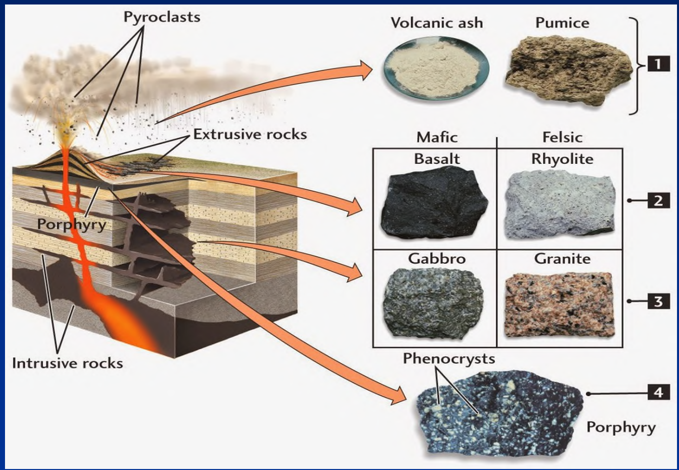
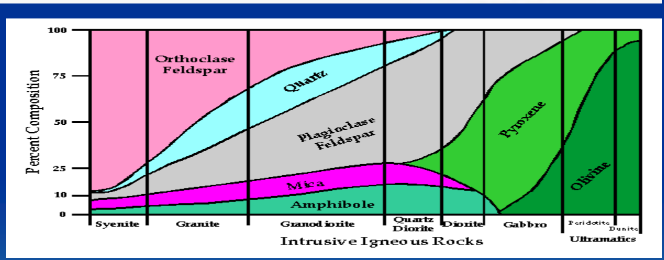
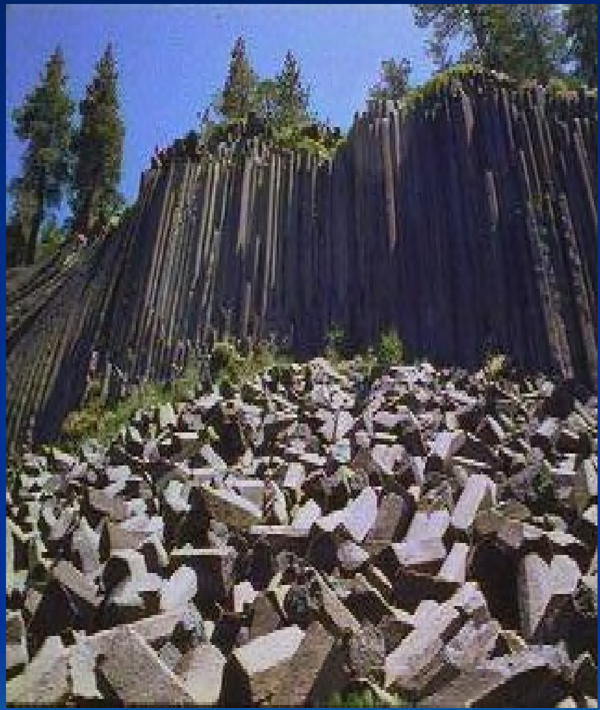
Igneous Rocks – Origin Classification, Crystallization Processes and Identification







Physical Geology – GEOL 100

Ray Rector - Instructor

Major Concepts

1) Igneous rocks form directly from the crystallization of a magma or lava
2) Three primary tectonic settings of global-scale magmatization are divergent boundaries, subduction-related convergent boundaries, and hot spots.
3) Tectonic environment controls the type of magmas generated, and hence the types of igneous rocks that form at each of the three tectonic settings.
4) Magma reaching the surface is termed lava, typically forming a volcano.
5) The type of igneous rock formed is controlled by two factors: magma composition and cooling history; also determines naming of igneous rocks
6) Magma compositions vary from mafic to intermediate to silicic-felsic.
7) Texture controlled by cooling history; Mineralogy by magma composition
8) Coarse-grained igneous rocks that cooled very slowly at depth are termed intrusive or plutonic
9) Fine-grained igneous rocks that cooled quickly at or near surface are termed extrusive or volcanic.
10) Identification of igneous rocks based on two criteria: texture and composition

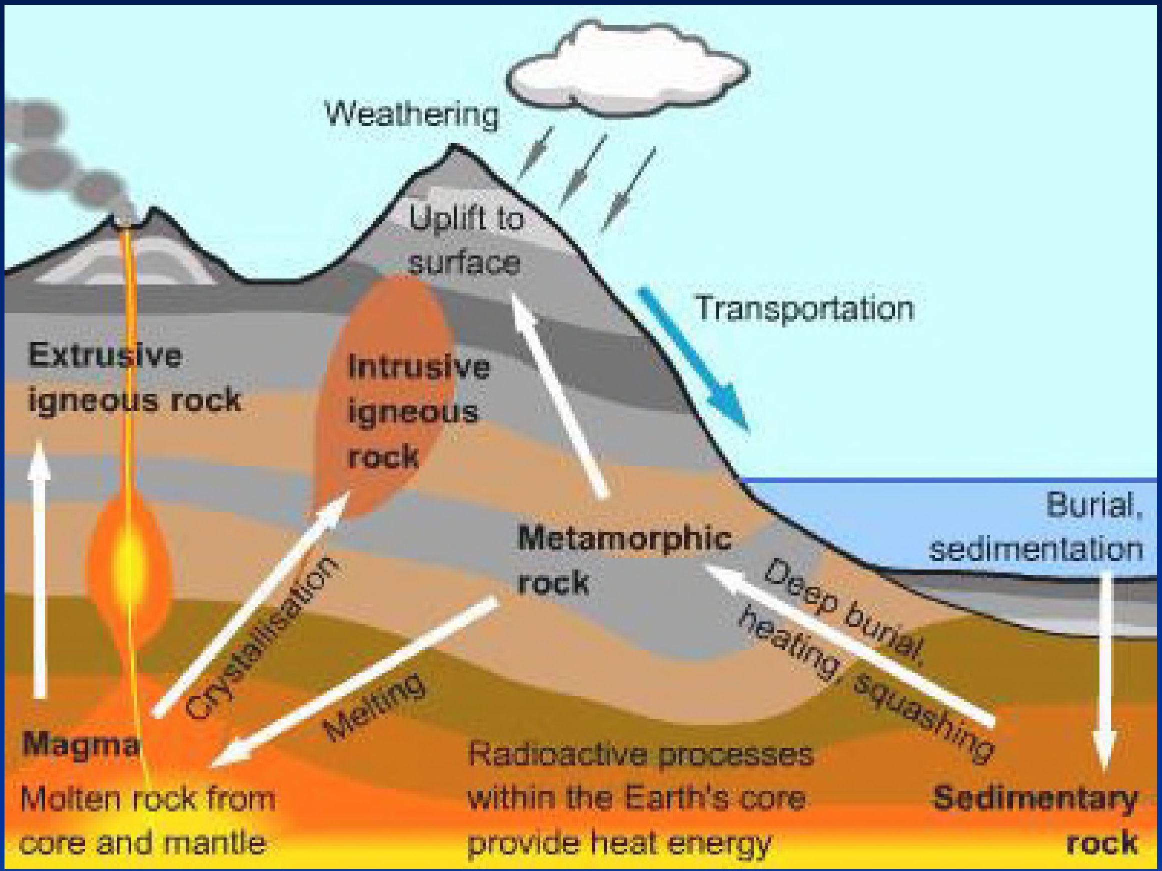
The Rock Cycle

Three Primary Rock Types

1) Igneous

2) Metamorphic

3) Sedimentary



Key Concept:

