Homework 2: Due Wednesday

EESC 2200
The Solid Earth System

Igneous Rocks And Relative Time

24 Sep 08

Continental Tectonics

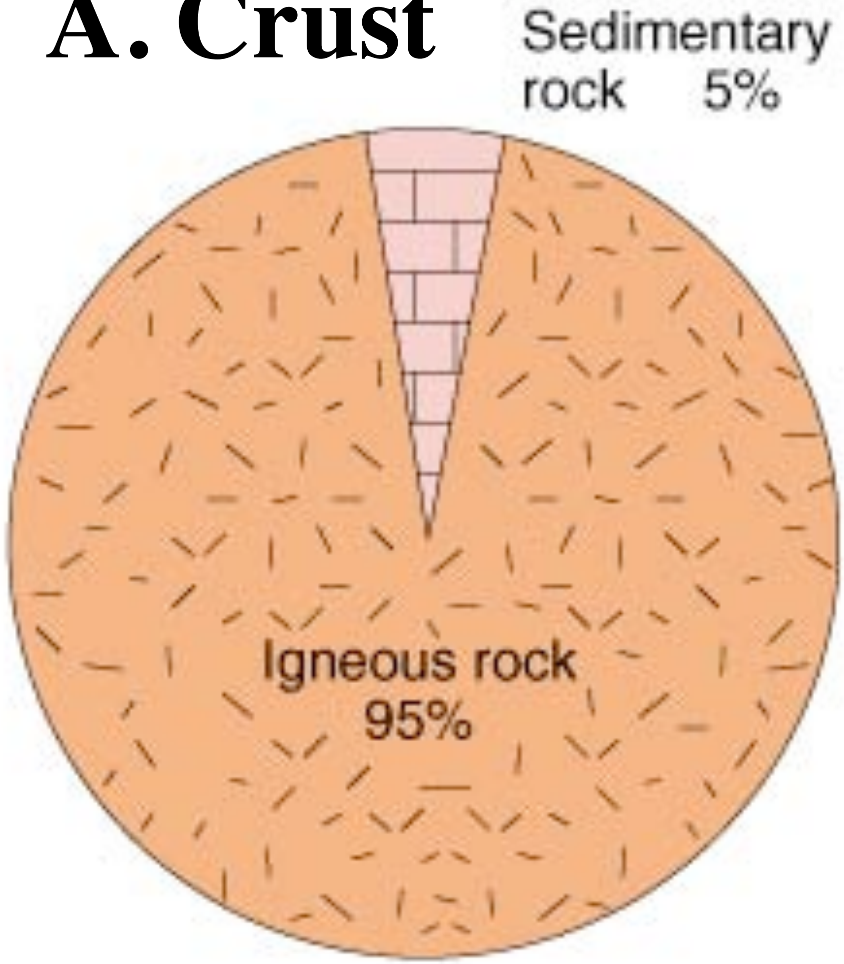
OPEN HOUSE 2008

"Science To Sustain The Planet"

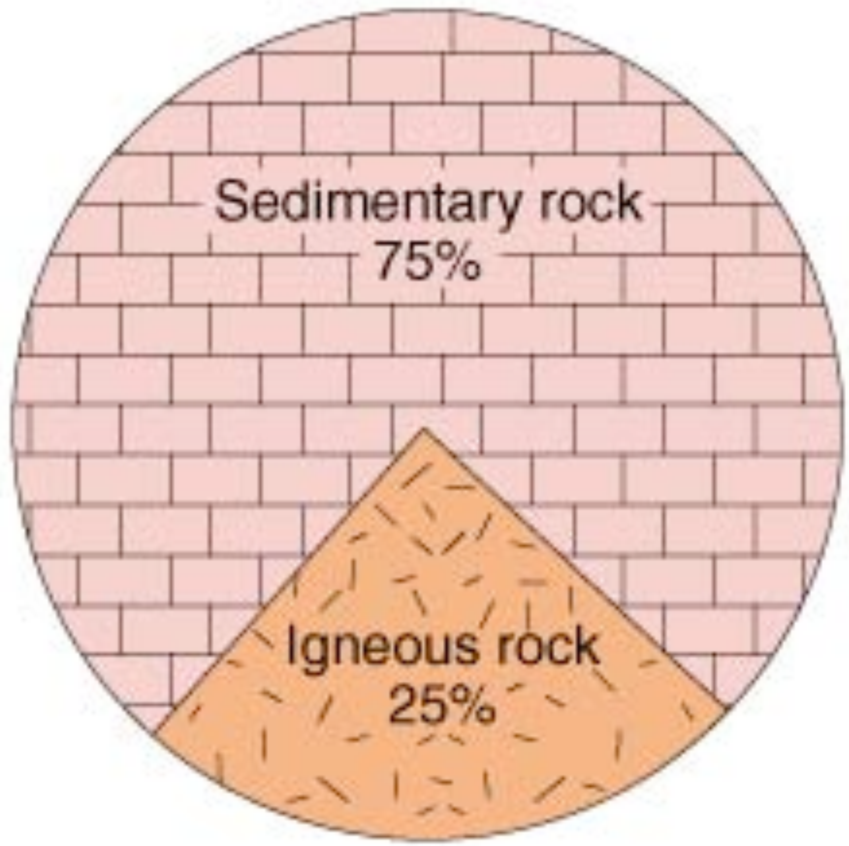
October 4th 10am-4pm

Relative Frequency of Rock Types

A. Crust



B. Surface



Magma chemistry
Two main classes

mafic magmas + rocks

ma - fic

magnesium + iron (Ferrous) rich

OR:

felsic magmas + rocks

fel - sic

Feldspar and **si**lica rich

felsic ->intermediate-> **mafic**

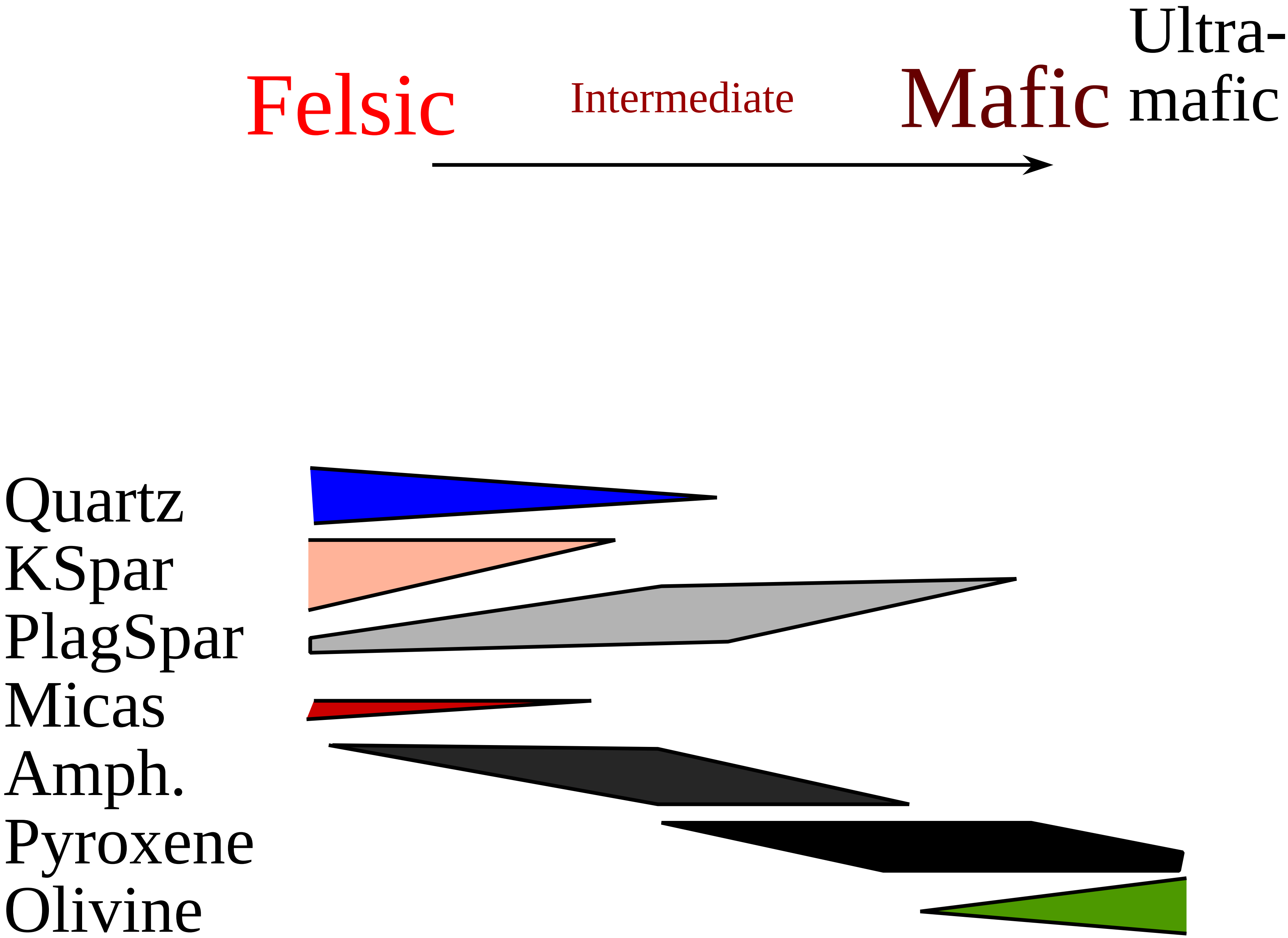
light	dark

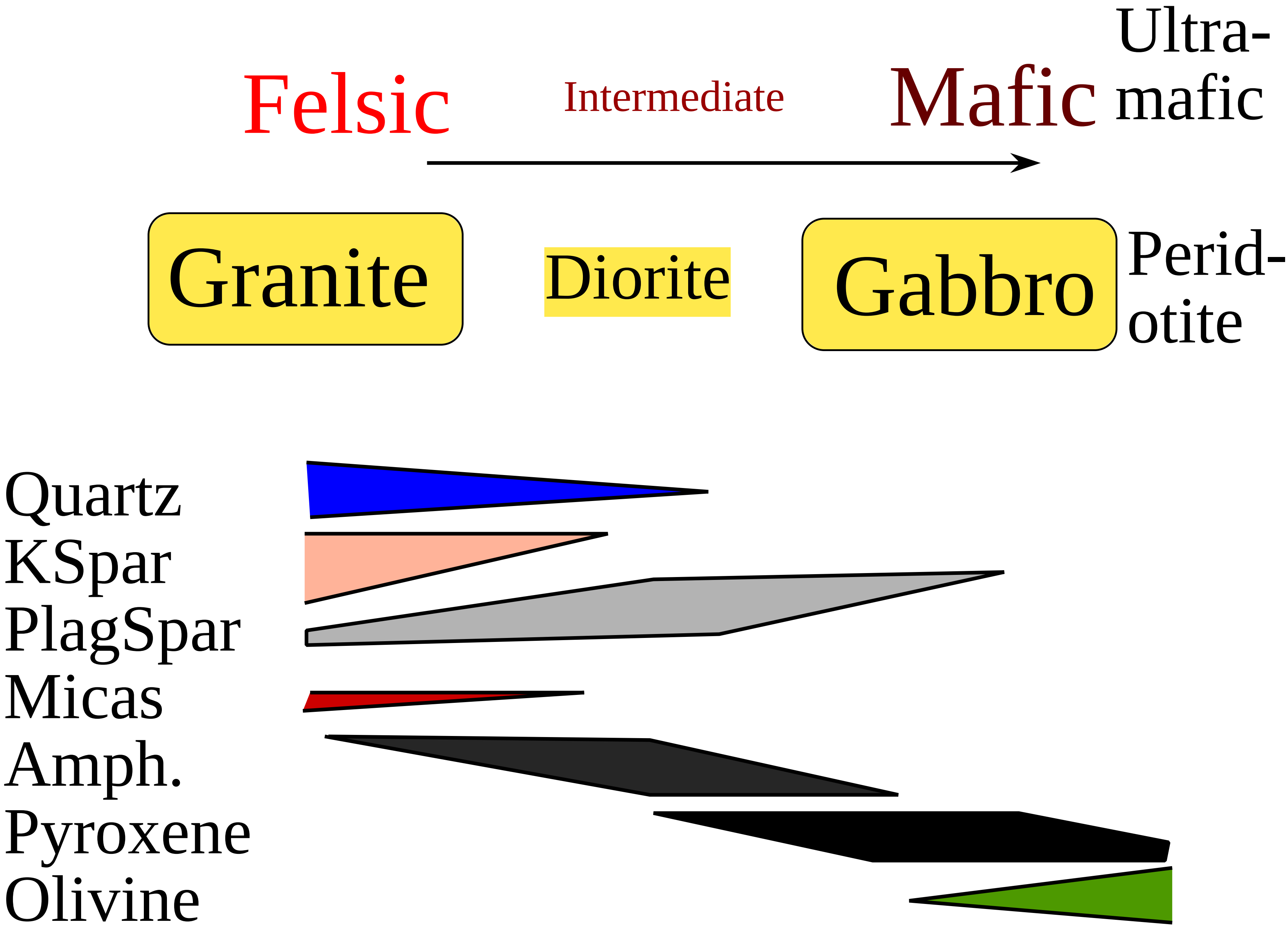
light	dark
large ions (K, Na)	small ions (Mg, Fe)
more Si (>60%)	less Si (≤ 50%)

