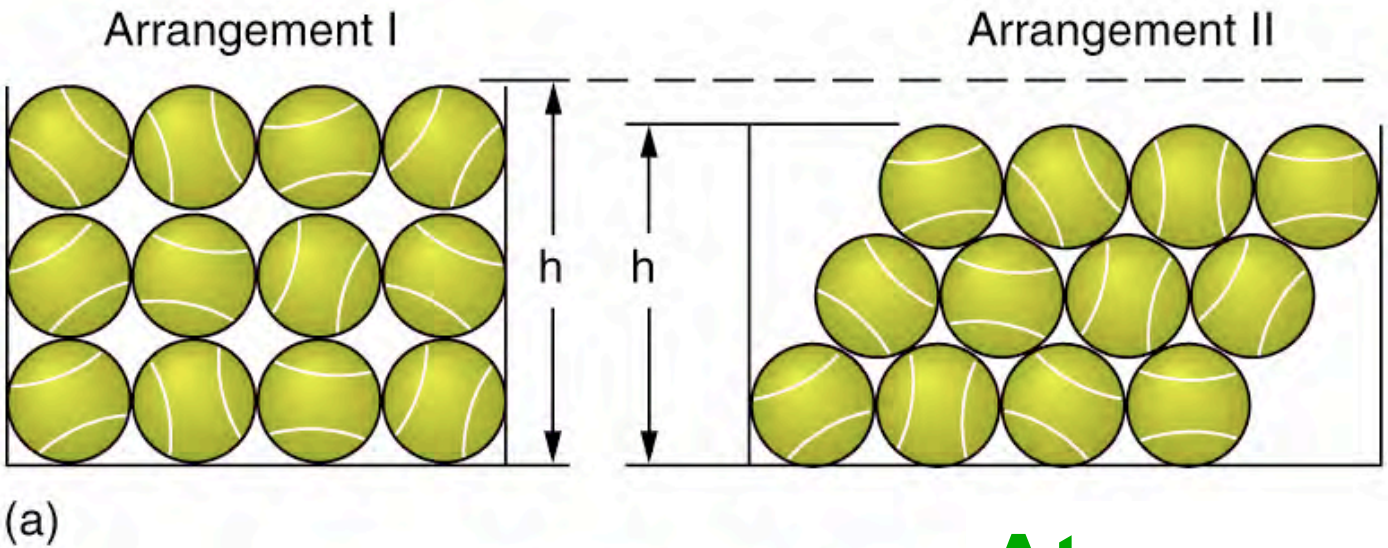
Graphite or
Diamond (C)