The Rock Cycle is Perpetuated by Several Major Processes

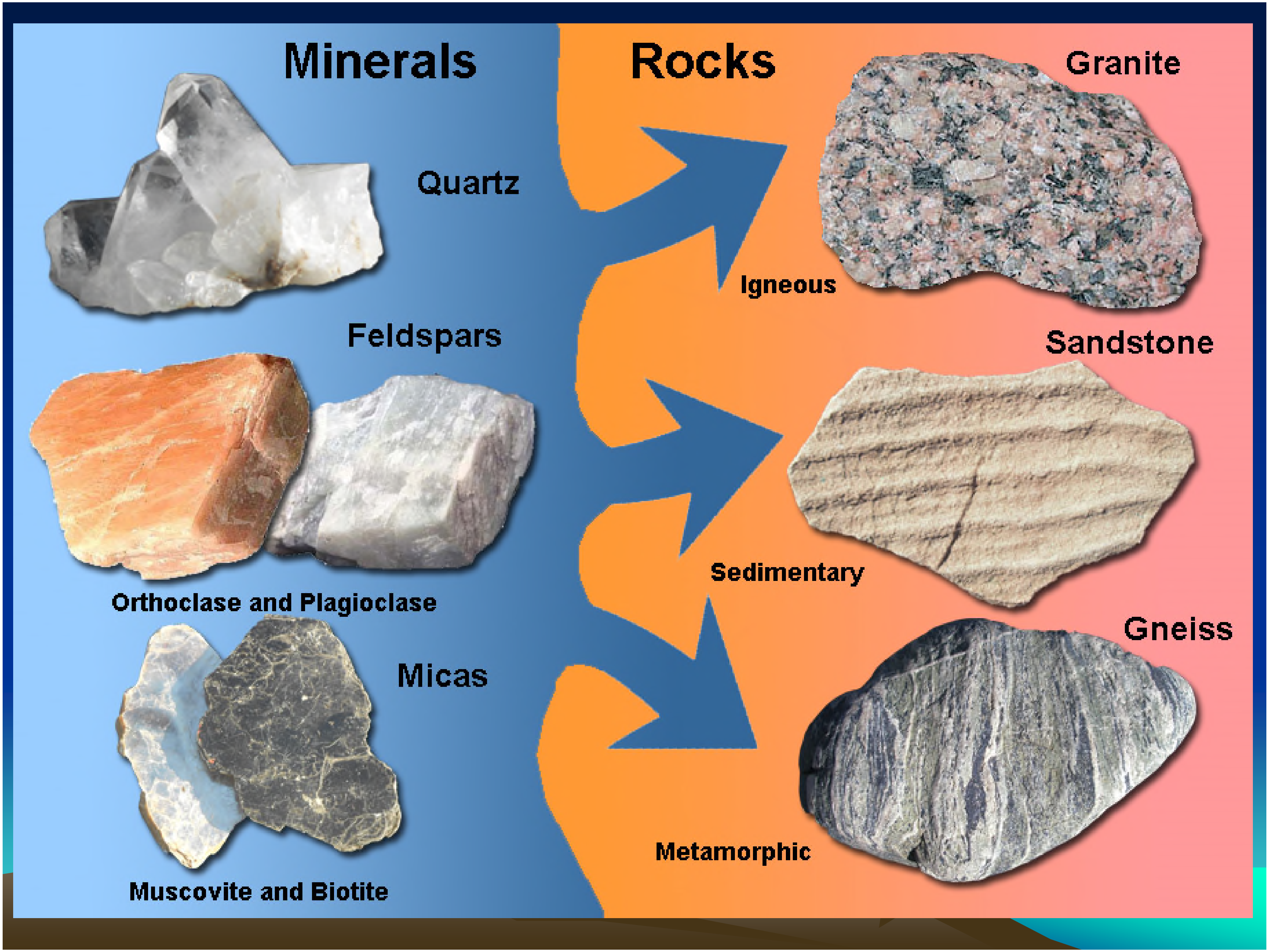
1) Magmatic Activity
2) Uplift and Mountain Building
3) Weathering, Erosion, Deposition, and Burial of Sediment

3 Major Rock Types

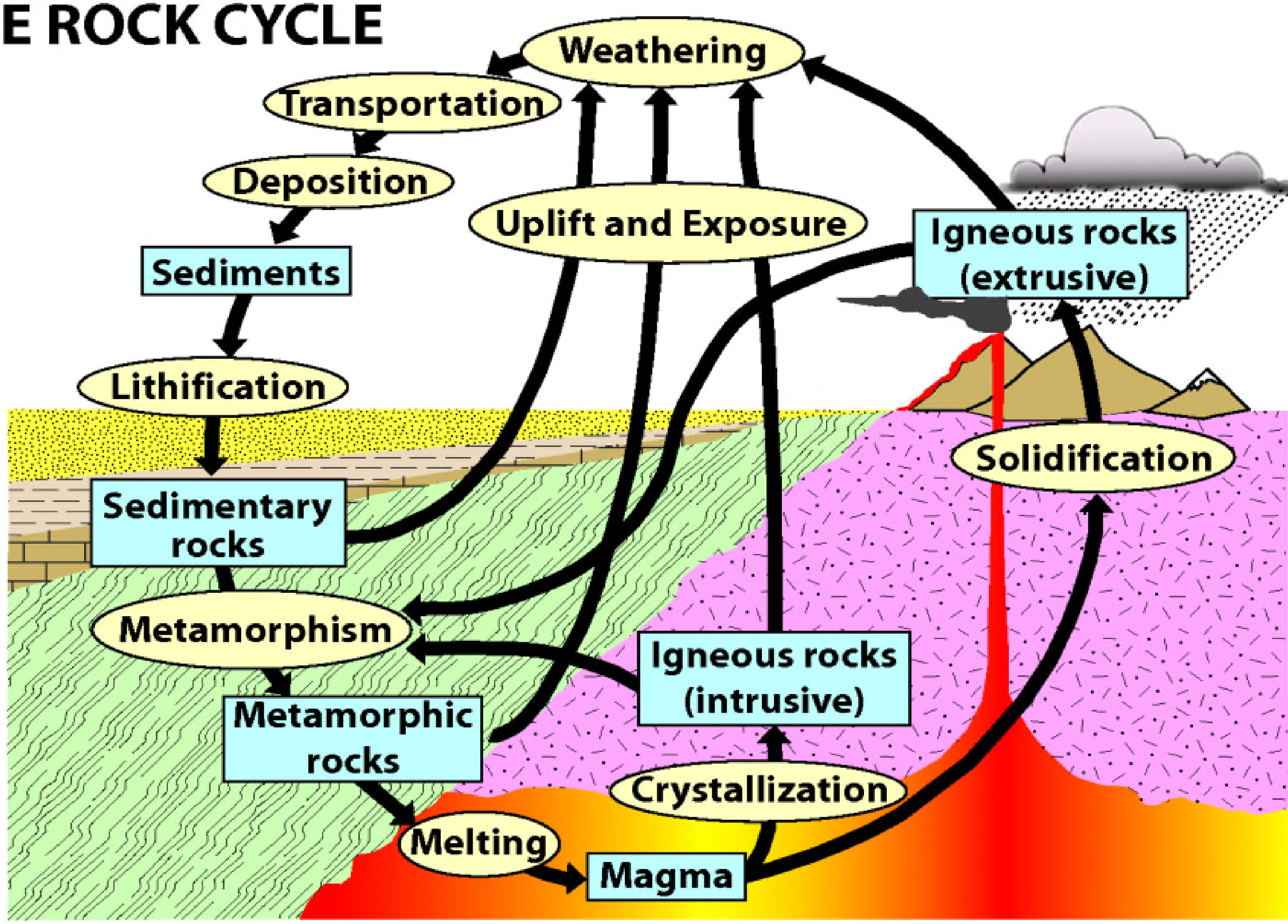
- Igneous
  – Formed from the solidification of molten rock (magmaor lava).

- Sedimentary
  – Formed at the Earth's surface from the accumulation and cementation of fragmented pieces of older rock produced by weathering.

- Metamorphic
  – Rocks that have undergone physical changes as a result of exposure to extreme pressure, temperature and fluids.


Minerals
Rocks
Quartz
Granite
Igneous
Feldspars
Sandstone
Orthoclase and Plagioclase
Sedimentary
Gneiss
Micas
Metamorphic
Muscovite and Biotite

THE ROCK CYCLE



Igneous Rocks -
Rocks that form from the cooling of motlen rock (magma), Example: granite and basalt

Sedimentary Rocks -
Rocks that are fromed from pieces of other rocks, Example: sandstone, or that are deposited from the ocean by chemical processes, Example: limestone

Metamorphic Rocks -
Rocks that are changed by heat and pressure without melting, Example: gneiss