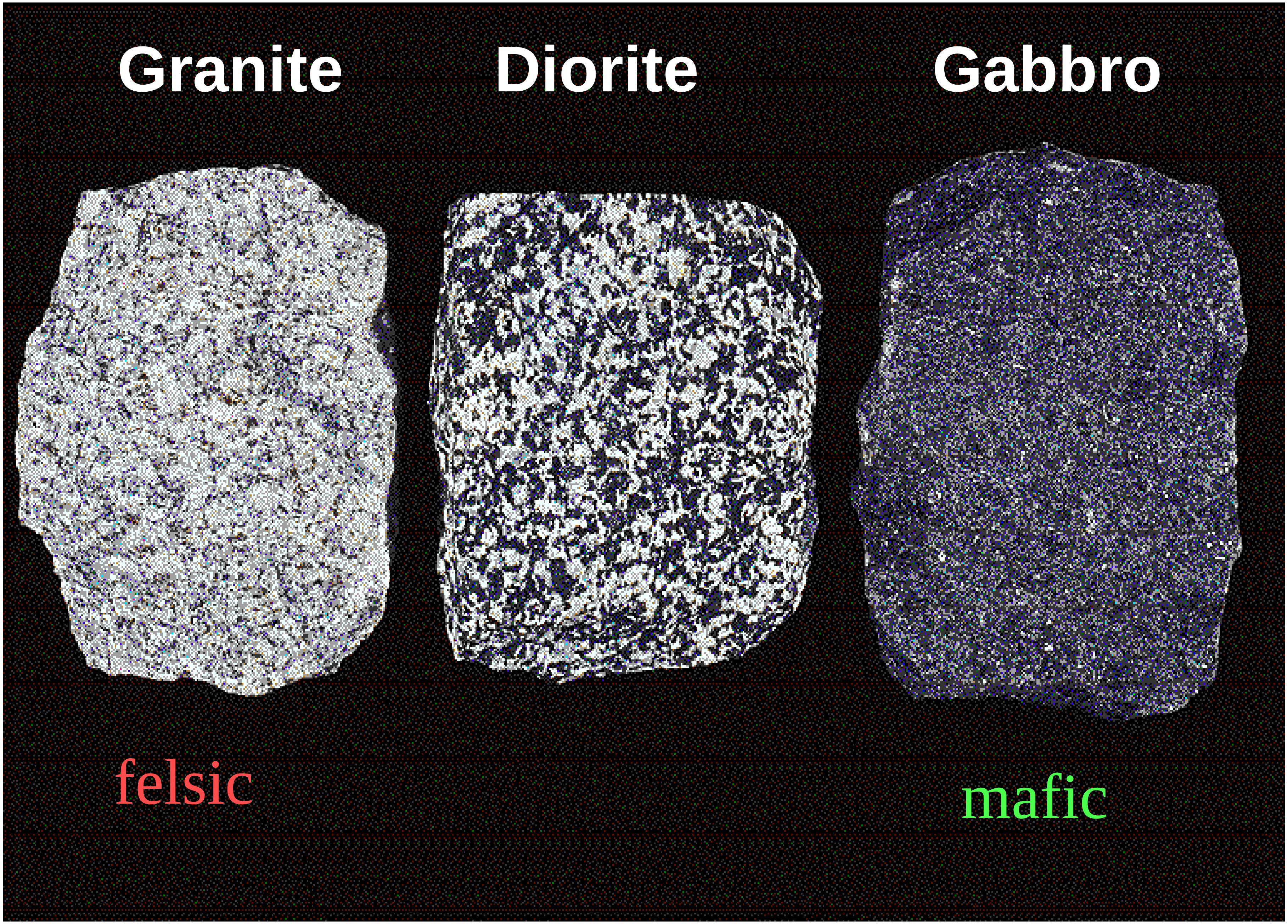
felsic ->intermediate-> **mafic**

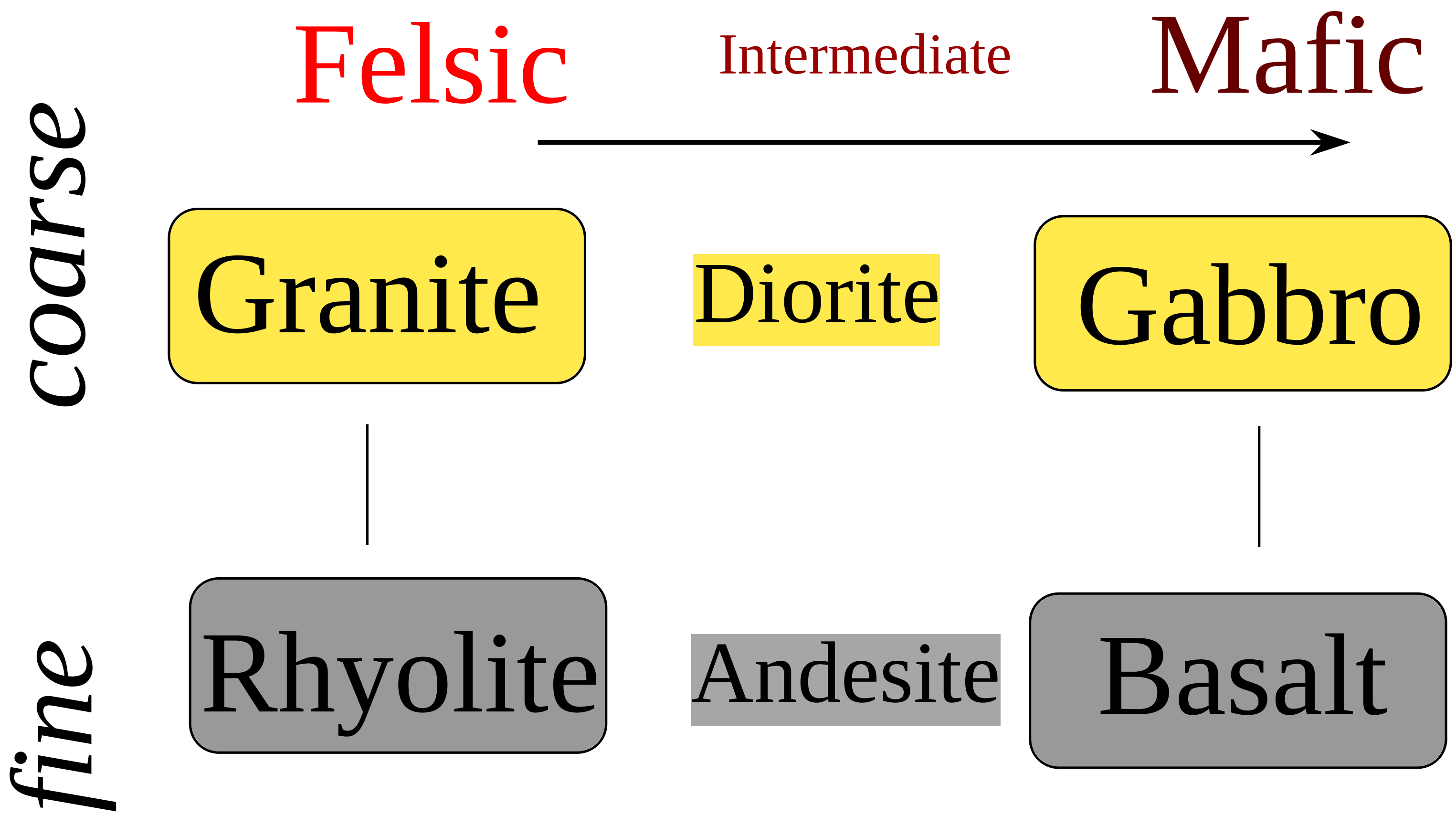
light	dark
large cations (K, Na)	small cations (Mg, Fe)
more Si (>60%)	less Si (≤ 50%)
cooler magmas	hotter magmas
light minerals	dense minerals

which more explosive? minerals?


Ultra-
Felsic
Intermediate
Mafic
mafic
Quartz
KSpar
PlagSpar
Micas
Amph.
Pyroxene
Olivine


Felsic
Intermediate
Mafic
Ultra-
mafic
Granite
Diorite
Gabbro
Perid-
otite
Quartz
KSpar
PlagSpar
Micas
Amph.
Pyroxene
Olivine


Granite
Diorite
Gabbro
felsic
mafic


Felsic
Intermediate
Mafic
coarse
Granite
Diorite
Gabbro
fine
Rhyolite
Andesite
Basalt

rock slides

Gabbro (coarse) Basalt (fine)

Mafic Igneous Rocks

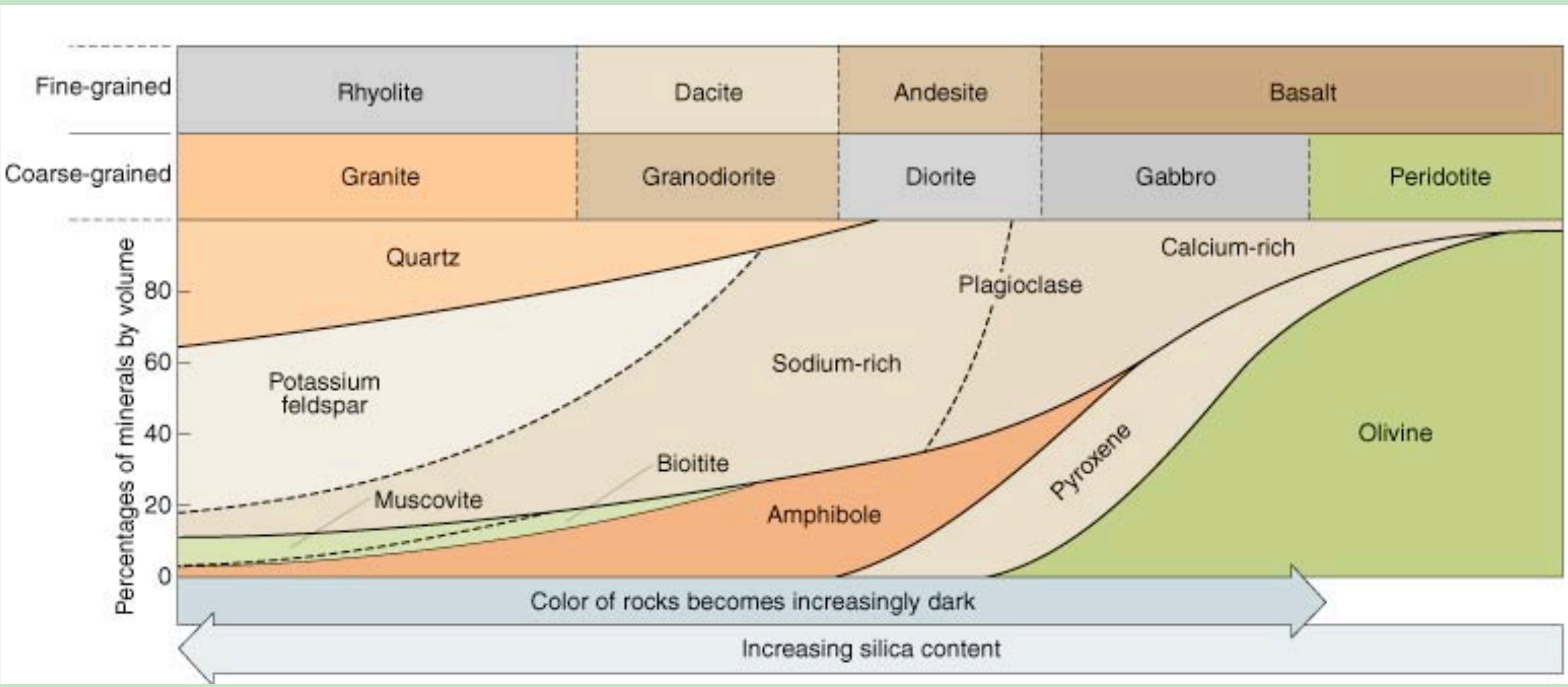
Diorite (coarse) Andesite (fine)

Intermediate Igneous Rocks

Granite (coarse) Rhyolite (fine)

Felsic Igneous Rocks

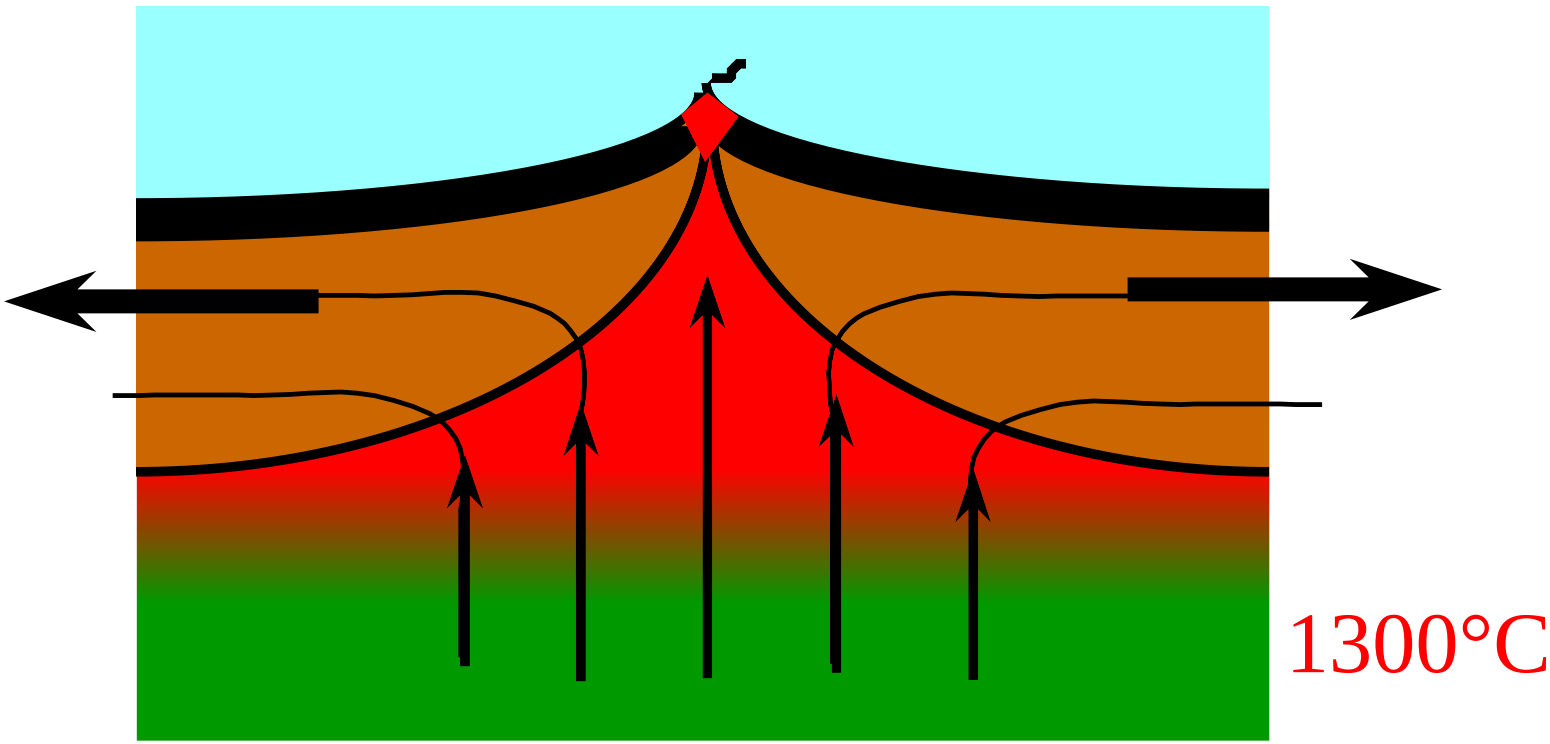
Classifying igneous rocks by composition and texture