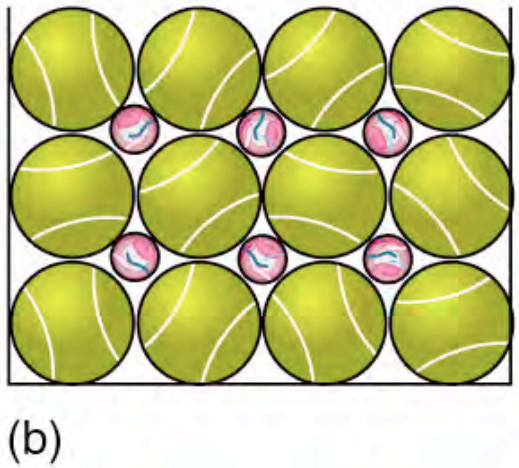
Van der Waals



Weak electrostatic attraction between layers of bound atoms

Crystal Structure; Composition



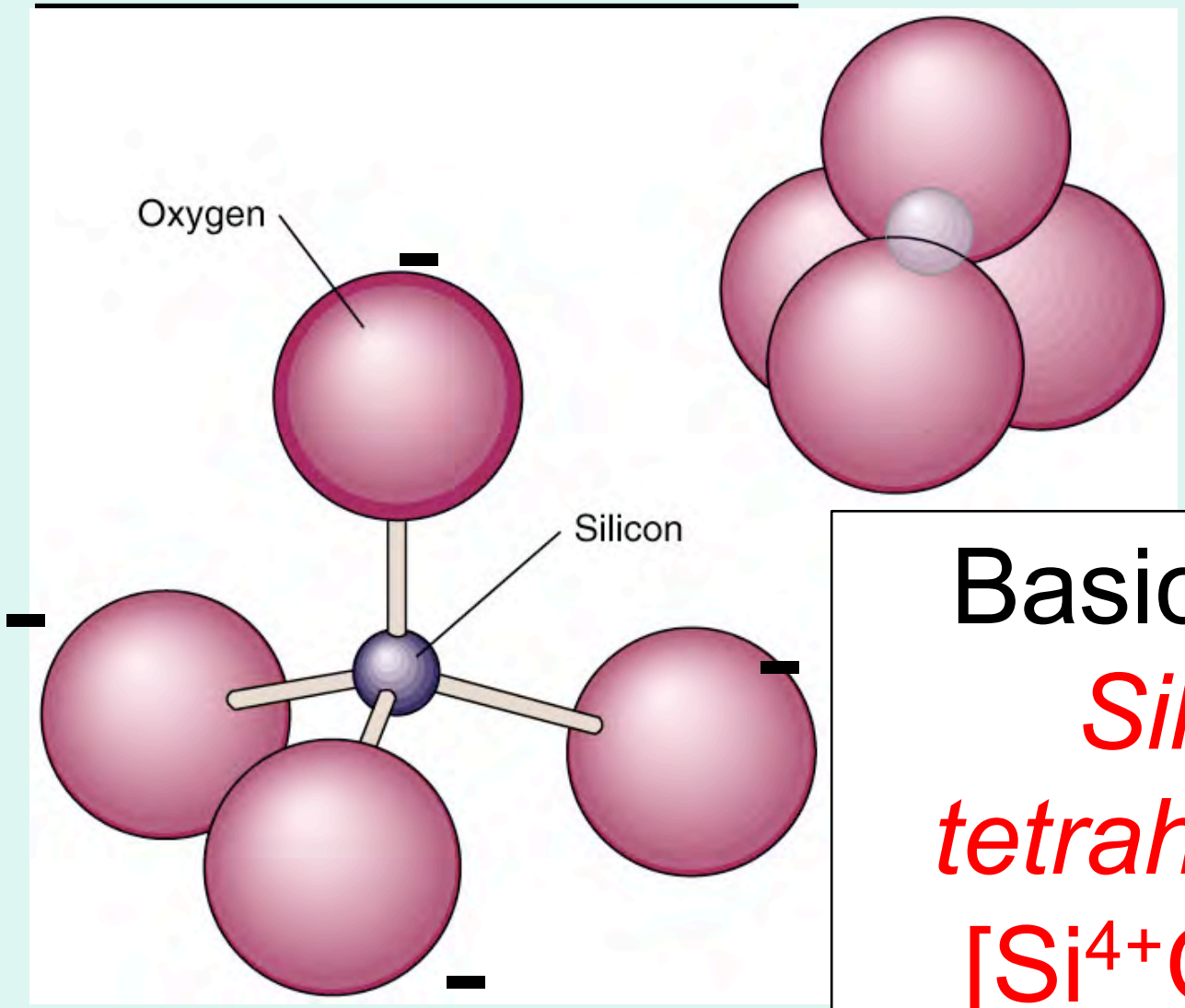


Atoms can be arranged in different crystal lattice forms

9 Mineral Groups

Group	Group Formula	Example
Silicate	$[SiO_4]^{4-}$	quartz
Oxides	$[O^{2-}]$	magnetite
Sulfides	$[S^{2-}]$	pyrite
Sulfates	$[SO_4]^{2-}$	gypsum
Halides	$[Cl, F]^{1-}$	halite
Carbonates	$[CO_3]^{2-}$	calcite
Hydroxides	$[OH]^{1-}$	Iron ore
Phosphates	$[PO_4]^{3-}$	apatite
Native element		Copper, gold