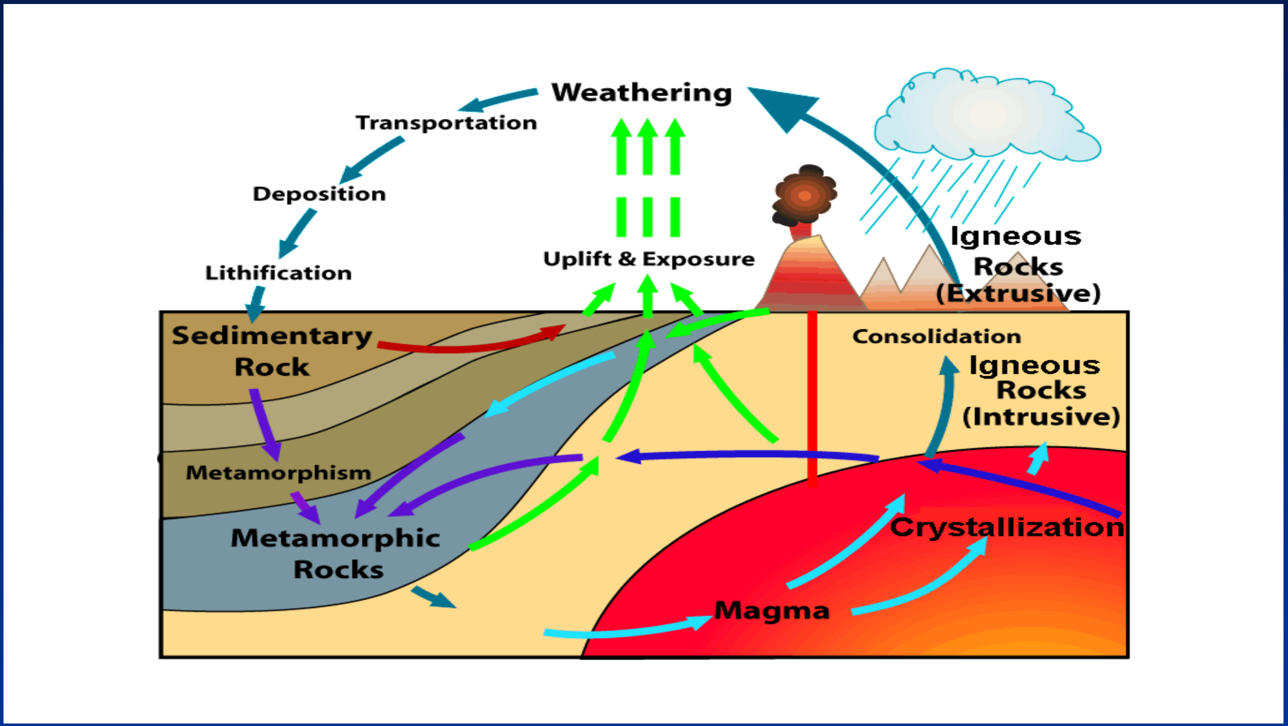
The Rock Cycle

Three Primary Rock Types

1) **Igneous**

2) **Metamorphic**

3) **Sedimentary**



Igneous rocks form by the *cooling* and *crystallization* of underground *magmas* and erupted *lavas*.

Igneous rocks are classified by two mineral criteria:

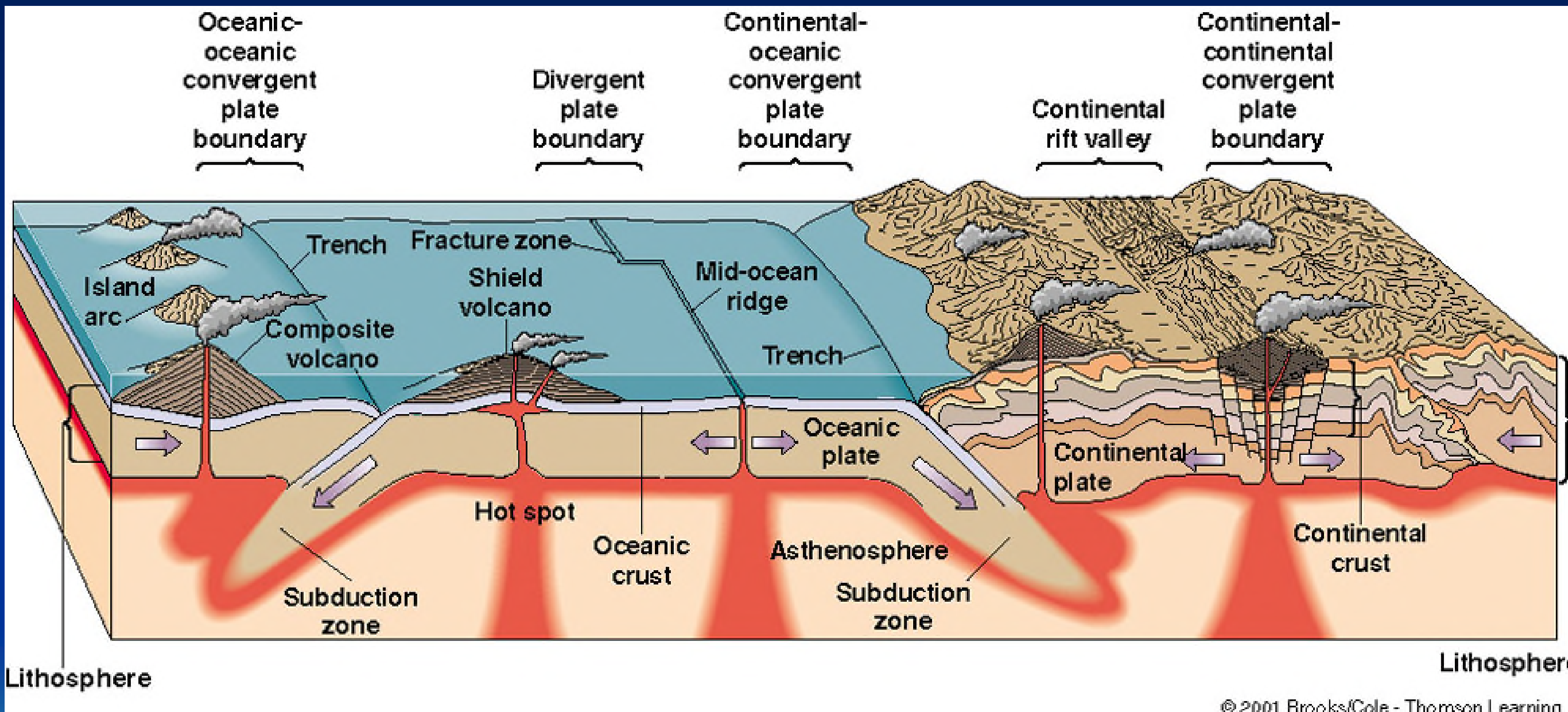
1) *Type and % of minerals* 2) *Crystal size & arrangement*

Magma and Lava = Mother Igneous

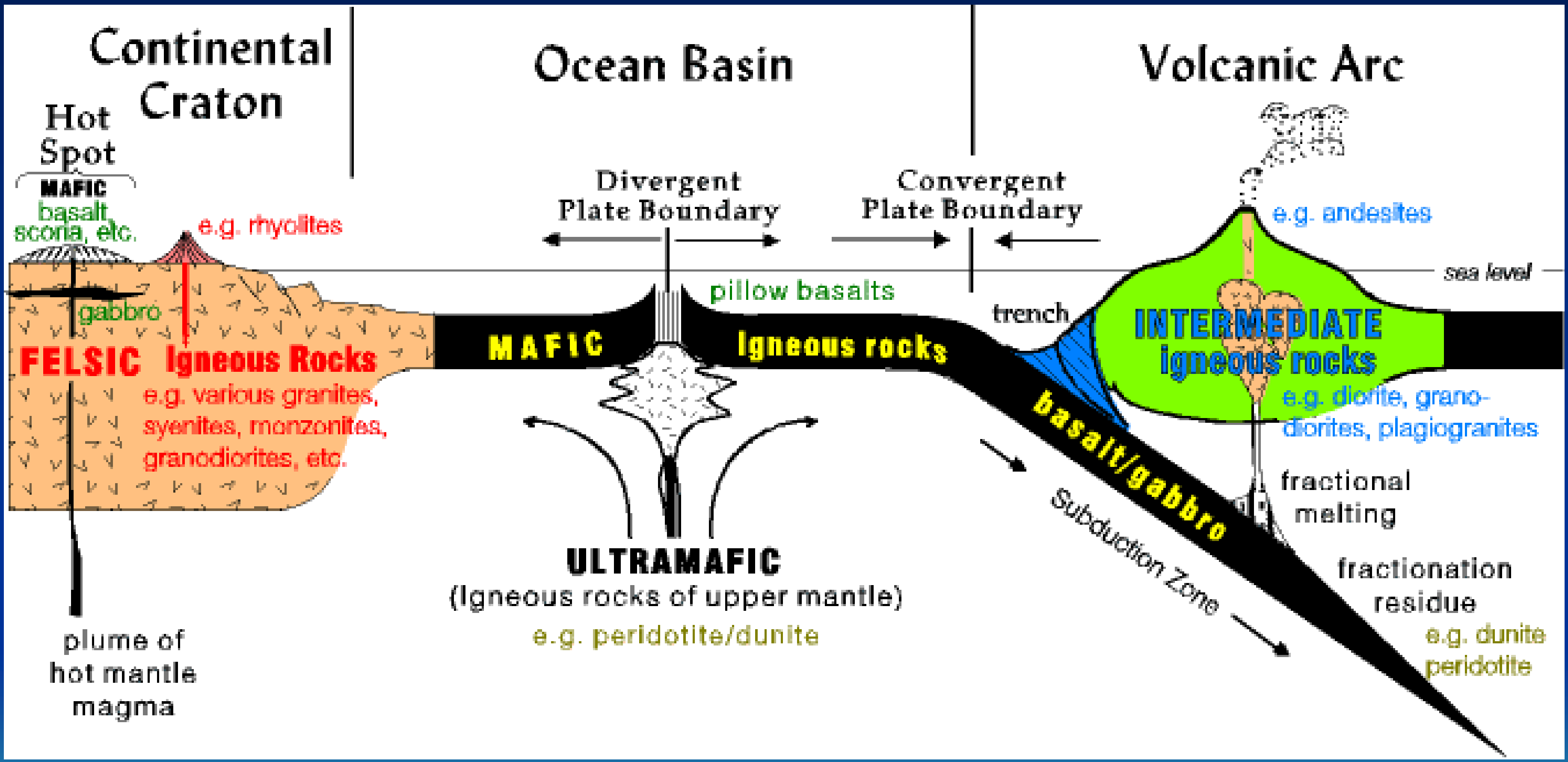
The mineralogy of an igneous rock is *primarily controlled* by the composition of the magma or lava that it cooled from.