<u>Ridges:</u>

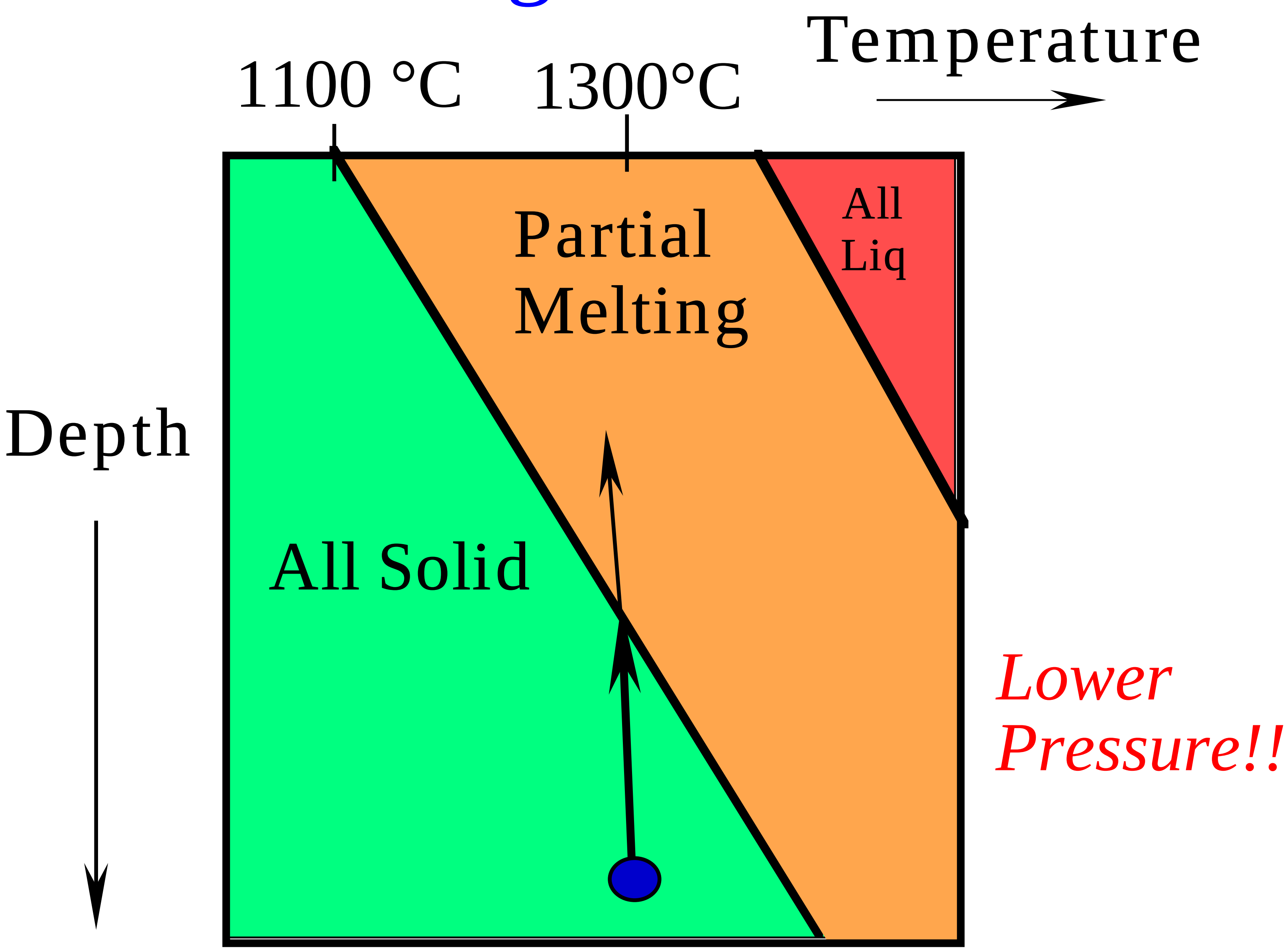
Mantle undergoes **decompression melting**

--->>> Basalts (dry)



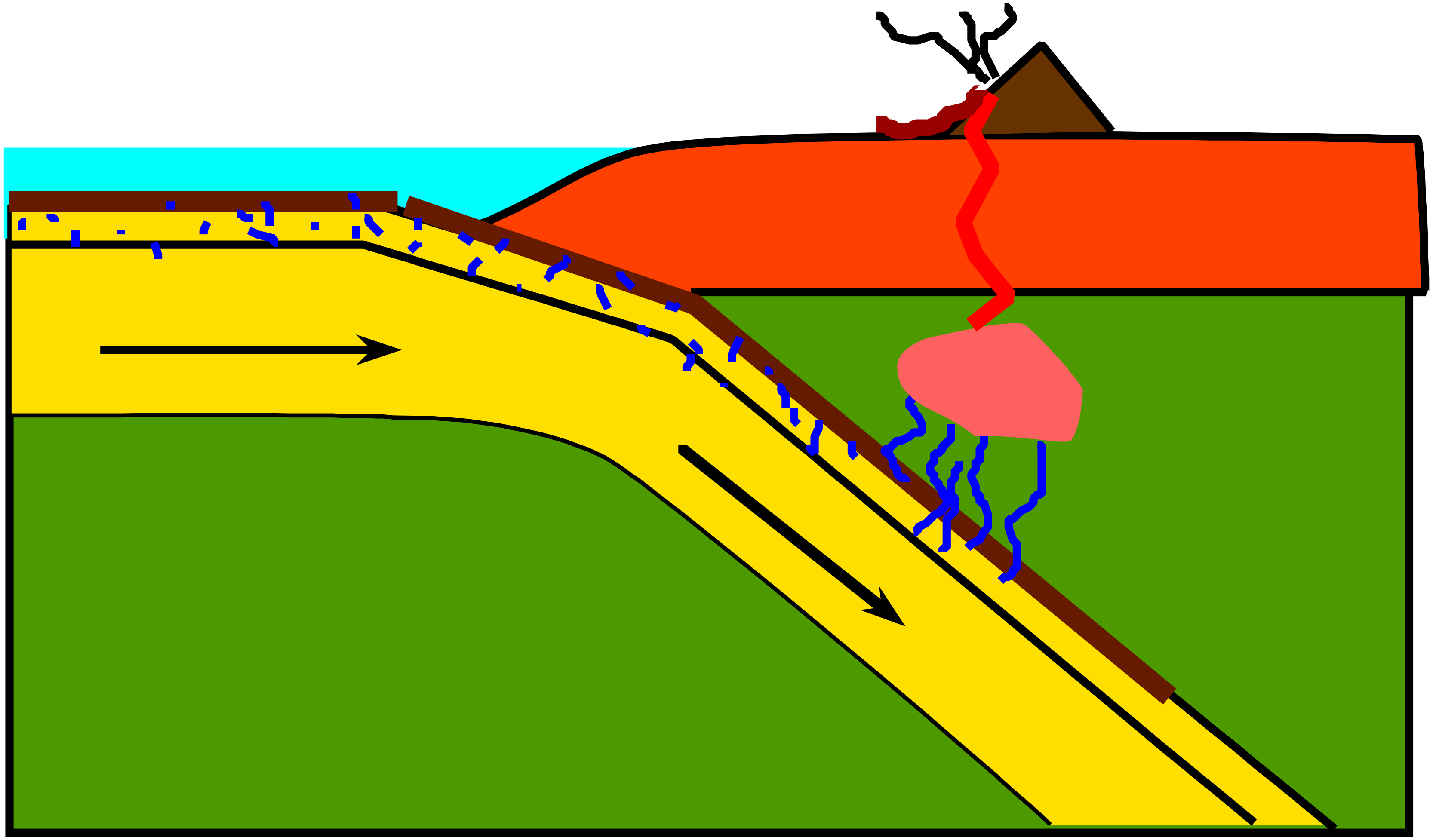
basalt = mantle melt ("blood of the Earth")

Mantle Melting

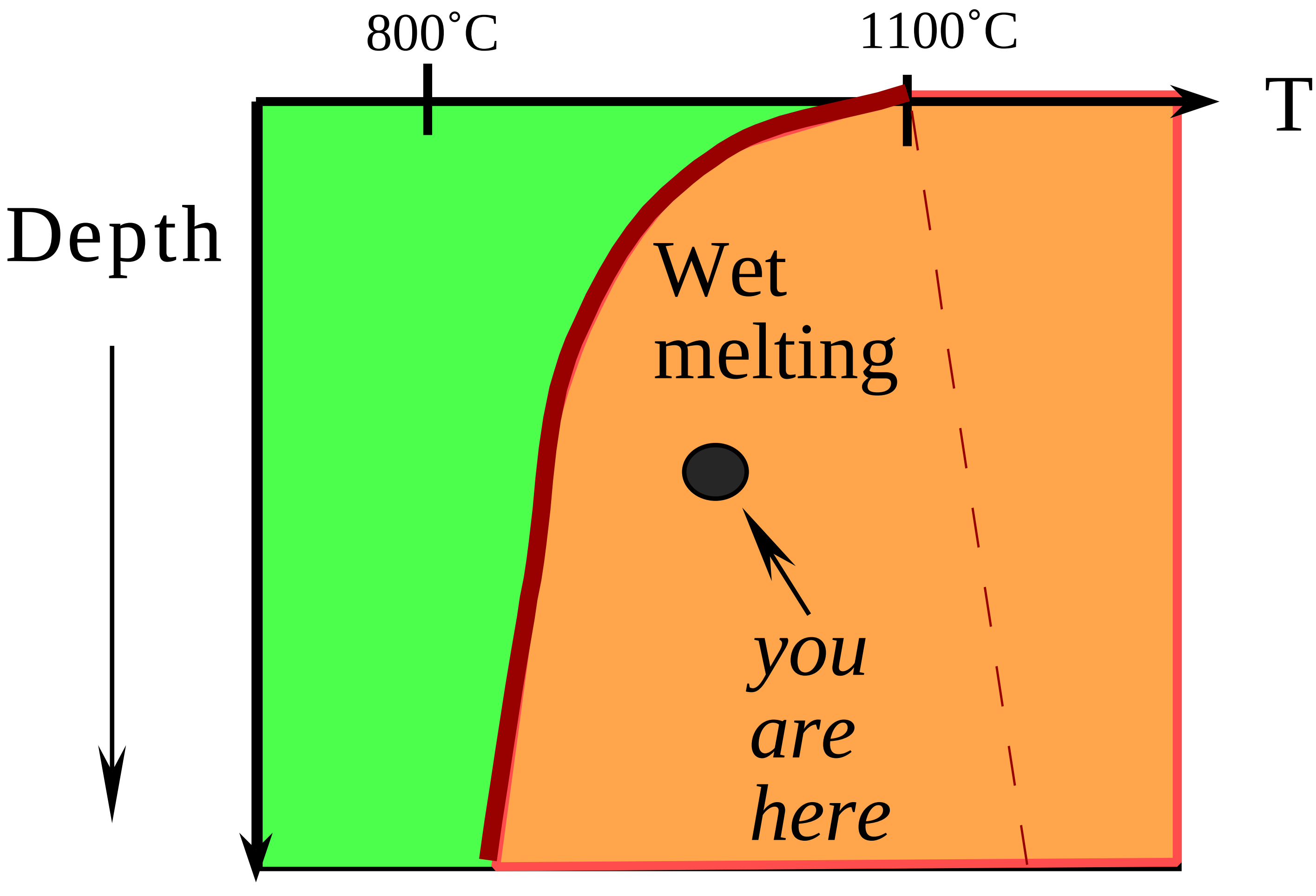


water --> **mantle wedge**,

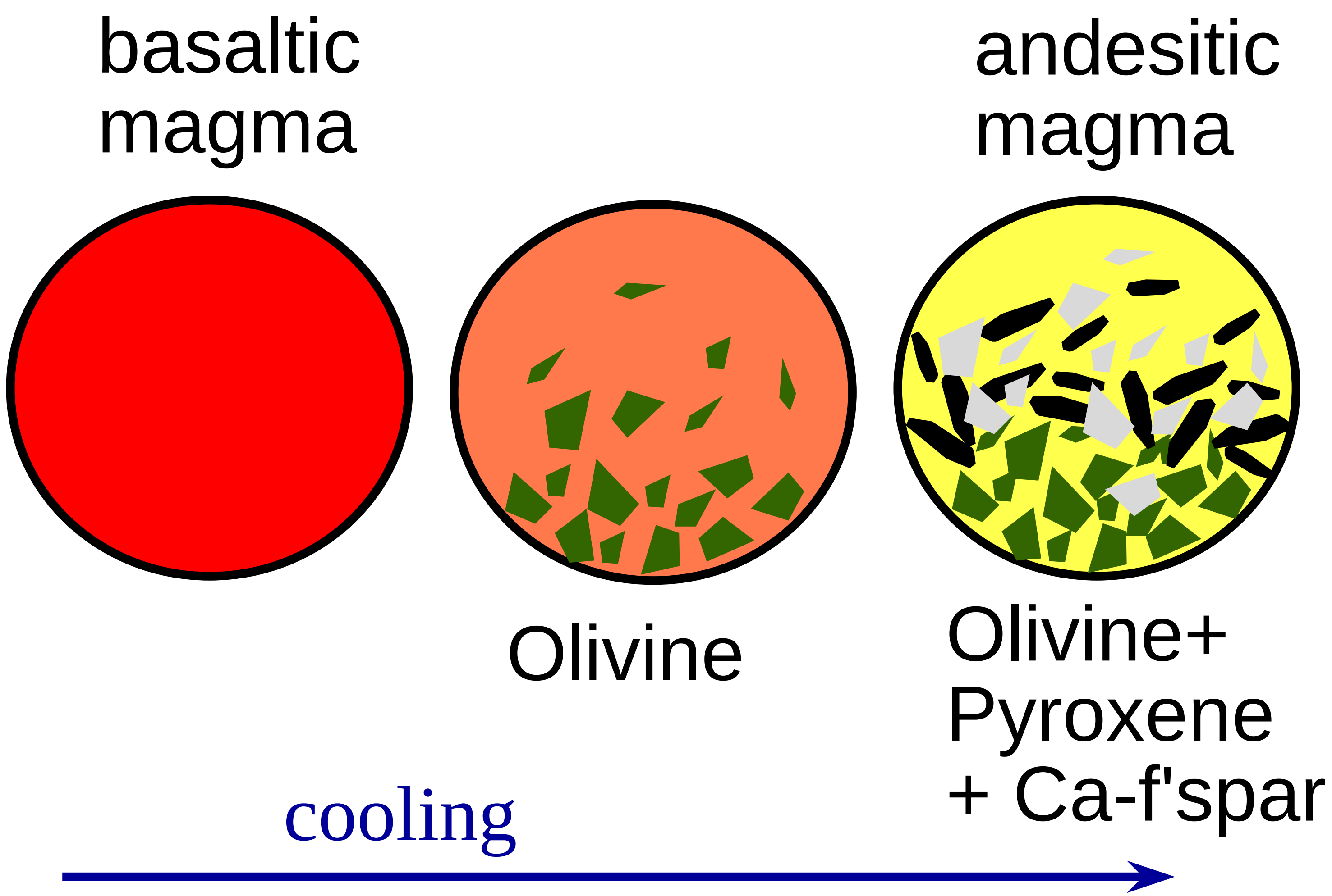
--> basalt arc volcanism...