Silicate Minerals



Basic Unit:

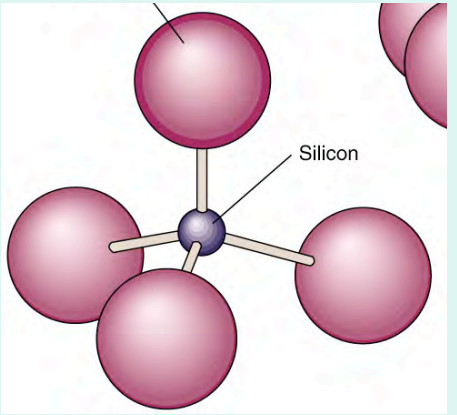
Silica tetrahedron

$[Si^{4+}O^{2-}_4]^{4-}$

Silicate Mineral Groups

1. Isolated tetrahedra
2. Single chain
3. Double chain
4. 2-dimensional sheet
5. 3-dimensional framework

Isolated Tetrahedra

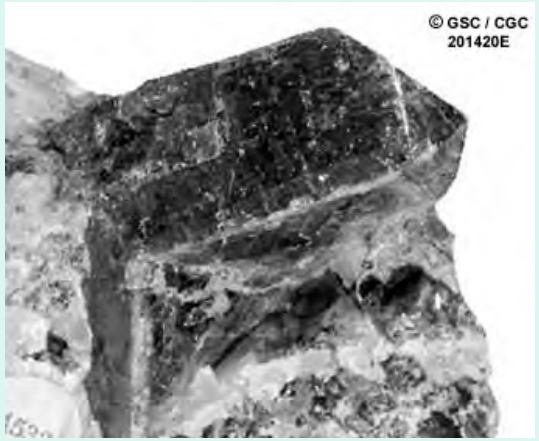


Individual tetrahedra held together by bonds with Fe of Mg cations; four available O's for bonding

	Silica tetrahedra (central Si^{4+} not shown)	Composition of a single unit	Mineral example
Isolated groups		$(SiO_4)^{4-}$	Olivine, $(Mg, Fe)_2 SiO_4$

Olivine: primary mineral in Earth's mantle (65%)

Single Chains: Pyroxenes

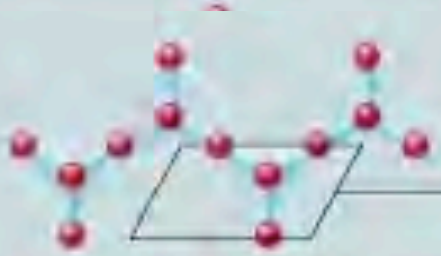


Two types:

Mg-Fe series (orthopyroxene)

Ca-Mg-Fe series (clinopyroxenes)

Together form rest of Earth's mantle
(2 free O's per ST)

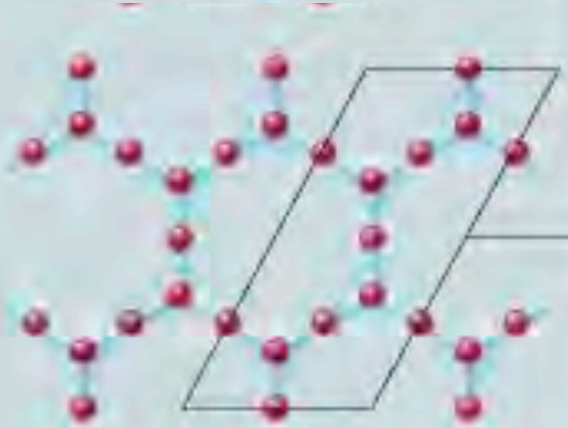
	Silica tetrahedra (central Si^{4+} not shown)	Composition of a single unit	Mineral example
Single		$(SiO_3)^{2-}$	Pyroxene e.g., Enstatite, $MgSiO_3$