The texture of an igneous rock is *primarily controlled* by the cooling rate of its parent crystallizing magma or lava.

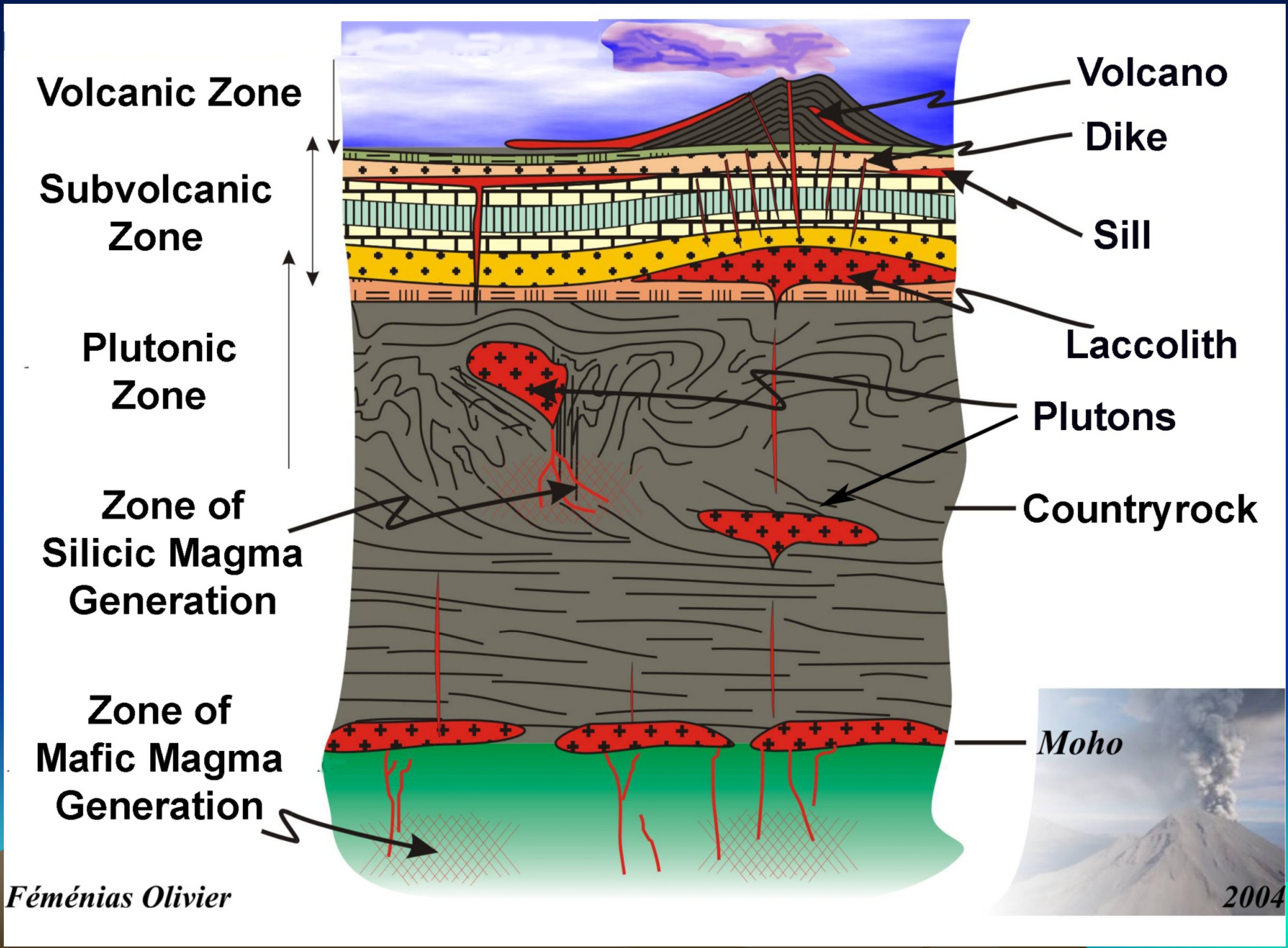
Tectonic Environments for Magma Generation



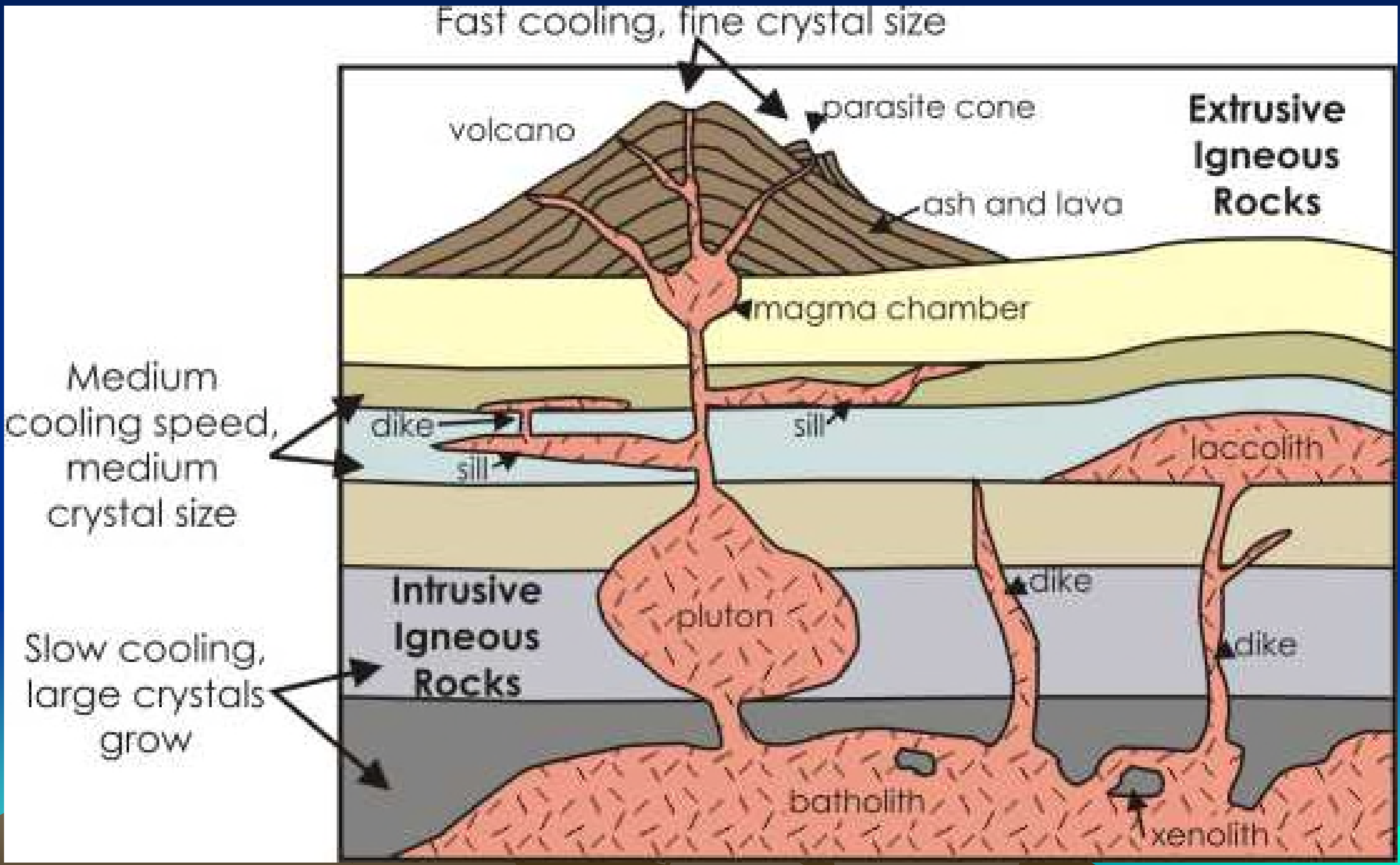
Predominant Igneous Rock Types at Specific Tectonic Settings



Igneous Environments



Affects of Cooling Rates on Crystal Size in Various Igneous Environment



Common Igneous Rock-Forming Minerals

1) Plagioclase
2) Potassium Feldspar
3) Quartz
4) Muscovite
9) Biotite
10) Hornblende
11) Augite (pyroxene)
12) Olivine
13) Tourmaline
14) Garnet
15) Magnetite

Igneous Rock Classification

The mineralogy of an igneous rock is *primarily controlled* by the composition of the magma or lava that it cooled from.

The texture of an igneous rock is *primarily controlled* by the cooling rate of its parent crystallizing magma or lava.