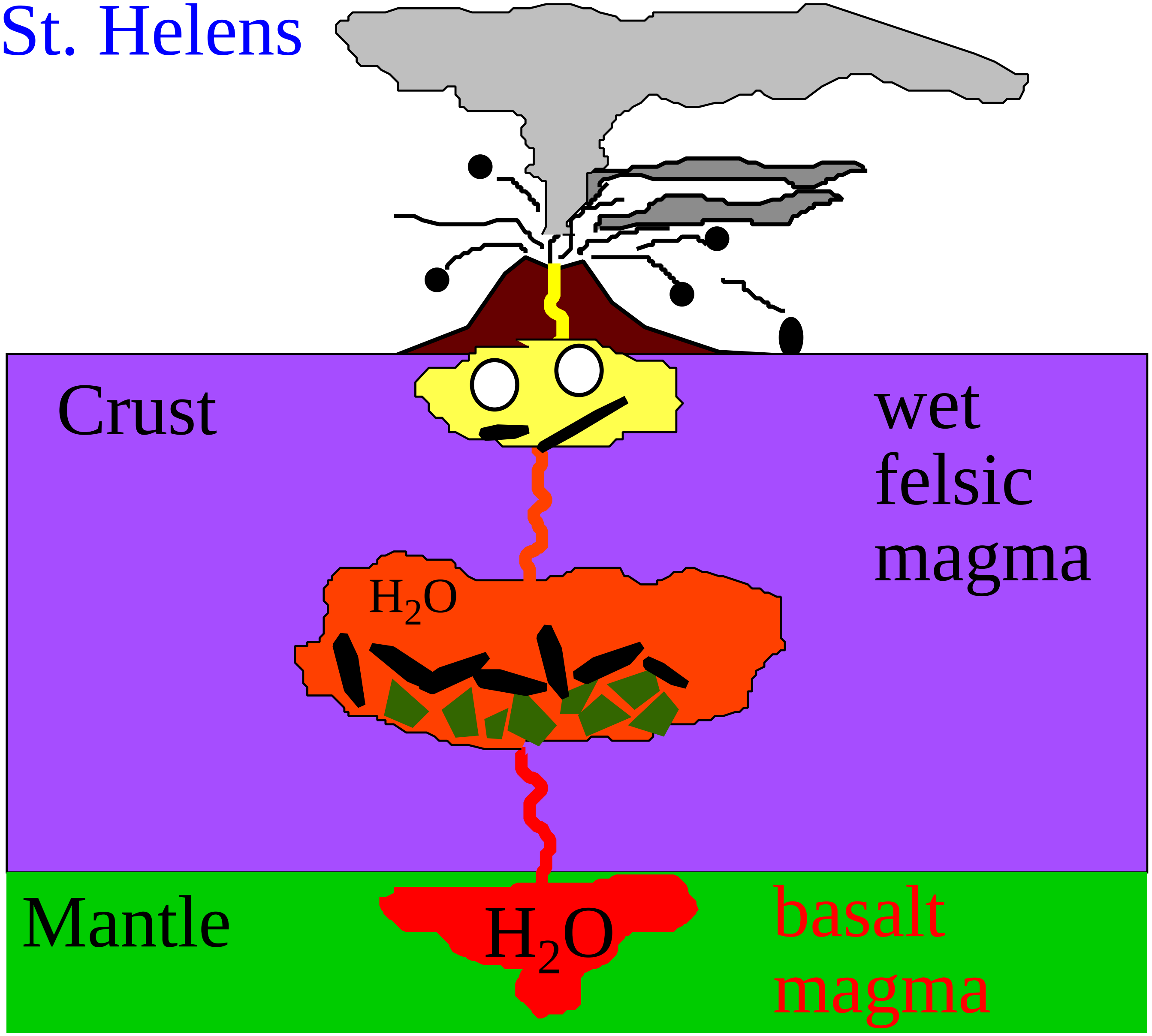
H_2O -- Lowers Melting Point

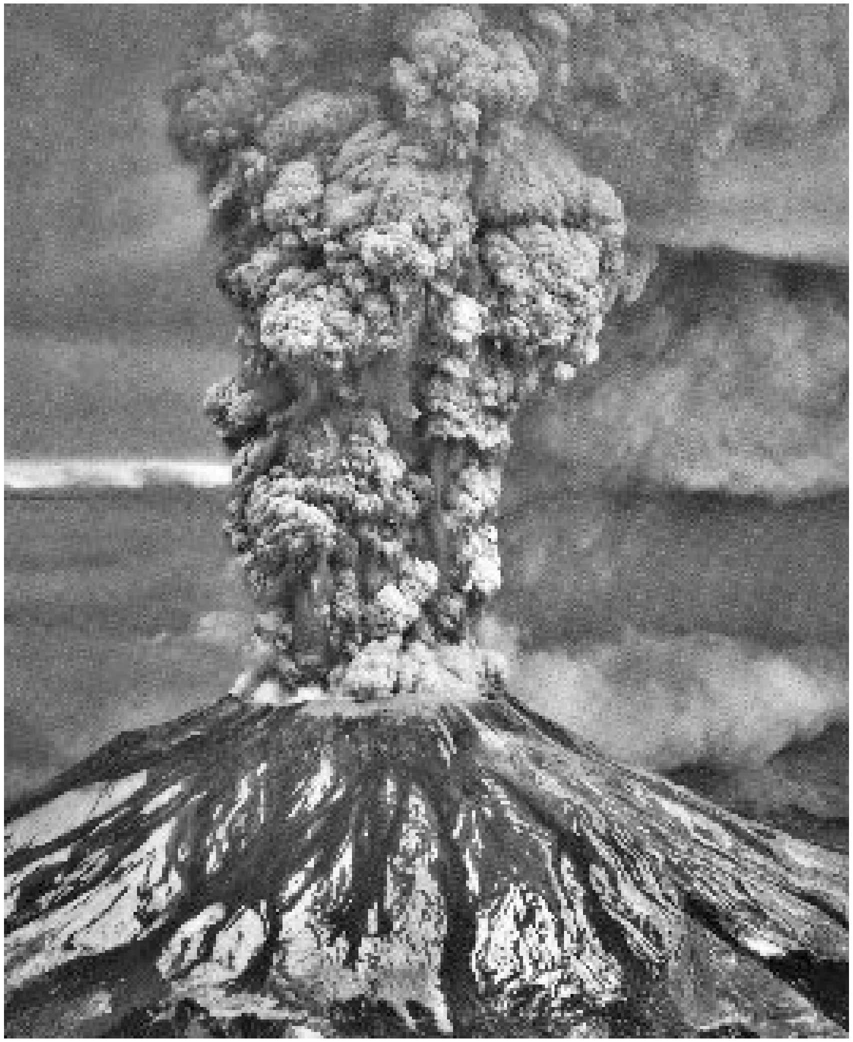


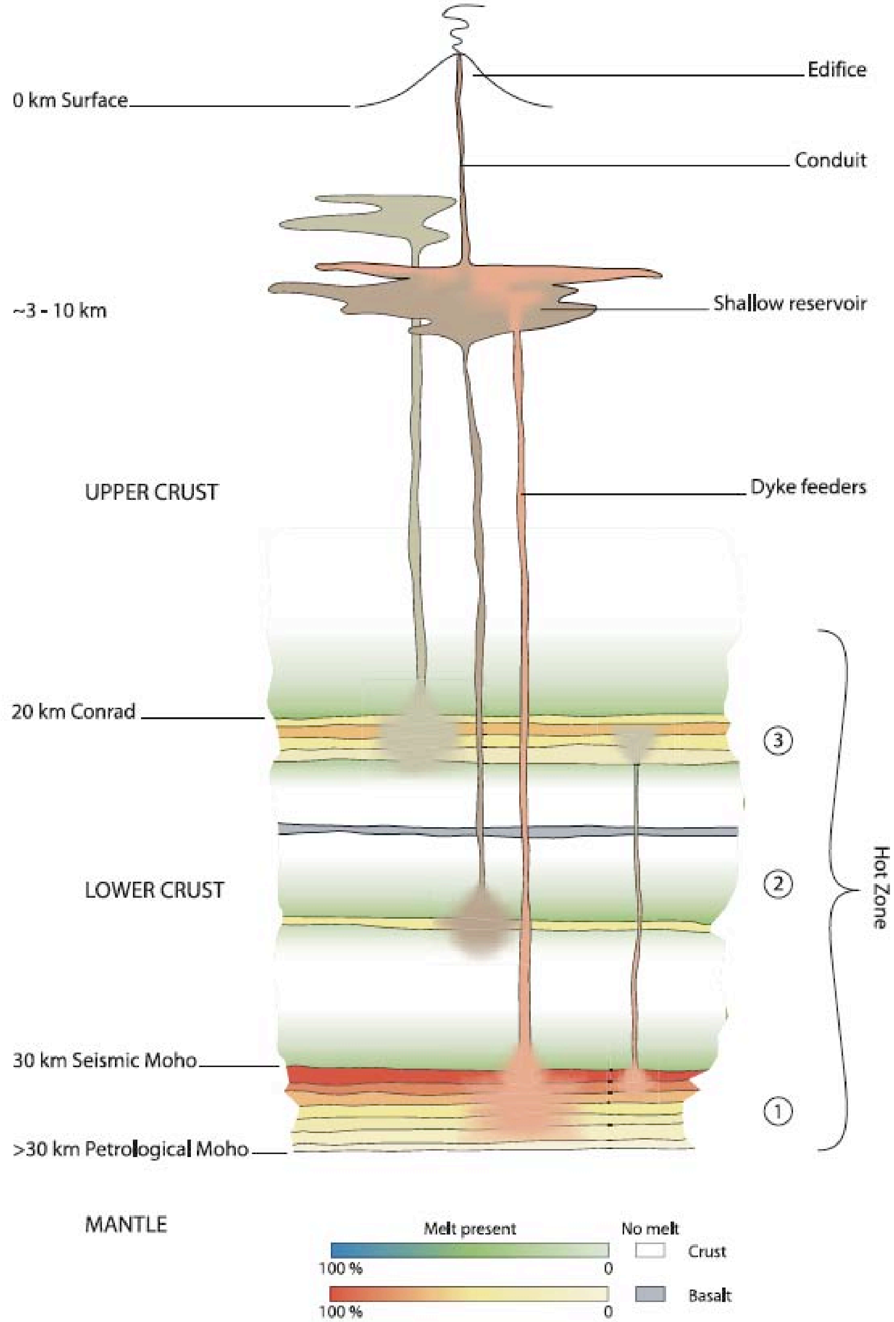
basaltic melts -> andesite melts



Mt. St. Helens



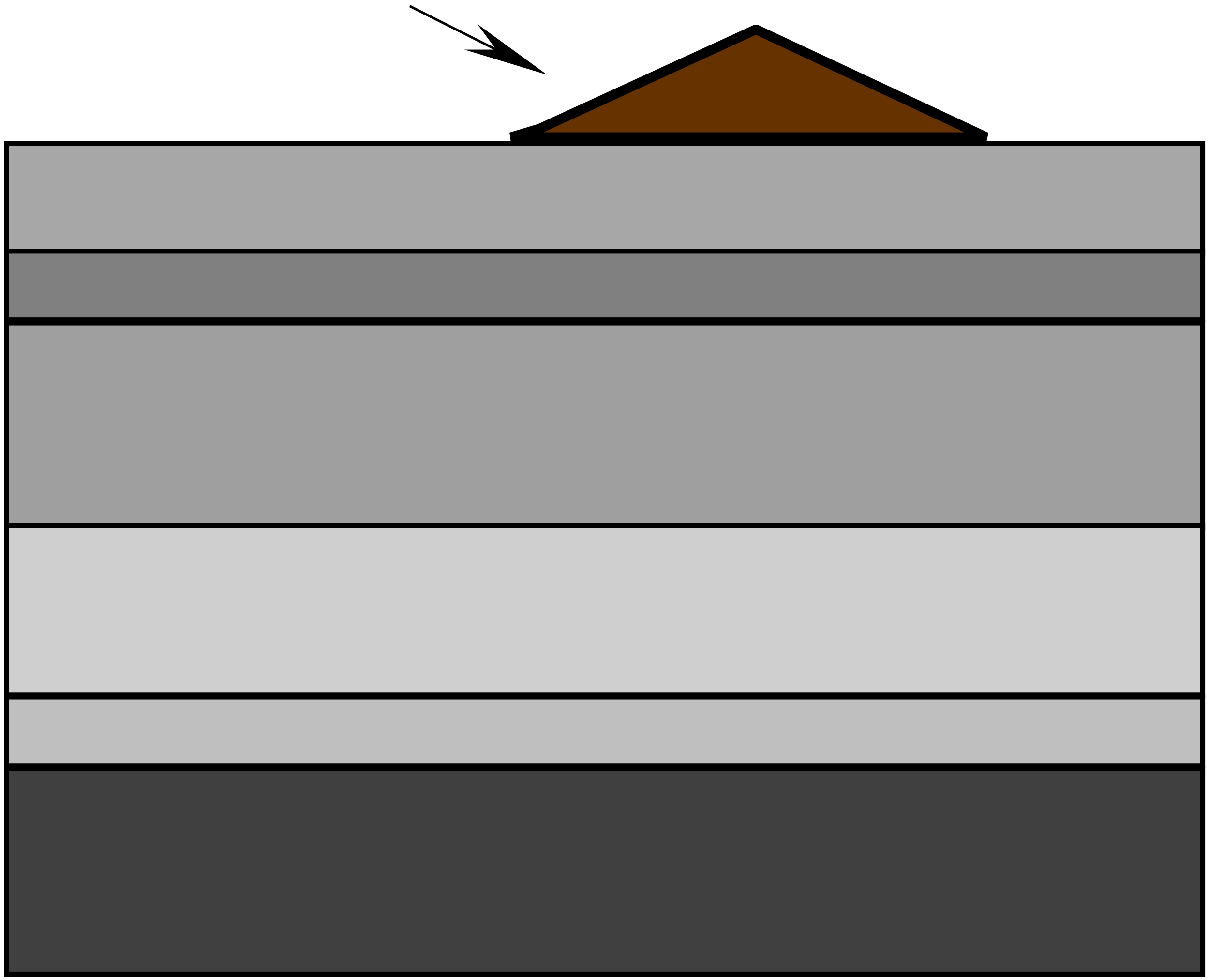




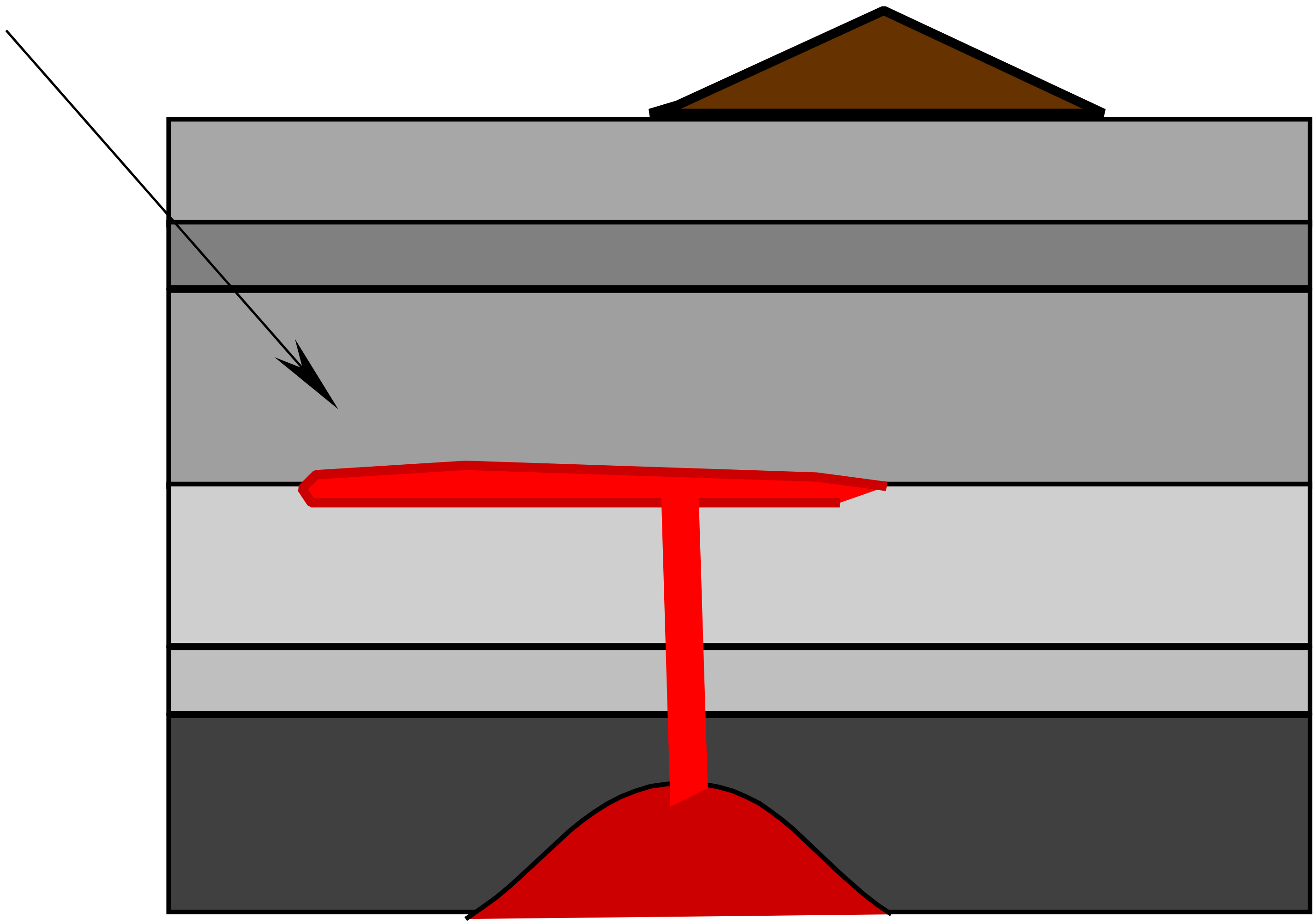
Edifice
0 km Surface
Conduit
~3 - 10 km
Shallow reservoir