Double Chains: Amphiboles

Compositionally diverse:

Mg, Fe, Ca, Al, Na, K, OH^-

(1 or 2 free O's per ST)

	Silica tetrahedra (central Si^{4+} not shown)	Composition of a single unit	Mineral example
Double		$(Si_4O_{11})^{6-}$	Amphibole e.g., Anthophyllite, $Mg_7Si_8O_{22}(OH)_2$

2-Dimensional Sheet Silicates

Distinctly layered crystals -
layers peel apart

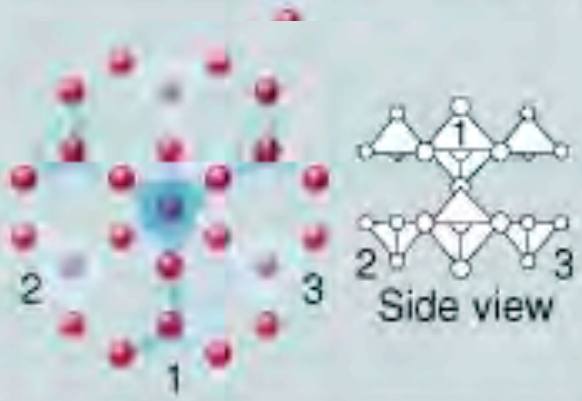
Elements fit between sheets

Framework Silicates

quartz

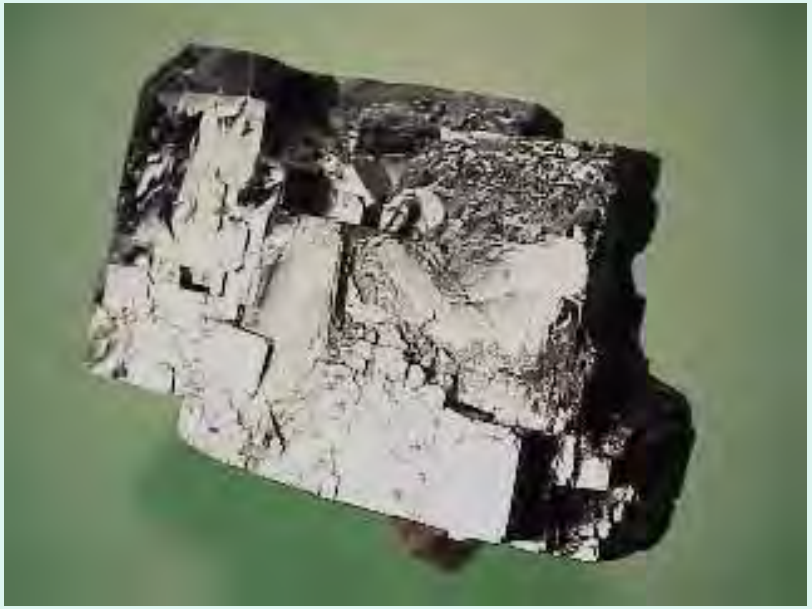
Complex structures - feldspars most common minerals in continental crust

Feldspars: Ca - Na- K substitution in lattice

	Silica tetrahedra (central Si^{4+} not shown)	Composition of a single unit	Mineral example
Three-dimensional framework		$(Si_4O_8)^{4-}$ and $(SiO_2)^0$	Feldspar e.g., Albite, $NaAlSi_3O_8$ Quartz, SiO_2