COMPOSITION

TEXTURE	Felsic (light color)	Intermediate	Mafic (dark color)	Ultramafic
Coarse	Granite	Diorite	Gabbro	Peridotite
Fine	Rhyolite	Andesite	Basalt	
Vesi-cular	Pumice		Scoria	
Glassy	Obsidian			
Minerals Present	QUARTZ K-FELDSPAR NA-PLAG	NA-CA PLAG AMPHIBOLE	CA PLAG PYROXENE	PYROXENE OLIVINE

COMPOSITION

- http://geology.csupomona.edu/alert/igneous/igclass.htm

Igneous Compositions

Ultramafic:

- ✓ Very Iron – Magnesium Rich
- ✓ Super undersaturated in silica
- ✓ Mantle rocks = **Peridotite**

Mafic:

- ✓ Iron–Magnesium-Calcium Rich
- ✓ Undersaturated in silica
- ✓ Oceanic rocks = **Gabbro and Basalt**

Sub-Mafic:

- ✓ Between Mafic and Sub-Felsic/Silicic
- ✓ Saturated in silica
- ✓ Volcanic Arc rocks = **Diorite and Andesite**

Sub-Felsic/Silicic:

- ✓ Between Sub-Mafic and Felsic/Silicic
- ✓ Saturated in silica
- ✓ Volcanic Arc rocks = **Granodiorite and Dacite**

Felsic/Silicic:

- ✓ Sodium – Potassium - Aluminum Rich
- ✓ Very Oversaturated in silica
- ✓ Continental rocks = **Granite** and **Rhyolite**

COMPOSITION

TEXTURE	Felsic (light color)	Intermediate	Mafic (dark color)	Ultramafic
Coarse	Granite	Diorite	Gabbro	Peridotite
Fine	Rhyolite	Andesite	Basalt	
Vesi-cular	Pumice		Scoria	
Glassy	Obsidian			
Minerals Present	QUARTZ K-FELDSPAR NA-PLAG	NA-CA PLAG AMPHIBOLE	CA PLAG PYROXENE	PYROXENE OLIVINE

COMPOSITION

- http://www.rockhounds.com/rockshop/rockkey/index.ht

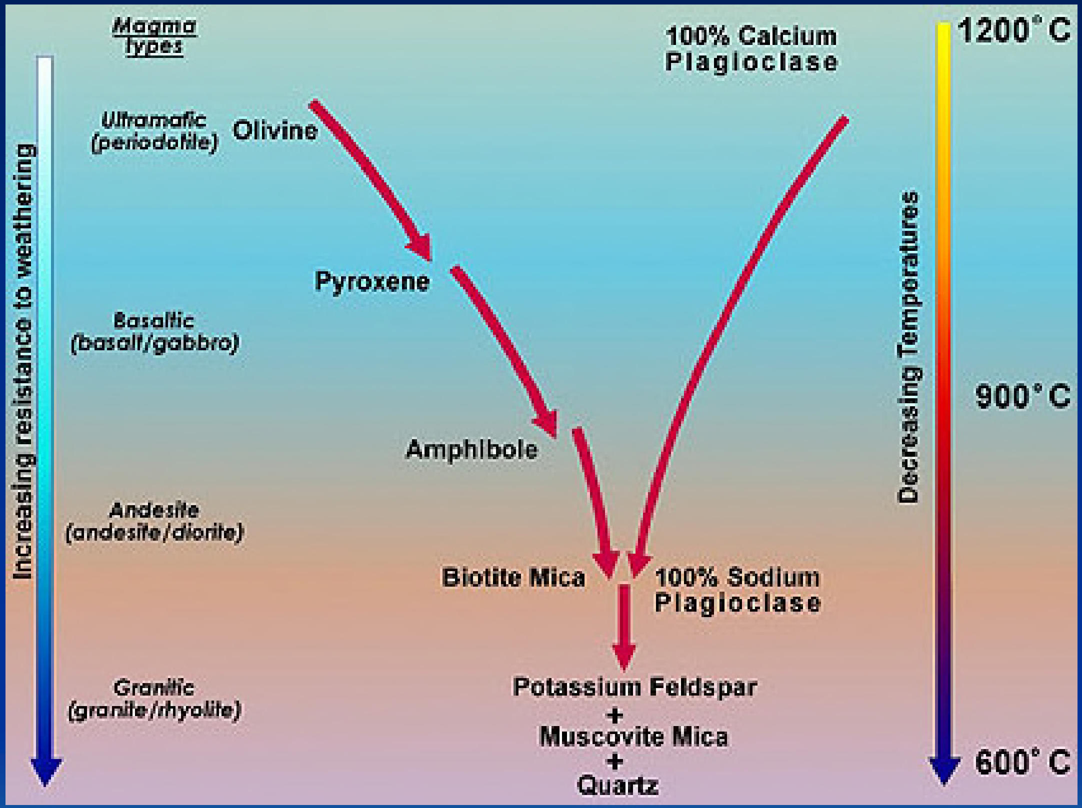
Cooling and Crystallization of a Magma

Bowen's Reaction Series

✓ Early forming minerals are Fe-Mg-Ca rich and silica poor @ high temps

✓ Later forming minerals become more richer in Na and silica @ mod temps

✓ Last forming minerals are most rich in K and silica @ low temps

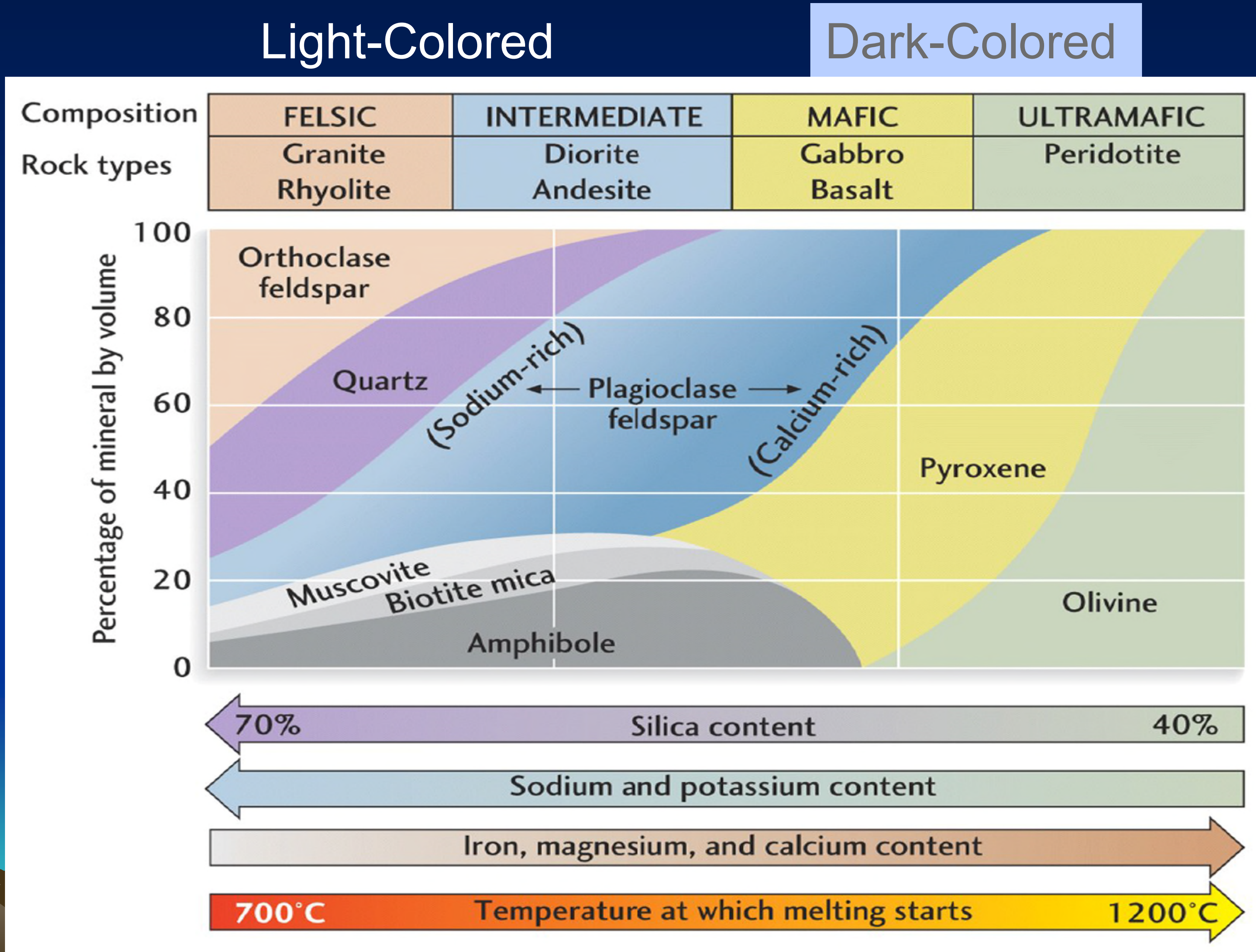


✓ Final rock type depends mostly on initial magma composition

✓ Crystal fractionation processes can also affect magma comp.