UPPER CRUST
Dyke feeders
20 km Conrad
3
LOWER CRUST
2
Hot Zone
30 km Seismic Moho
1
>30 km Petrological Moho
MANTLE
Melt present
No melt
100 %
0
Crust
100 %
0
Basalt

Volcanic/Extrusive Rocks

cool fast, fine-grained

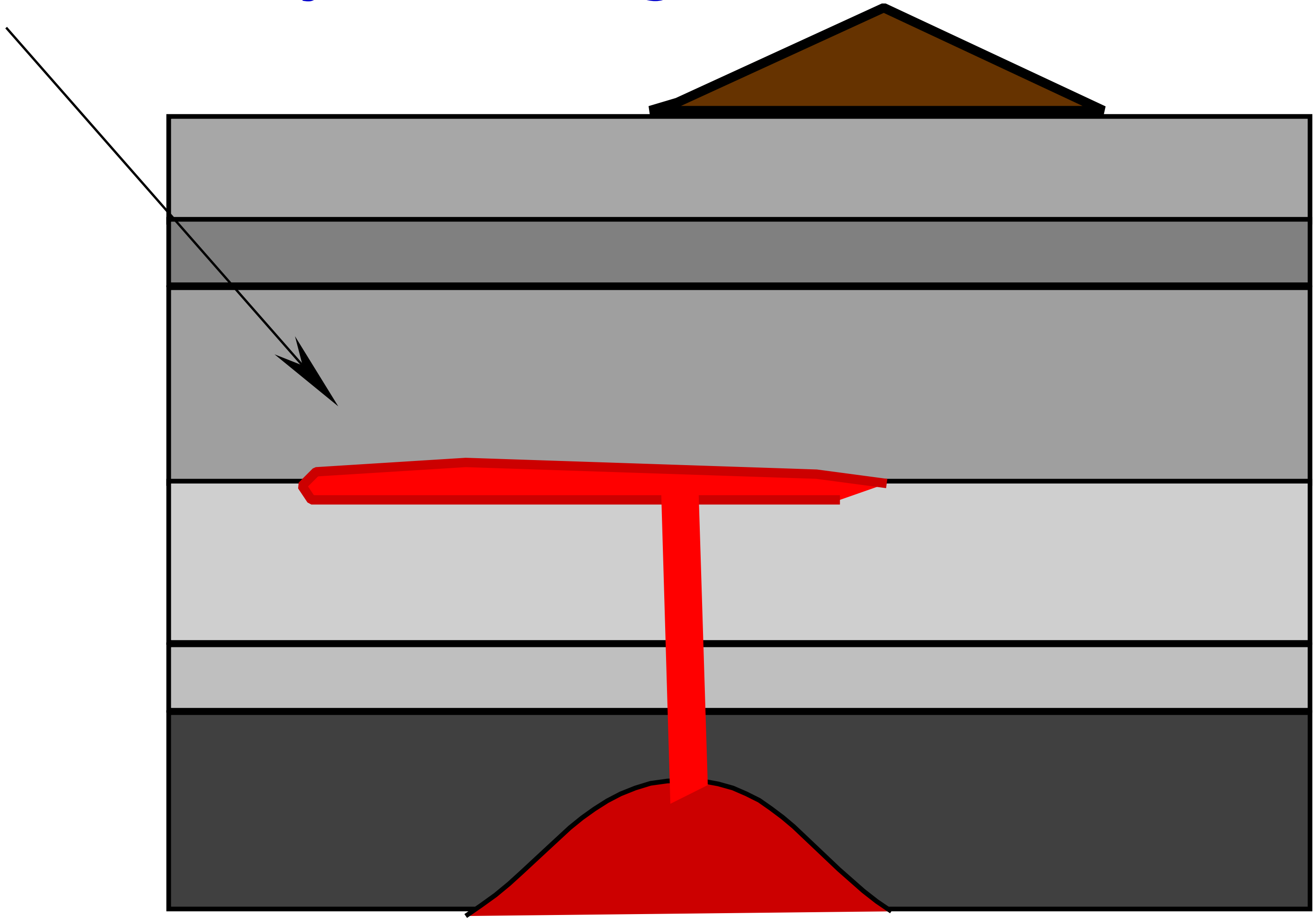


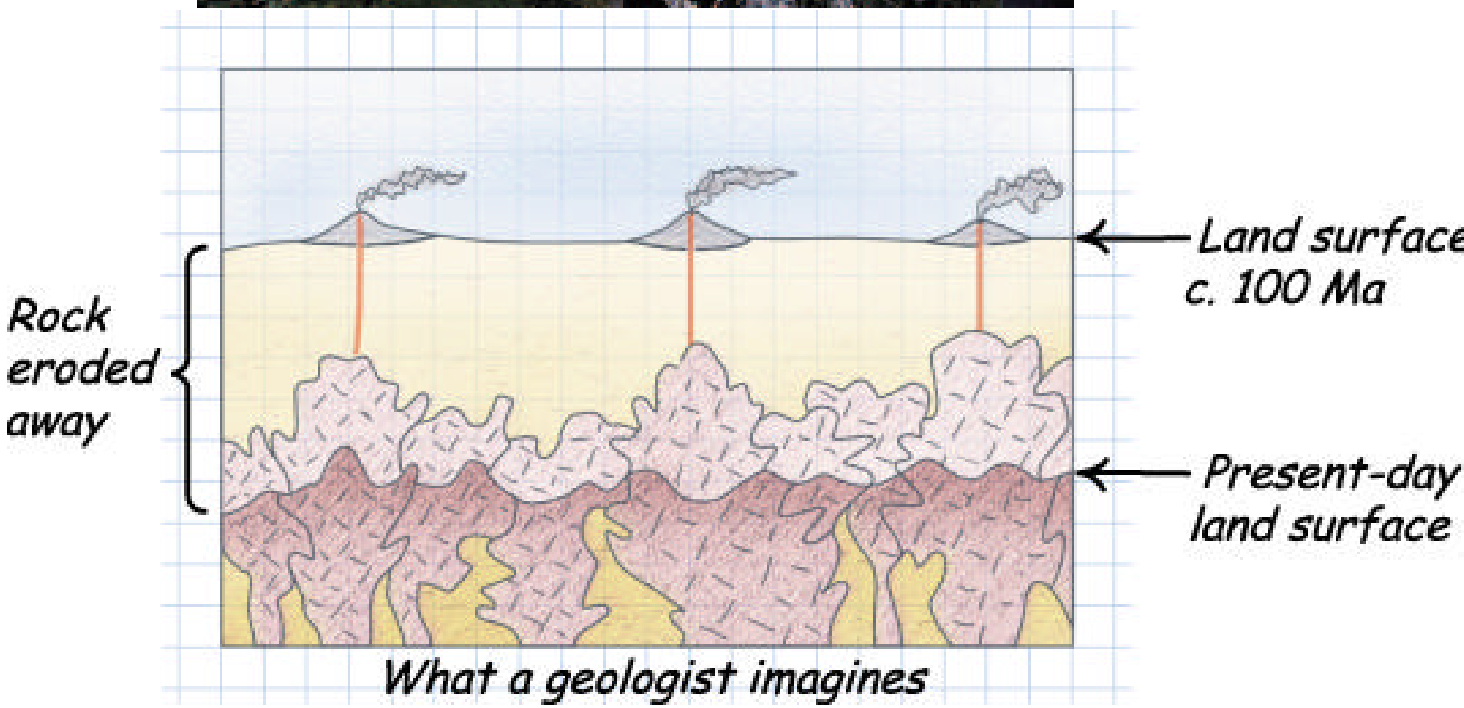
magma also cools under ground......