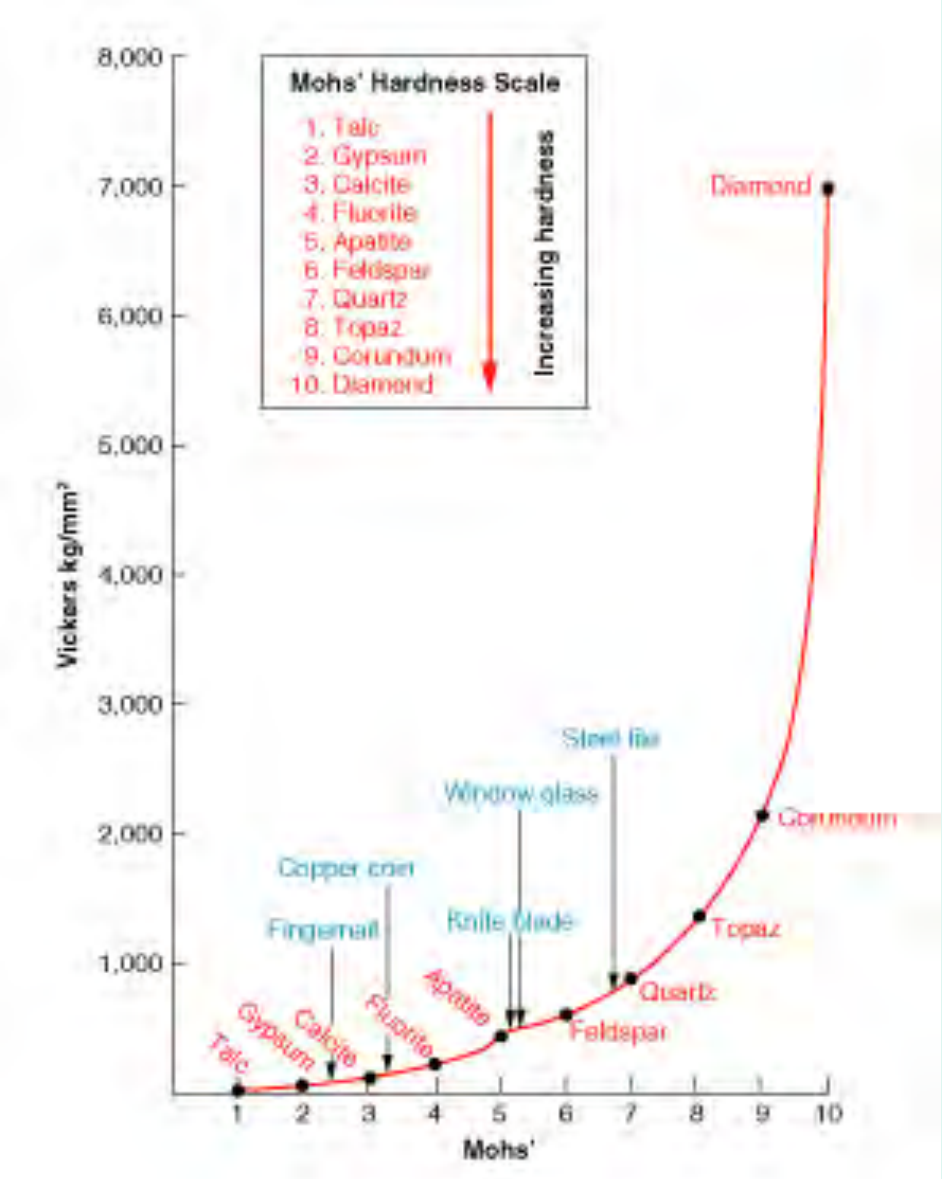
Mineral ID: Properties

1) Lustre: the way that light is reflected from mineral surface



Metallic

Non-metallic



1812

Carl Friedrich Mohs

Hardness: Moh's Scale

Vickers Indentation Values: force to make small indentation

To Help You Remember:

Toronto	talc
Girls	gypsum
Can	calcite
Flirt	fluorite
And	apatite
Other	orthoclase feldspar
Quirky	quartz
Things	topaz
Can	corundum
Do	diamond

Density: "Specific Gravity"