- http://www.rockhounds.com/rockshop/rockkey/index.html

Mineral Assemblages of Igneous Rock



Igneous Rock Textures

Phaneritic Texture:

- ✓ **Coarse Grain Size =** Slow Cooling
- ✓ **Plutonic Rocks** = Coarse-grained

Aphanitic Texture:

- ✓ **Fine Grain Size =** Fast Cooling
- ✓ **Volcanic Rocks** = Fine-grained

Porphyritic Texture:

- ✓ Large crystals in aphanitic groundmass = slow cooling followed by rapid cooling
- ✓ **Porphyry Rocks** = Mixed-grain

Vesicular Texture:

- ✓ Fine-grained to glassy with Cavities
- ✓ Lots of tiny vesicles = pumice
- ✓ Fewer larger vesicles = scoria

Glassy Texture:

- ✓ Little to no crystals = natural glass
- ✓ Super rapid cooling
- ✓ Obsidian is dark in color
- ✓ Pumice is light in color

COMPOSITION

TEXTURE	Felsic (light color)	Intermediate	Mafic (dark color)	Ultramafic
Coarse	Granite	Diorite	Gabbro	Peridotite
Fine	Rhyolite	Andesite	Basalt	
Vesi-cular	Pumice		Scoria	
Glassy	Obsidian			
Minerals Present	QUARTZ K-FELDSPAR NA-PLAG	NA-CA PLAG AMPHIBOLE	CA PLAG PYROXENE	PYROXENE OLIVINE

COMPOSITION

- http://www.rockhounds.com/rockshop/rockkey/index.html

Igneous Rock Pairs

Classification by texture

Extrusive	*Intrusive*
Fine grained	*Coarse grained*
Basalt	gabbro
Andesite	diorite
Rhyolite	granite

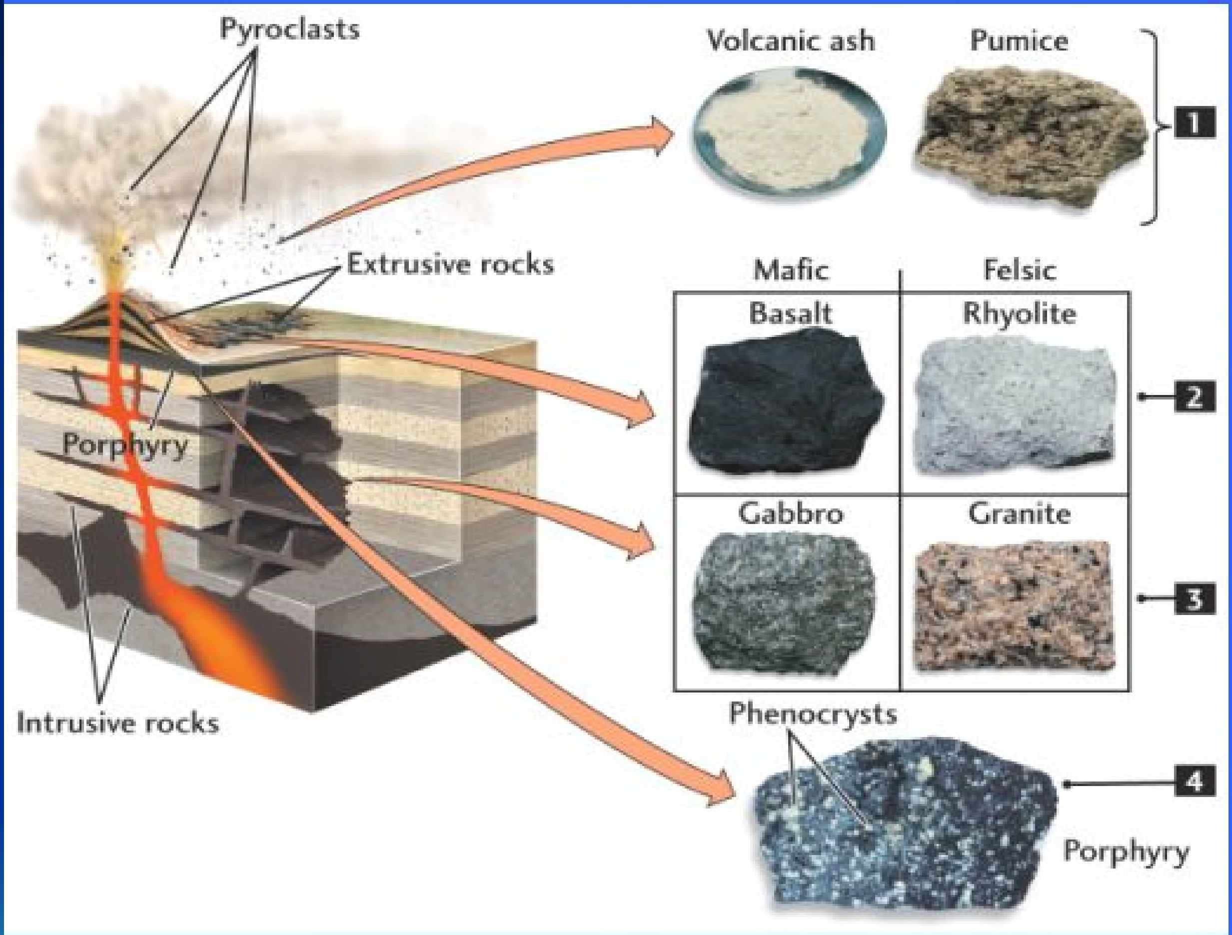
Classification by composition

- magnesium (Mg) + iron (Fe) = mafic
- feldspar + quartz (Si) = felsic

Fast Cooling

Slow Cooling

Formation and texture



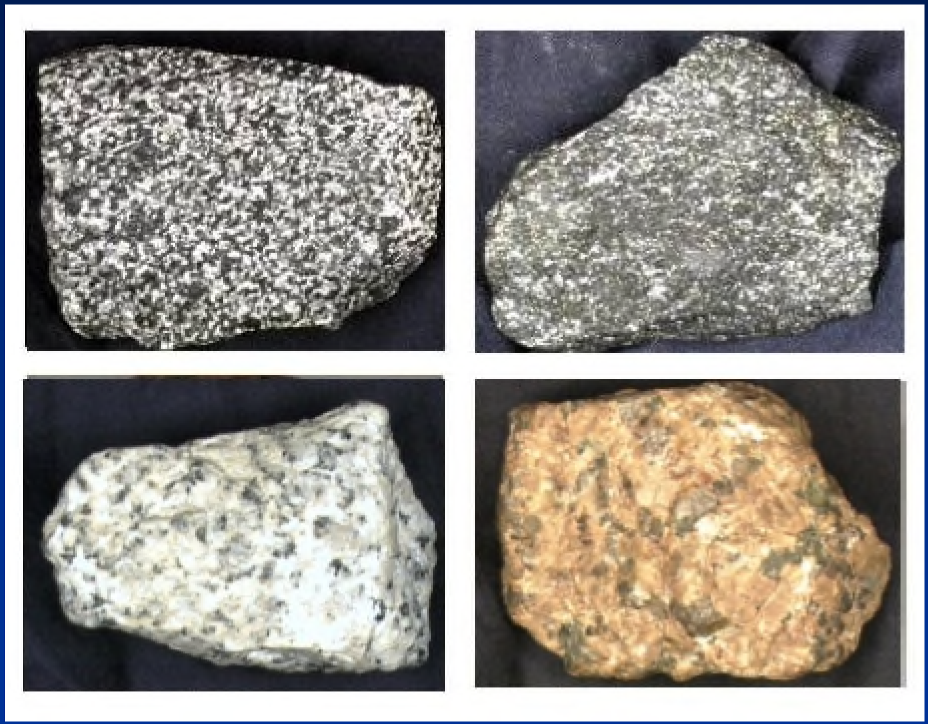
1. **Pyroclasts** form from airborne lava in violent eruption

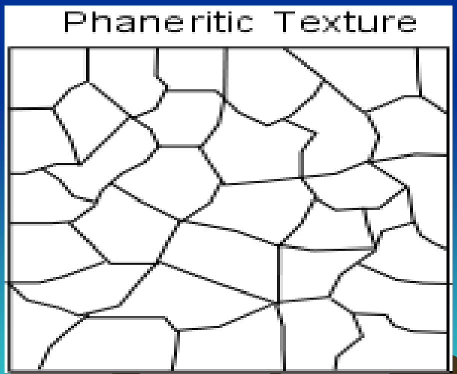
2. **Extrusive igneous rocks**. Cool rapidly on the Earth's surface

3. **Intrusive igneous rocks**. Cool slowly in the Earth's interior allowing large crystals to form

4. **Porphyry** starts to grow below the surface but before solidification is brought to the surface