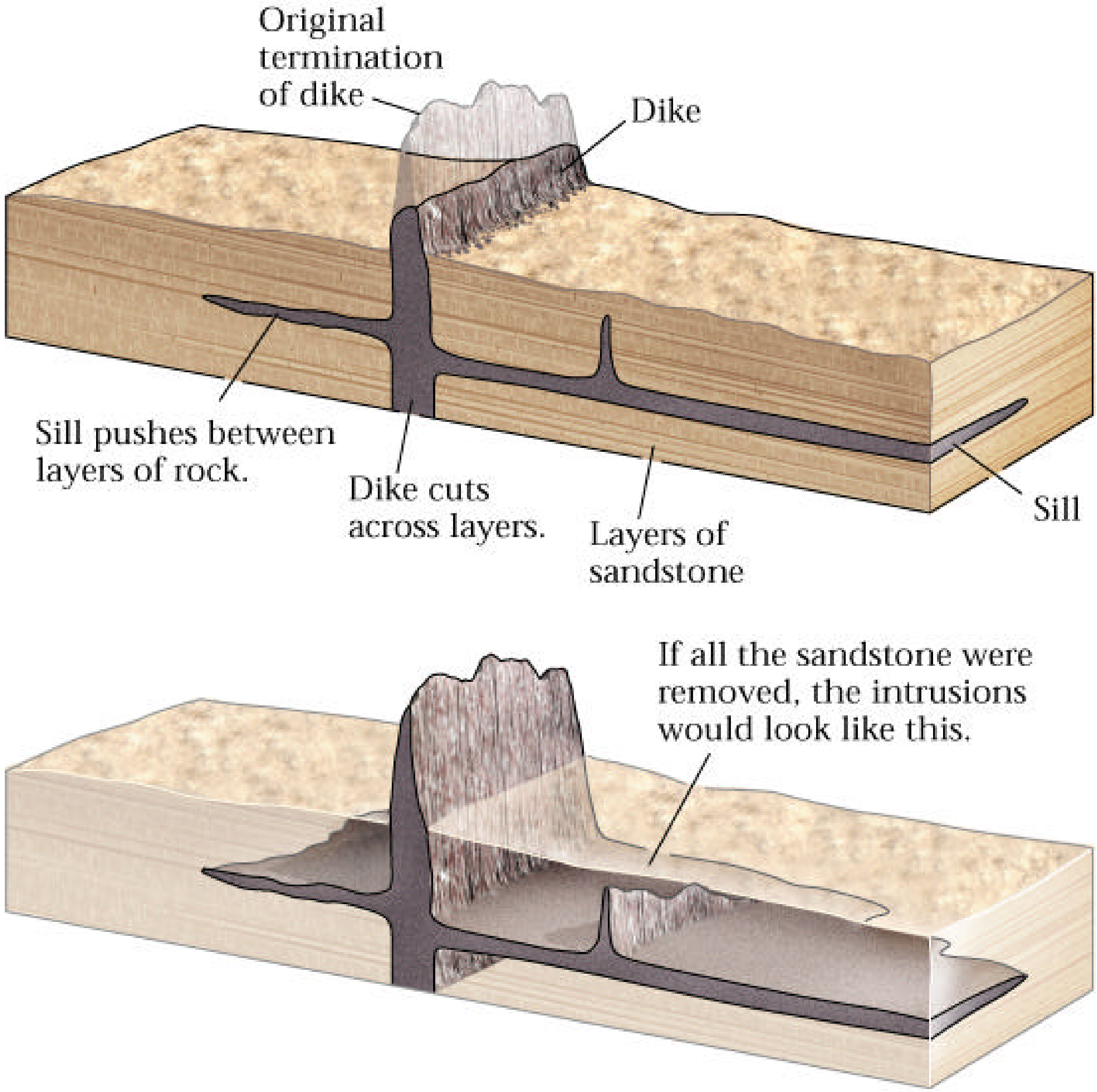


Plutonic/Intrusive Rocks

cool slowly, coarse-grained

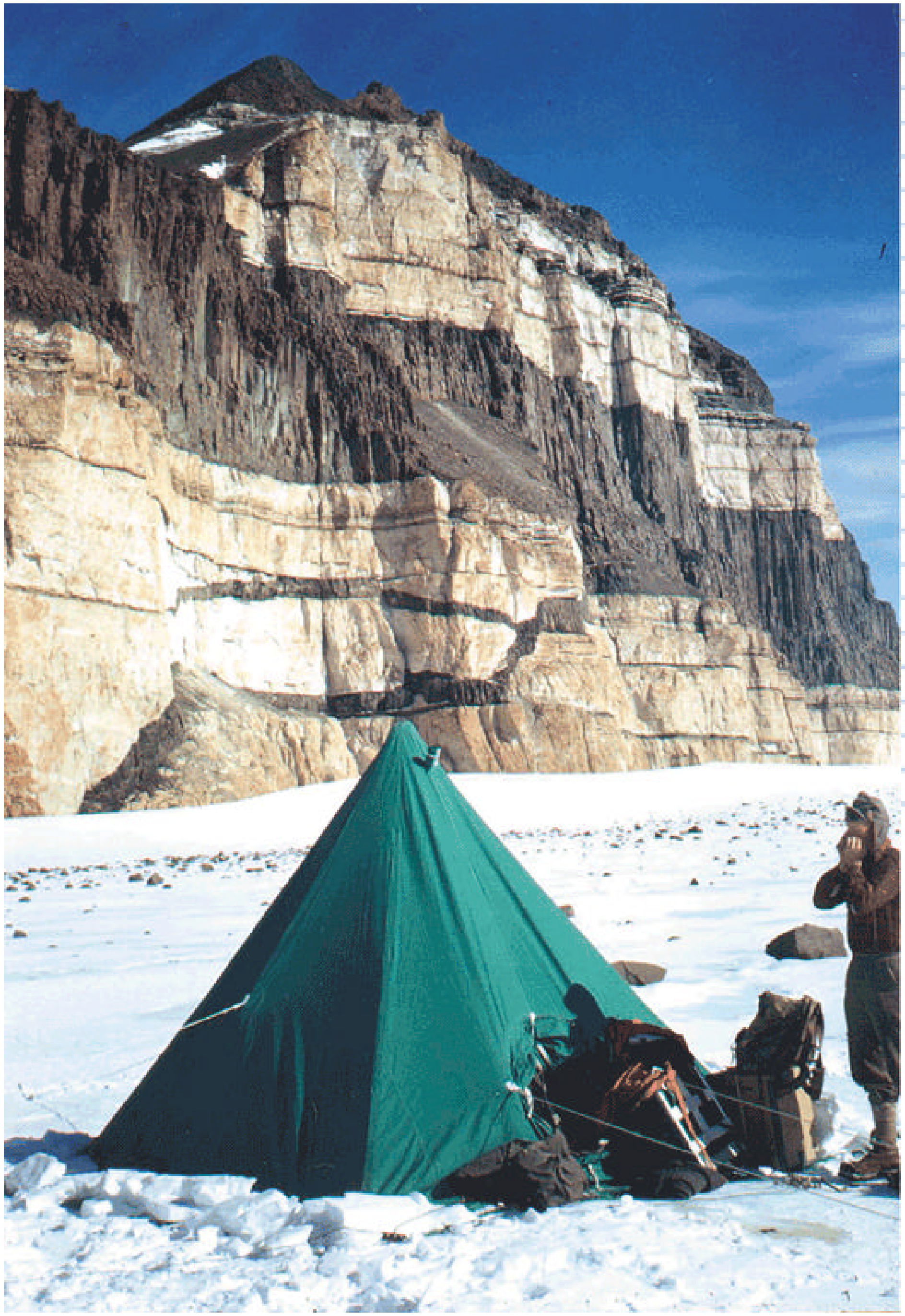


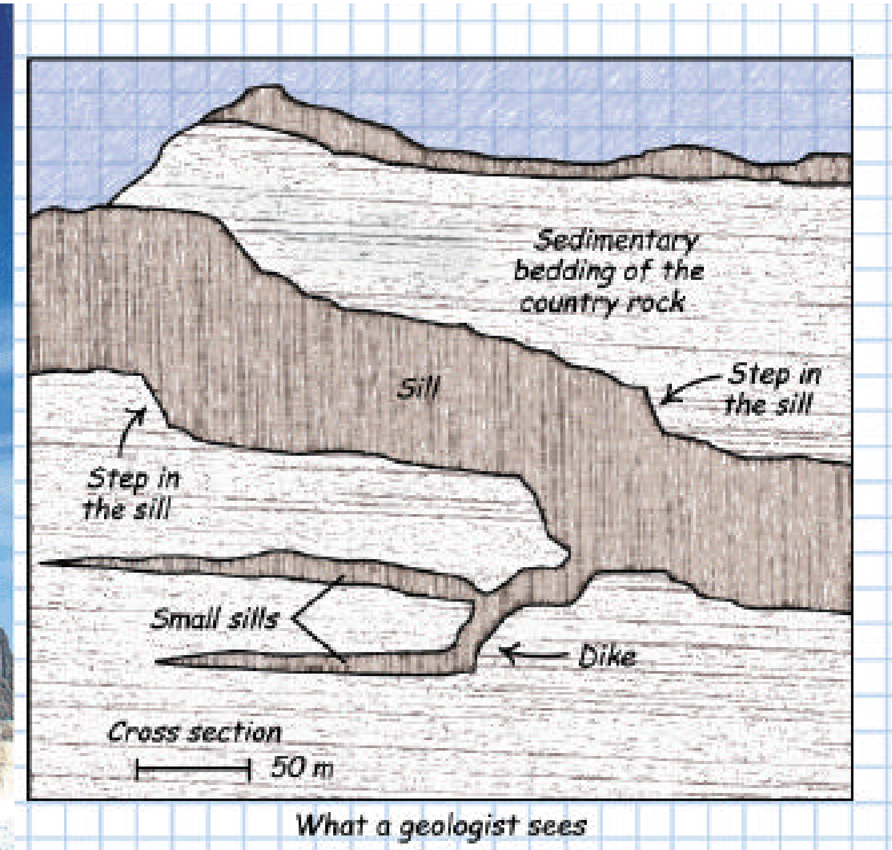

Rock
eroded
away
Land surface
c. 100 Ma
Present-day
land surface
What a geologist imagines


Original termination of dike
Dike
Sill pushes between layers of rock.
Dike cuts across layers.
Layers of sandstone
Sill
If all the sandstone were removed, the intrusions would look like this.

Dike

Stephen Marshak

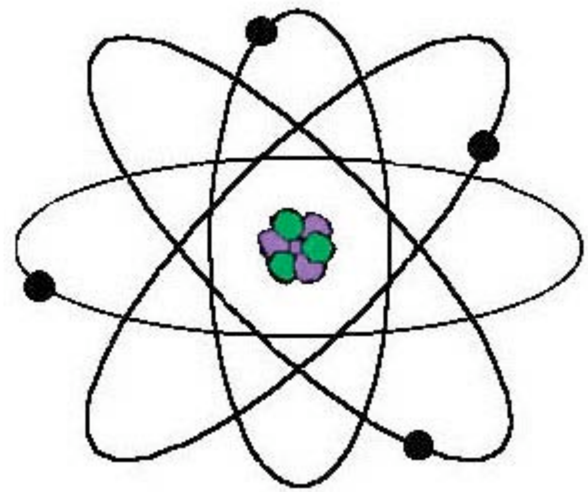



Sedimentary
bedding of the
country rock
Sill
Step in
the sill
Step in
the sill
Small sills
Dike
Cross section
50 m
What a geologist sees

Geochronology Outline:

1) Relative ages

2. Absolute Radiometric Ages

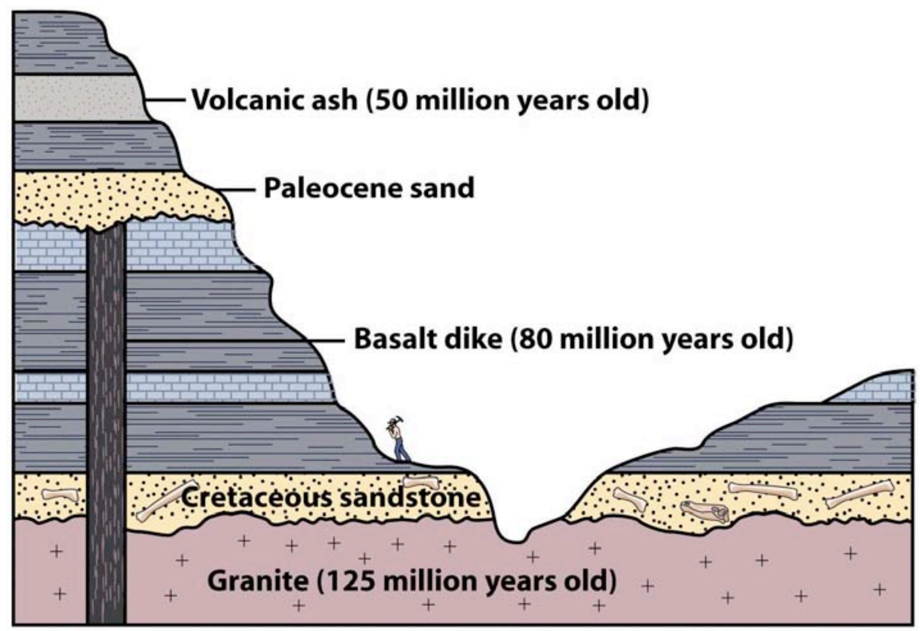


Geologic Time

Principles of Geochronology

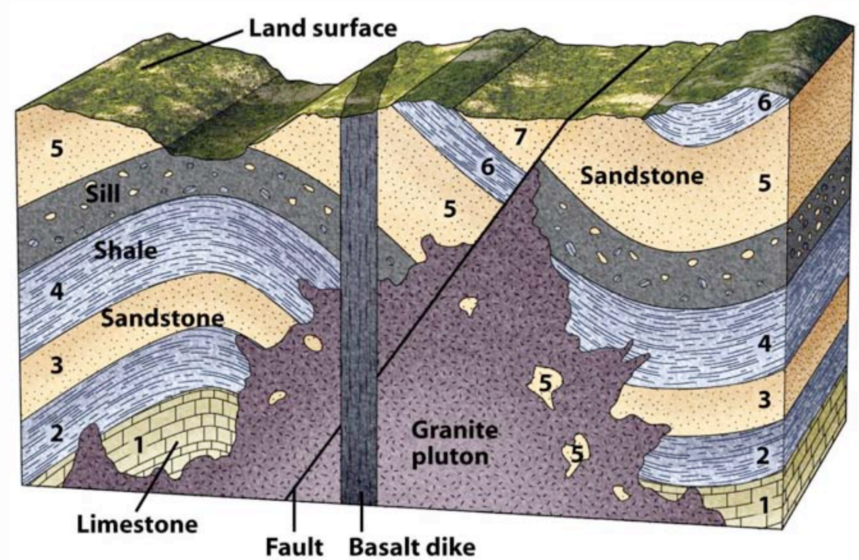
How do we determine age in the geological record?

Go out to the field. Observations yield *relative age.*



Relative Ages

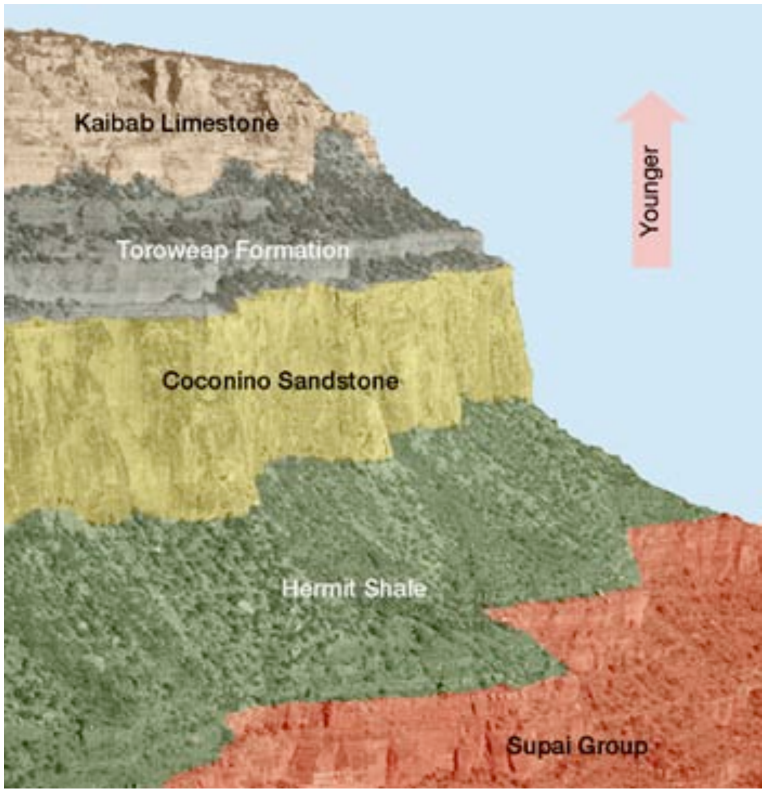
- Logical tools are useful for defining relative age.
  - Principle of uniformitarianism.
  - Principle of superposition.
  - Principle of original horizontality.
  - Principle of original continuity.
  - Principle of cross-cutting relationships.
  - Principle of inclusions.
  - Principle of baked contacts.



Geologic Time

- Uniformitarianism – The present is key to the past.
  - Physical processes that we observe today operated in the same way in the geological past.
  - Modern processes help us understand ancient events in the rock record.