Weight of mineral relative to weight of equal volume of water

Silicates: 2.5 - 3.3

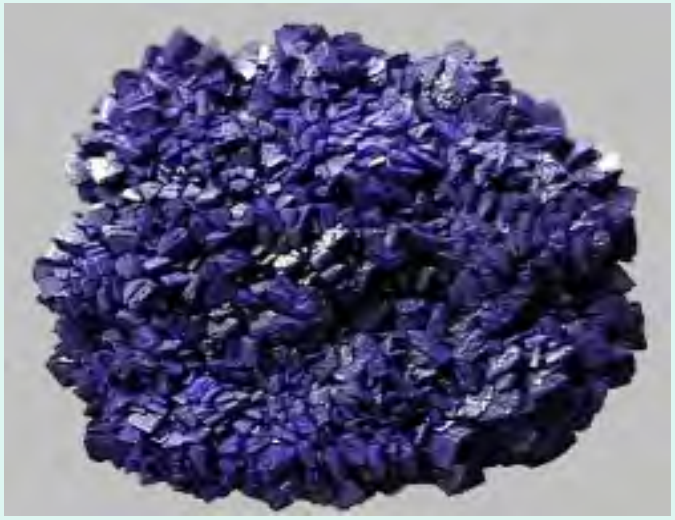
Gold: 15!

Colour

Sulfur

Sulfur Photo from MII, courtesy of the Smithsonian Institution

Azurite



Diagnostic for some minerals, not for others

Colour….

Quartz!