Plutonic Rock Textures



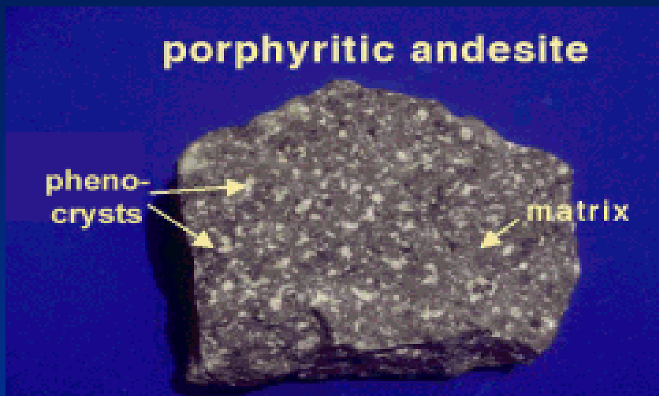


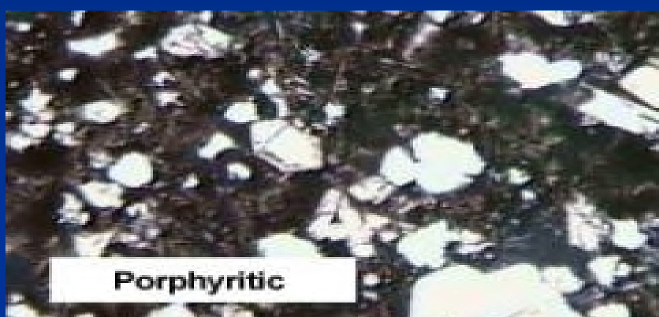
- ✓ Intrusive -Plutonic
- ✓ Coarse-grained
- ✓ Cooled Slowly

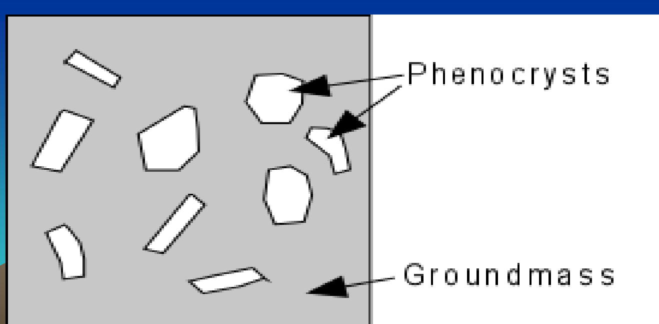
Field Outcrops of Plutonic Rocks

Volcanic Rock Textures

Porphyritic







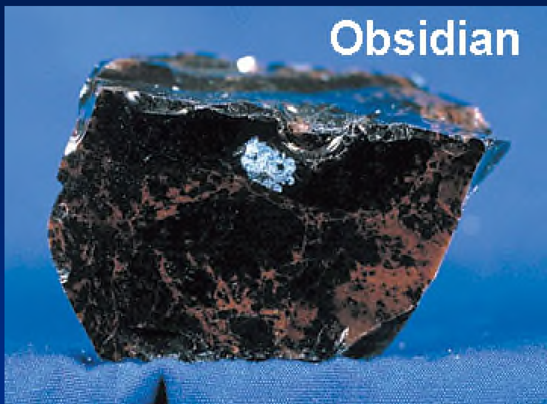
Aphanitic

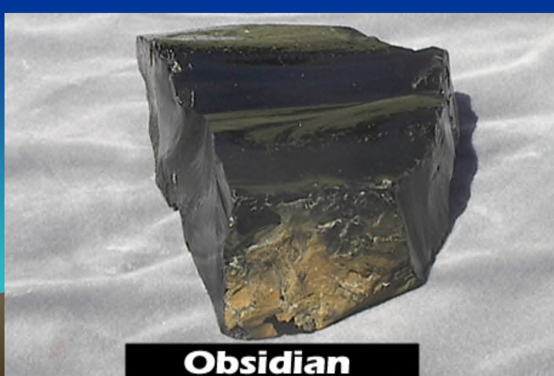
- ✓ Extrusive -Volcanic
- ✓ Fine-grained
- ✓ Cooled Rapidly

- ✓ Combo Plutonic -Volcanic
- ✓ Coarse-grained phenocrysts in a fine-grained groundmass
- ✓ First cooled Slow, then Fast