Law of Superposition

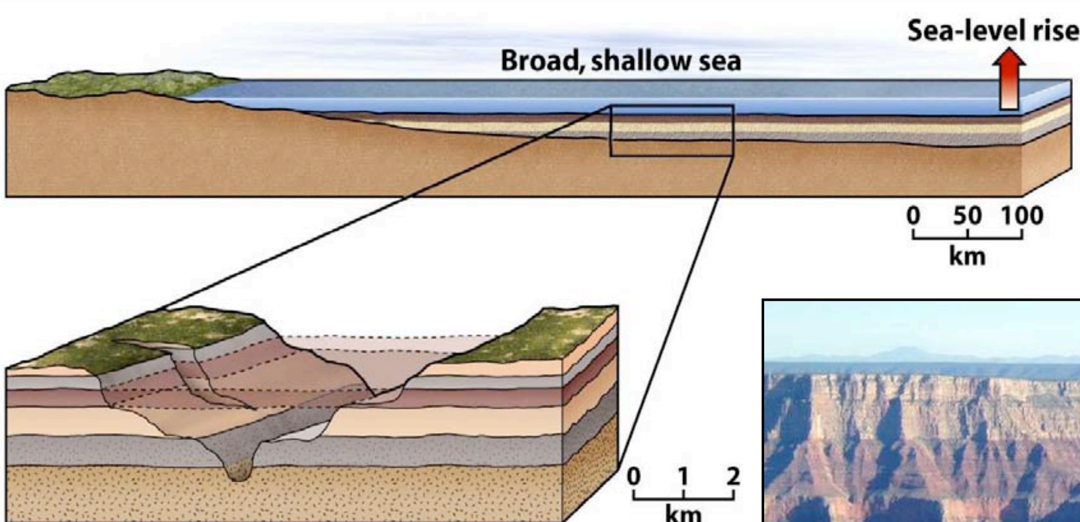


Each layer of rock is older than the layer above it and younger than the rock layer below it.

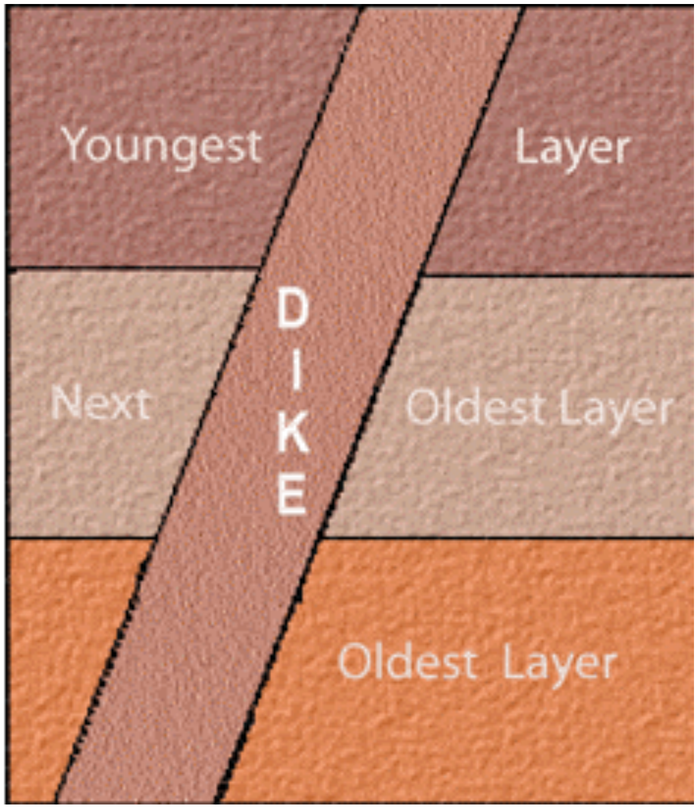
Nicolaus Steno, a Danish anatomist, geologist, and priest (1636 - 1686)

Relative Age

- Horizontality and continuity.
  - Strata often form laterally extensive horizontal sheets.
  - Subsequent erosion dissects once-continuous layers.
  - Flat-lying rock layers are unlikely to have been disturbed.



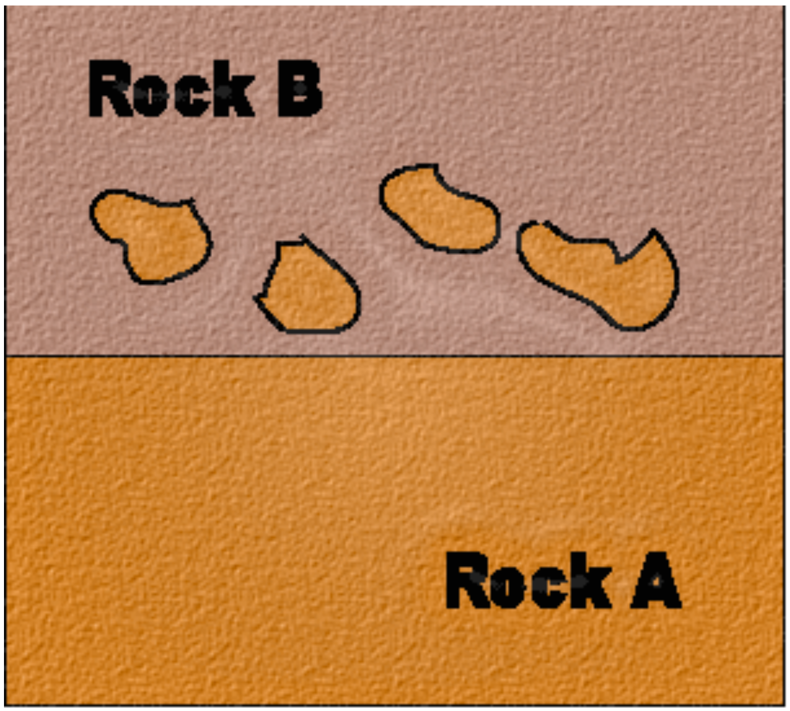
Law of Cross-cutting Relationships



A fault or dike that cuts through another body of rock must be younger than the rock it cuts

Scotsman James Hutton (1726-1797)

Law of Inclusions

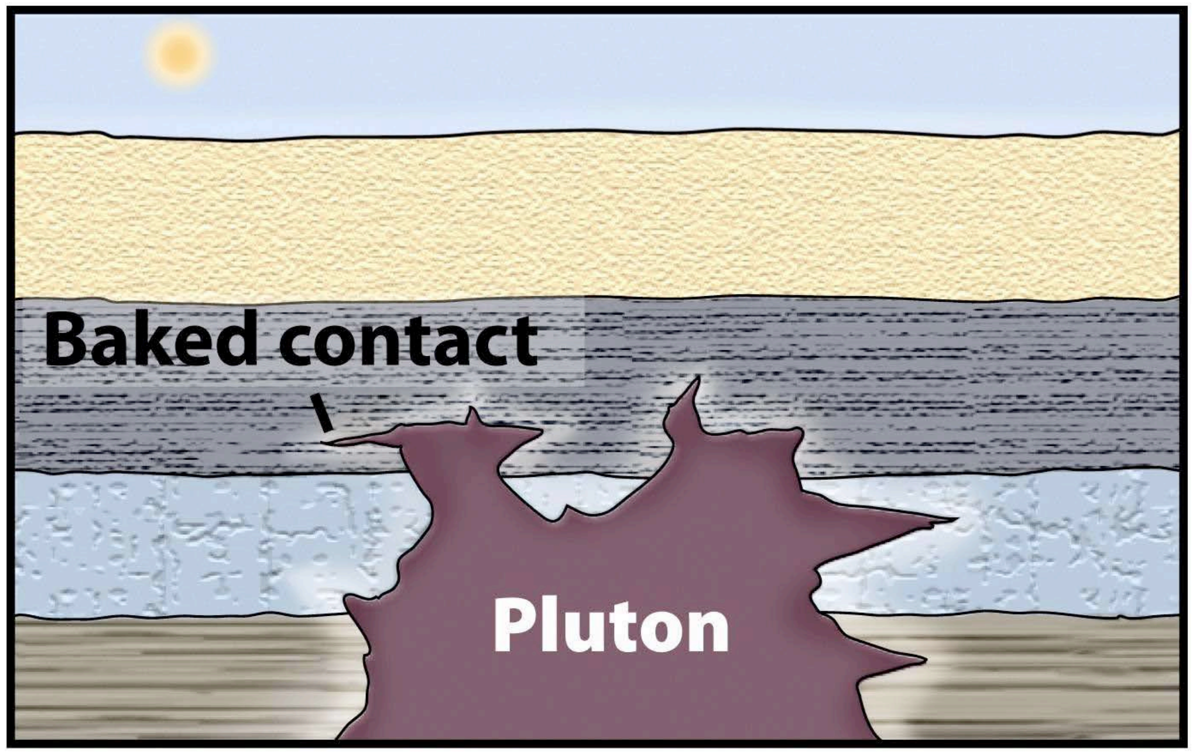


If a rock body (Rock B) contains fragments of another rock body (Rock A), it must be younger than the fragments of rock it contains.

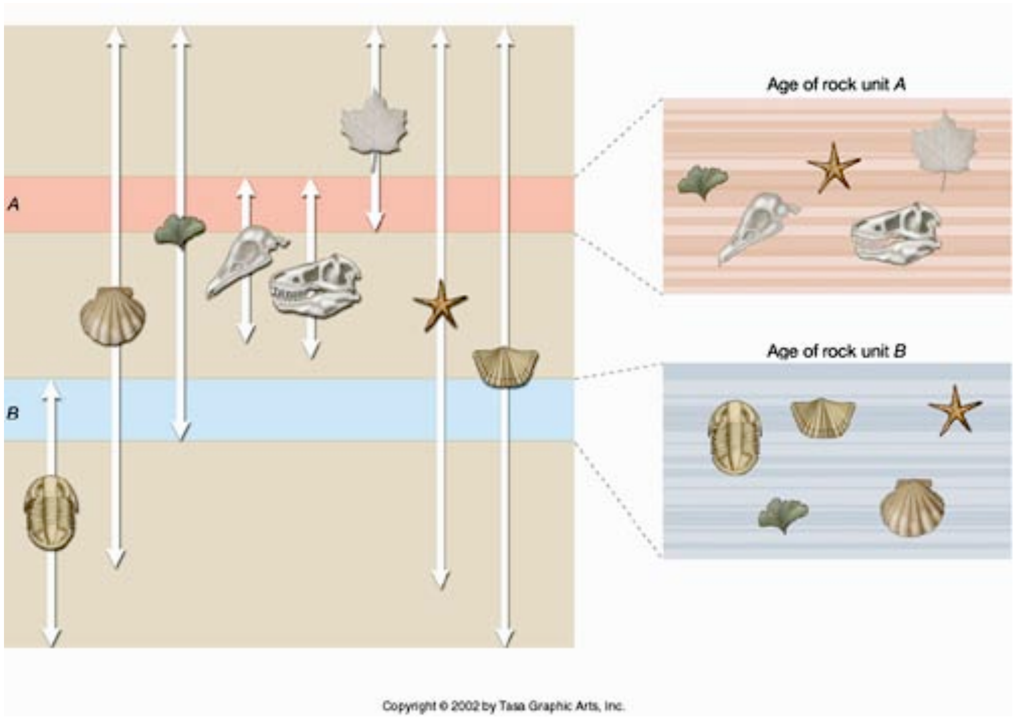
James Hutton

Relative Age

- **Baked contacts.**
  - **Thermal metamorphism occurs when country rock is invaded by a plutonic igneous intrusion.**
  - **The baked rock must have been there first (it is older).**



Law of Faunal Successions



Fossils in rock layers appeared in a predictable sequence, within a discrete period of time.