Streak: colour of powder

Non-metallic minerals: white

Metallic minerals: varies, but diagnostic

Hematite - red

Goethite - brown

Habit: crystal form

Quartz

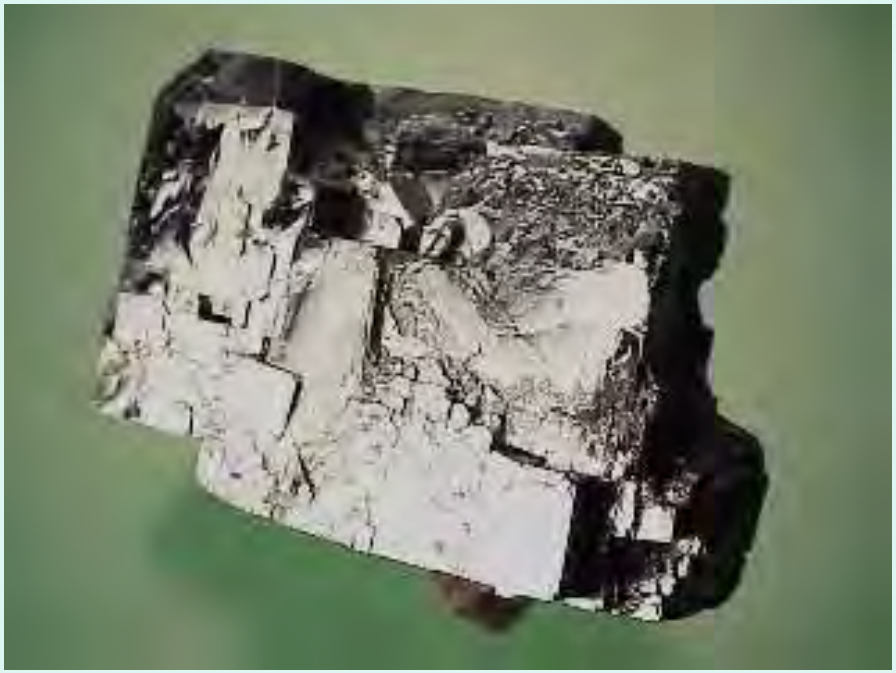
Sulfur

Galena

GROWTH FACES - slow growth

Cleavage: breakage surfaces

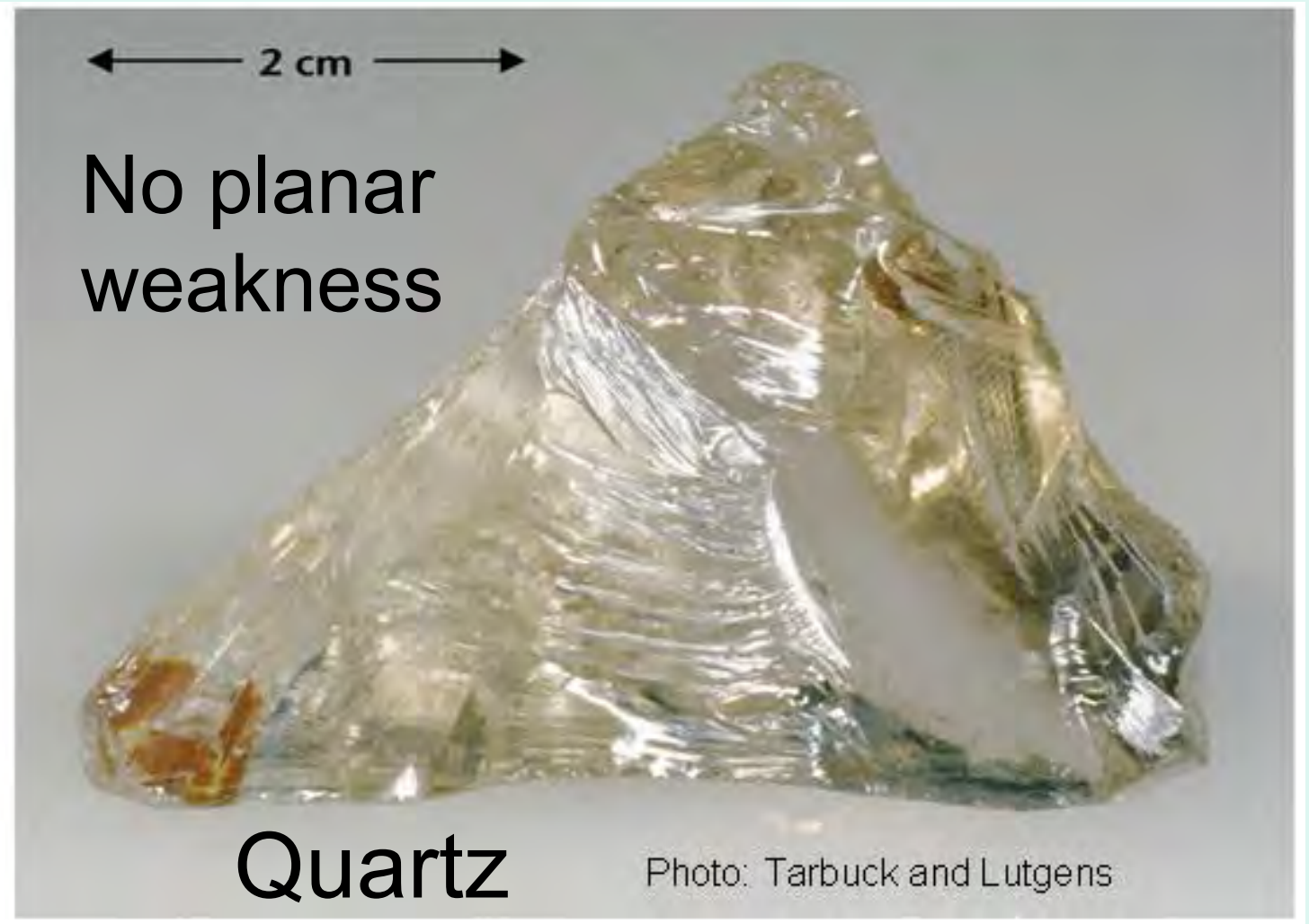
Planes of weakness in lattice



Galena - cubic

Amphibole - prismatic

Fracture - irregular breakage



Next: More on Minerals, Chapter 2