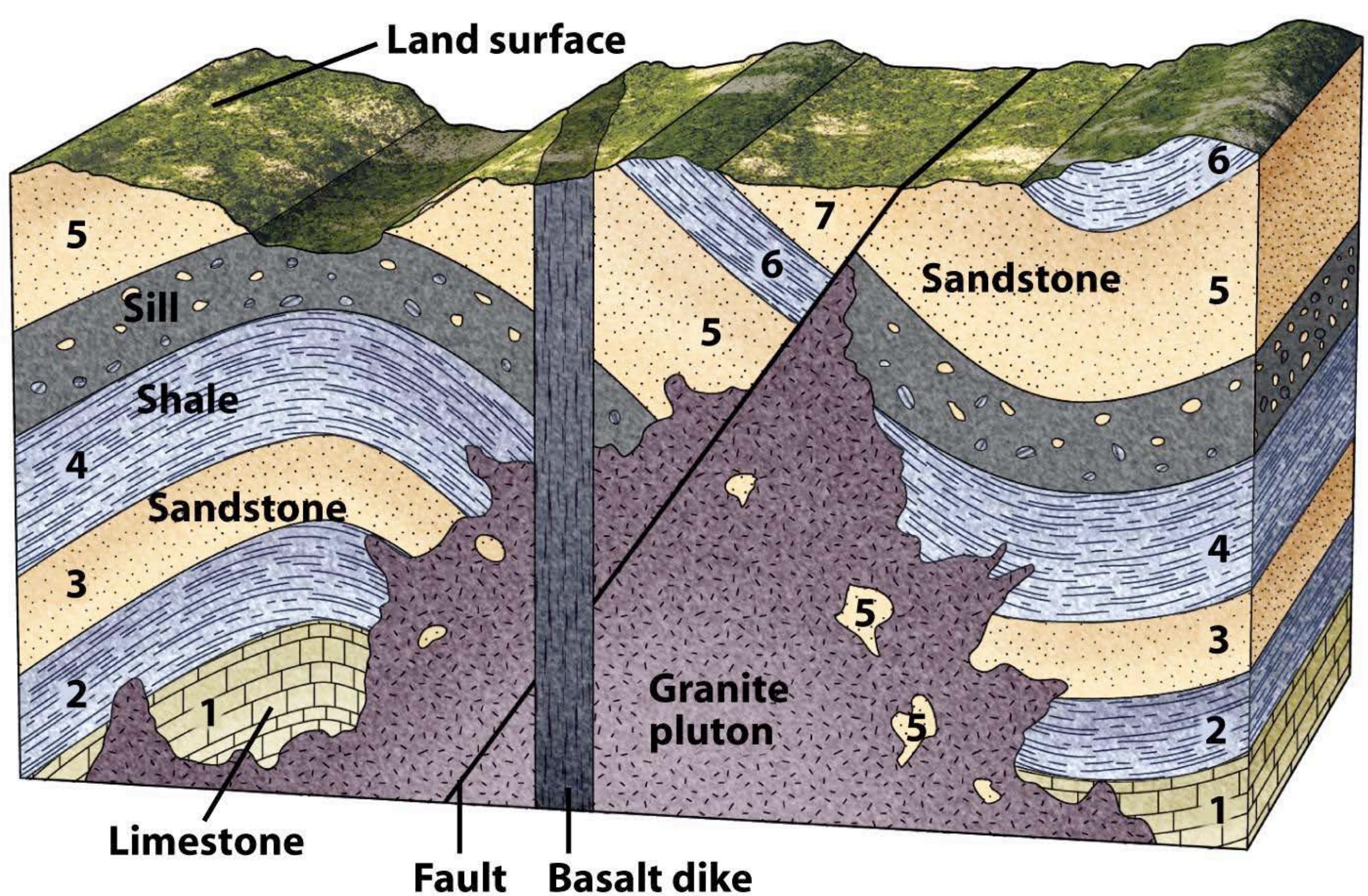
William Smith

Unconformities

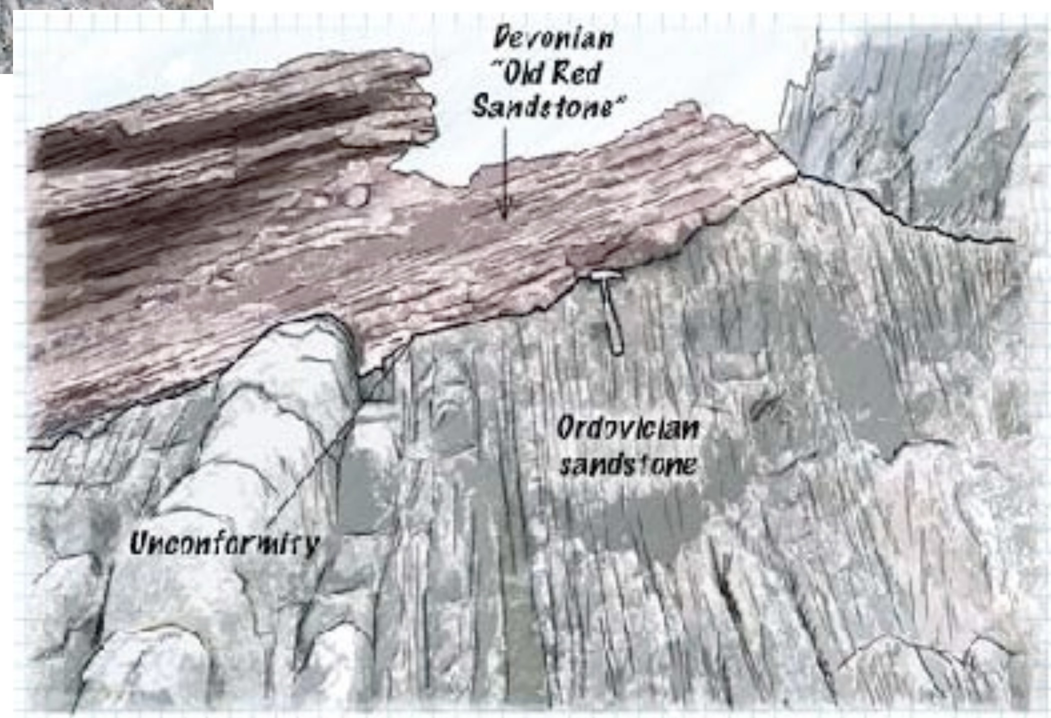
- An unconformity is a time gap in the rock record.
  - Nondeposition.
  - Erosion.


Relative Age

- **Determining <u>relative</u> ages empowers geologists to easily unravel complicated geologic histories.**

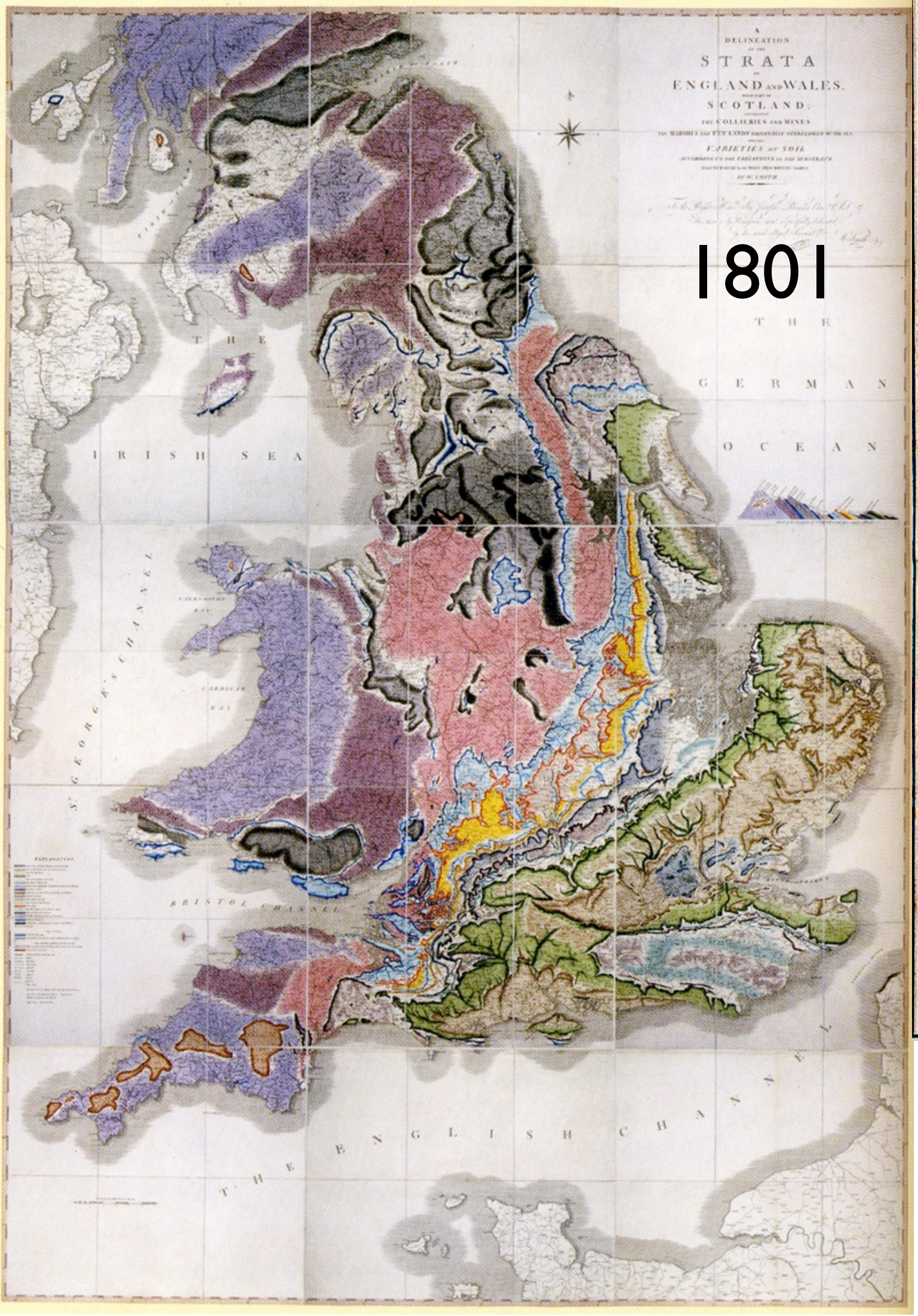


James Hutton (1726-1797)



"... we find no vestige of a beginning,–no prospect of an end."

Images of Siccar point outcrop from http://www.wwnorton.com/college/geo/earth2/content/index/animations.asp



1801

Winchester, S., 2001, *The map that changed the world: William Smith and the birth of modern geology*, HarperCollins.

INTERNATIONAL STRATIGRAPHIC CHART

ICS

IUGS

International Commission on Stratigraphy

Eonothem Eon	Erathem Era	System Period	Series Epoch	Stage Age	Age Ma	GSSP
Phanerozoic	Cenozoic	Quaternary * / Neogene	Holocene		0.0118	
			Pleistocene	Upper	0.126	
				Middle	0.781	
				Lower	1.806	GSSP
			Pliocene	Gelasian	2.588	GSSP
				Piacenzian	3.600	GSSP
				Zanclean	5.332	GSSP
			Miocene	Messinian	7.246	GSSP
				Tortonian	11.608	GSSP
				Serravallian	13.65	
				Langhian	15.97	
				Burdigalian	20.43	
				Aquitanian	23.03	GSSP
		Paleogene	Oligocene	Chattian	28.4 ±0.1	
				Rupelian	33.9 ±0.1	GSSP
			Eocene	Priabonian	37.2 ±0.1	
				Bartonian	40.4 ±0.2	
				Lutetian	48.6 ±0.2	
				Ypresian	55.8 ±0.2	GSSP
			Paleocene	Thanetian	58.7 ±0.2	
				Selandian	61.7 ±0.2	
				Danian	65.5 ±0.3	GSSP
	Mesozoic	Cretaceous	Upper	Maastrichtian	70.6 ±0.6	GSSP
				Campanian	83.5 ±0.7	
				Santonian	85.8 ±0.7	
				Coniacian	89.3 ±1.0	
				Turonian	93.5 ±0.8	GSSP
				Cenomanian	99.6 ±0.9	GSSP
			Lower	Albian	112.0 ±1.0	
				Aptian	125.0 ±1.0	
				Barremian	130.0 ±1.5	
				Hauterivian	136.4 ±2.0	
				Valanginian	140.2 ±3.0	
				Berriasian	145.5 ±4.0	

* proposed by ICS

Eonothem Eon	Erathem Era	System Period	Series Epoch	Stage Age	Age Ma	GSSP
					145.5 ±4.0	
Phanerozoic	Mesozoic	Jurassic	Upper	Tithonian	150.8 ±4.0	
				Kimmeridgian	155.7 ±4.0	
				Oxfordian	161.2 ±4.0	
			Middle	Callovian	164.7 ±4.0	
				Bathonian	167.7 ±3.5	
				Bajocian	171.6 ±3.0	GSSP
				Aalenian	175.6 ±2.0	GSSP
			Lower	Toarcian	183.0 ±1.5	
				Pliensbachian	189.6 ±1.5	GSSP
				Sinemurian	196.5 ±1.0	GSSP
				Hettangian	199.6 ±0.6	
		Triassic	Upper	Rhaetian	203.6 ±1.5	
				Norian	216.5 ±2.0	
				Carnian	228.0 ±2.0	
			Middle	Ladinian	237.0 ±2.0	GSSP
				Anisian	245.0 ±1.5	
			Lower	Olenekian	249.7 ±0.7	
				Induan	251.0 ±0.4	GSSP
	Paleozoic	Permian	Lopingian	Changhsingian	253.8 ±0.7	GSSP
				Wuchiapingian	260.4 ±0.7	GSSP
			Guadalupian	Capitanian	265.8 ±0.7	GSSP
				Wordian	268.0 ±0.7	GSSP
				Roadian	270.6 ±0.7	GSSP
			Cisuralian	Kungurian	275.6 ±0.7	
				Artinskian	284.4 ±0.7	
				Sakmarian	294.6 ±0.8	
				Asselian	299.0 ±0.8	GSSP
		Carboniferous	Pennsylvanian Upper	Gzhelian	303.9 ±0.9	
				Kasimovian	306.5 ±1.0	
			Pennsylvanian Middle	Moscovian	311.7 ±1.1	
			Pennsylvanian Lower	Bashkirian	318.1 ±1.3	GSSP
			Mississippian Upper	Serpukhovian	326.4 ±1.6	
			Mississippian Middle	Visean	345.3 ±2.1	
			Mississippian Lower	Tournaisian	359.2 ±2.5	GSSP

Eonothem Eon	Erathem Era	System Period	Series Epoch	Stage Age	Age Ma	GSSP
					359.2 ±2.5	
Phanerozoic	Paleozoic	Devonian	Upper	Famennian	374.5 ±2.6	GSSP
				Frasnian	385.3 ±2.6	GSSP
			Middle	Givetian	391.8 ±2.7	GSSP
				Eifelian	397.5 ±2.7	GSSP
			Lower	Emsian	407.0 ±2.8	GSSP
				Pragian	411.2 ±2.8	GSSP
				Lochkovian	416.0 ±2.8	GSSP
		Silurian	Pridoli		418.7 ±2.7	GSSP
			Ludlow	Ludfordian	421.3 ±2.6	GSSP
				Gorstian	422.9 ±2.5	GSSP
			Wenlock	Homerian	426.2 ±2.4	GSSP
				Sheinwoodian	428.2 ±2.3	GSSP
			Llandovery	Telychian	436.0 ±1.9	GSSP
				Aeronian	439.0 ±1.8	GSSP
				Rhuddanian	443.7 ±1.5	GSSP
		Ordovician	Upper	Hirnantian	445.6 ±1.5	
				Stage 6	455.8 ±1.6	
				Stage 5	460.9 ±1.6	GSSP
			Middle	Darriwilian	468.1 ±1.6	GSSP
				Stage 3	471.8 ±1.6	
			Lower	*Stage 2*	478.6 ±1.7	GSSP
				Tremadocian	488.3 ±1.7	GSSP
		Cambrian	Furongian	*Stage 10*	~ 492.0 *	
				Stage 9	~ 496.0 *	
				Paibian	501.0 ± 2.0	GSSP
			Series 3	*Stage 7*	~ 503.0 *	
				Stage 6	~ 506.5 *	
				Stage 5	~ 510.0 *	
			Series 2	*Stage 4*	~ 517.0 *	
				Stage 3	~ 521.0 *	
			Series 1	*Stage 2*	~ 534.6 *	
				Stage 1	542.0 ±1.0	GSSP

This chart was drafted by Gabi Ogg. Intra Cambrian unit ages with * are informal, and awaiting ratified definitions.

Eonothem Eon	Erathem Era	System Period	Age Ma	GSSP GSSA
			542	
Precambrian	Proterozoic	Neo-proterozoic	Ediacaran	~630	GSSP
			Cryogenian	850	GSSA
			Tonian	1000	GSSA
		Meso-proterozoic	Stenian	1200	GSSA
			Ectasian	1400	GSSA
			Calymmian	1600	GSSA
		Paleo-proterozoic	Statherian	1800	GSSA
			Orosirian	2050	GSSA
			Rhyacian	2300	GSSA
			Siderian	2500	GSSA
	Archean	Neoarchean		2800	GSSA
		Mesoarchean		3200	GSSA
		Paleoarchean		3600	GSSA
		Eoarchean	Lower limit is not defined		

Subdivisions of the global geologic record are formally defined by their lower boundary. Each unit of the Phanerozoic (~542 Ma to Present) and the base of Ediacaran are defined by a basal Global Standard Section and Point (GSSP), whereas Precambrian units are formally subdivided by absolute age (Global Standard Stratigraphic Age, GSSA). Details of each GSSP are posted on the ICS website (*www.stratigraphy.org*).

International chronostratigraphic units, rank, names and formal status are approved by the International Commission on Stratigraphy (ICS) and ratified by the International Union of Geological Sciences (IUGS).

Numerical ages of the unit boundaries in the Phanerozoic are subject to revision. Some stages within the Ordovician and Cambrian will be formally named upon international agreement on their GSSP limits. Most sub-Series boundaries (e.g., Middle and Upper Aptian) are not formally defined.

Colors are according to the Commission for the Geological Map of the World (*www.cgmw.org*).

The listed numerical ages are from 'A Geologic Time Scale 2004', by F.M. Gradstein, J.G. Ogg, A.G. Smith, et al. (2004; Cambridge University Press).