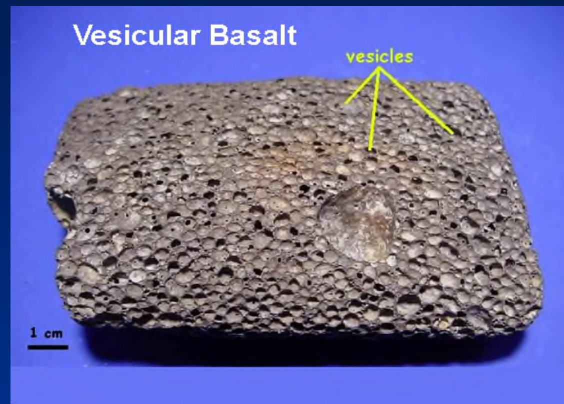
Other Volcanic Rock Textures

Glassy

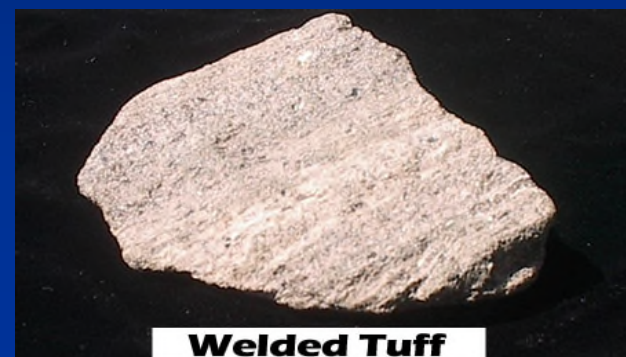




Vesicular



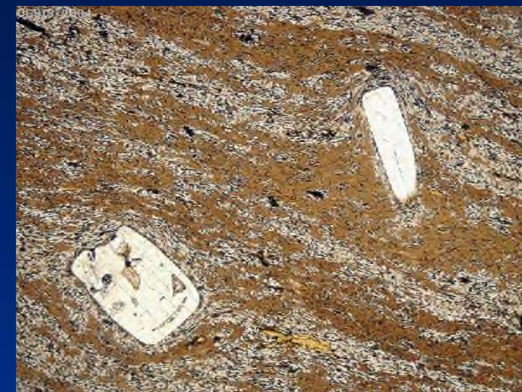
Fragmental



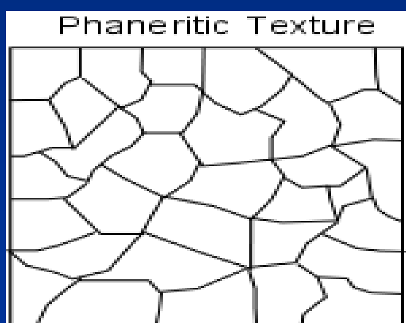
Igneous Rocks Under a Microscope

Granite

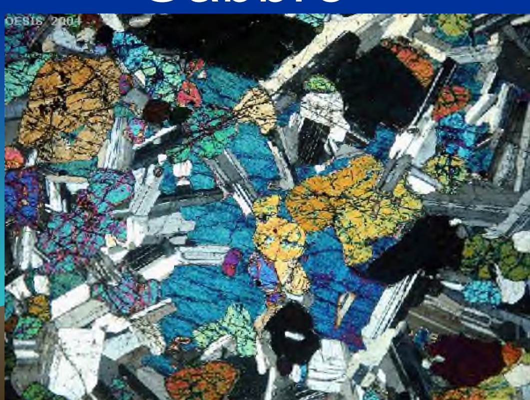
Rhyolite

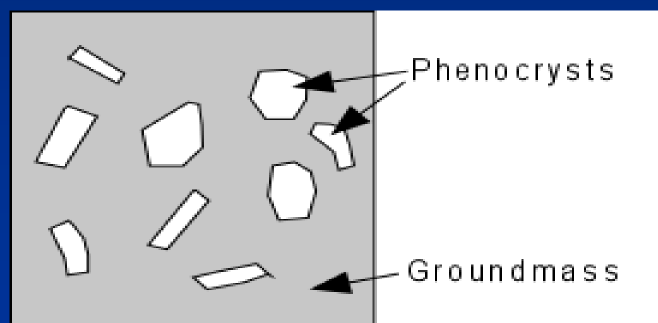


Obsidian

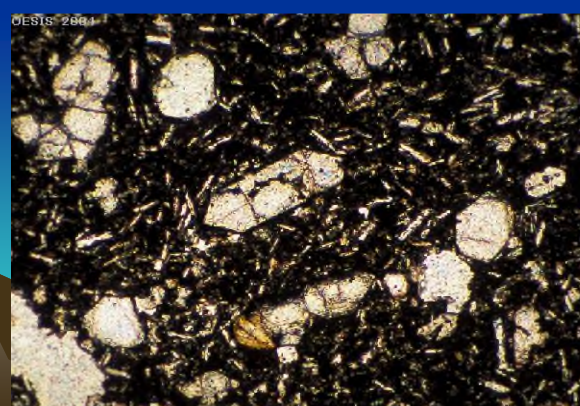


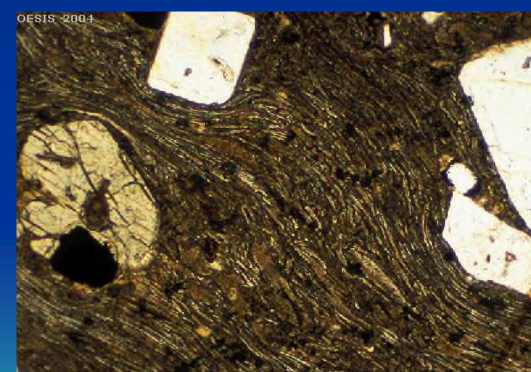
Gabbro





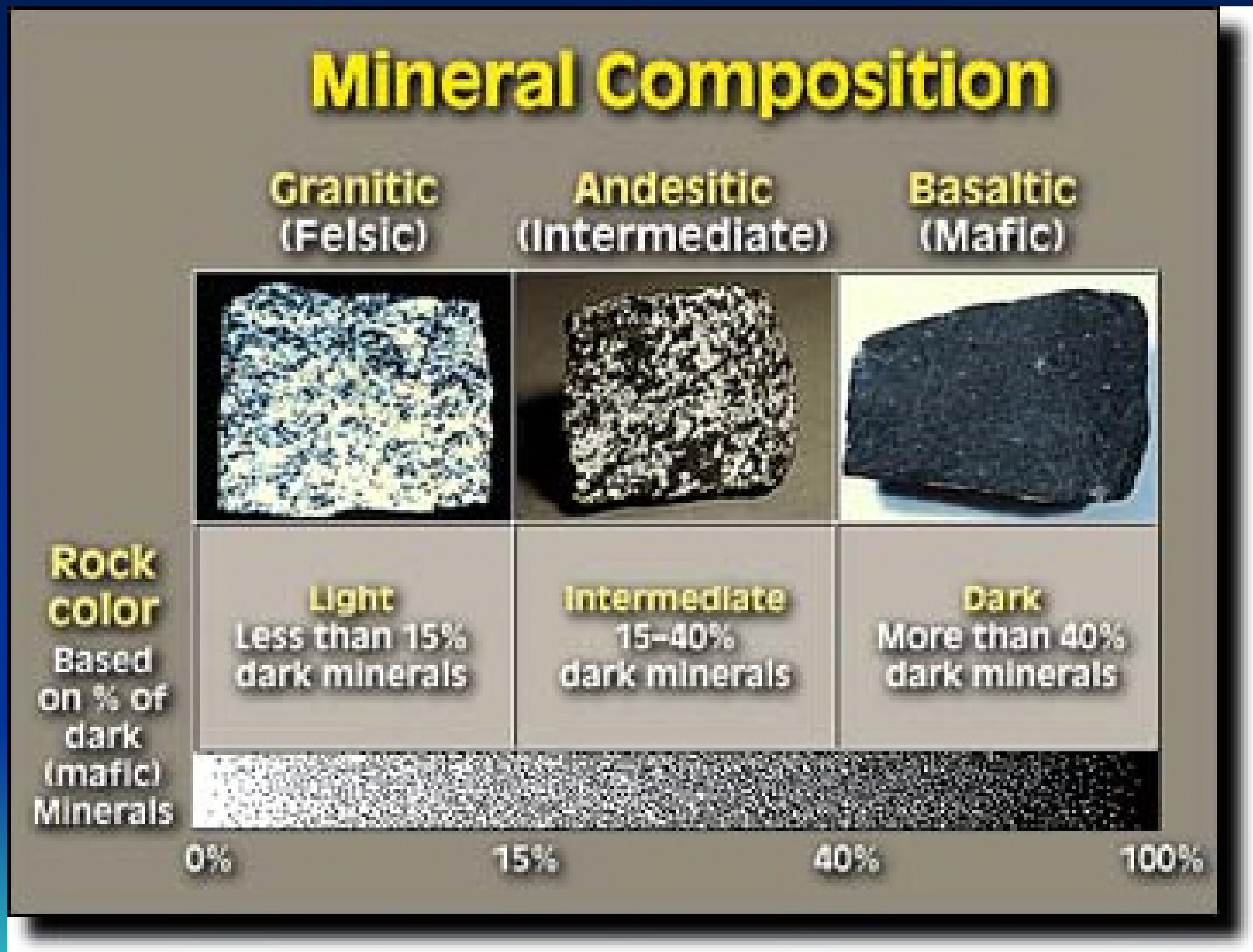
Basalt





Welded Tuff

Color Index of Plutonic Rocks

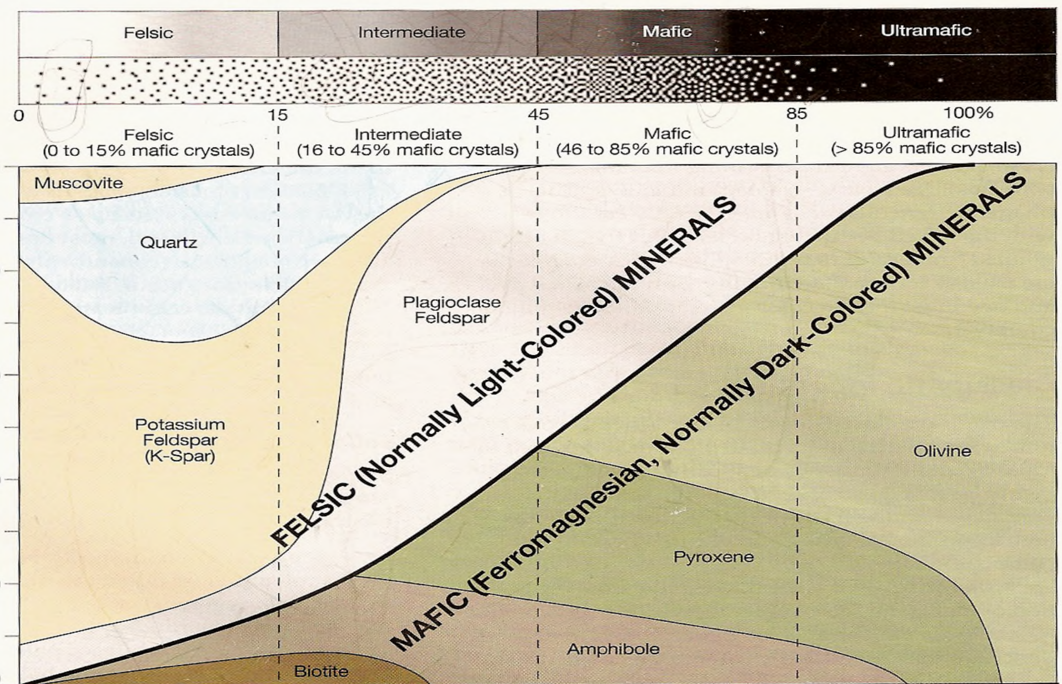


Igneous Rock Classification

IGNEOUS ROCKS CLASSIFICATION

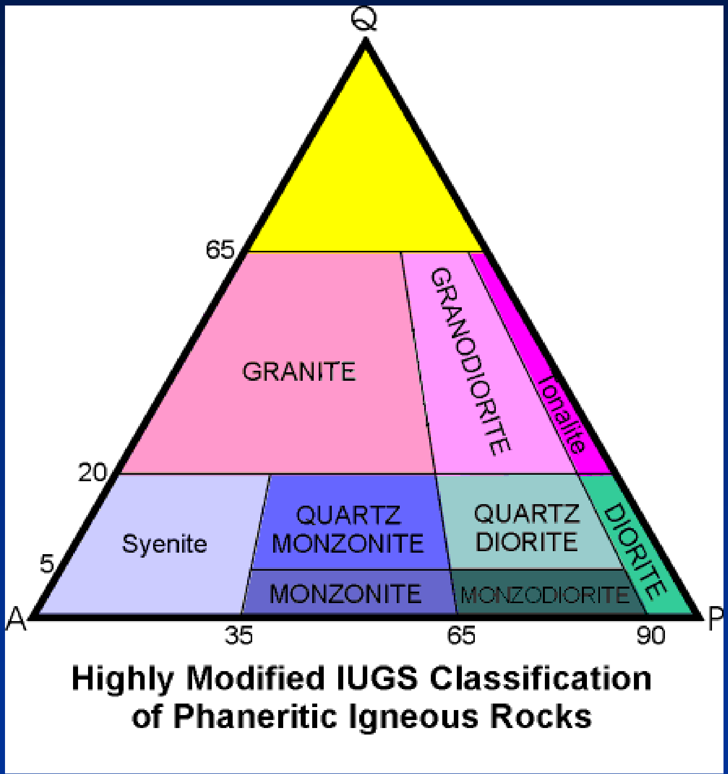
1. Color Index
Estimate the rock's color index (CI): % of mafic mineral crystals or darkness of the rock.

2. Minerals
Identify minerals in the rock, if possible, and their percent (by volume) of the whole rock. Skip this step if mineral crystals are not visible or are too small to identify.

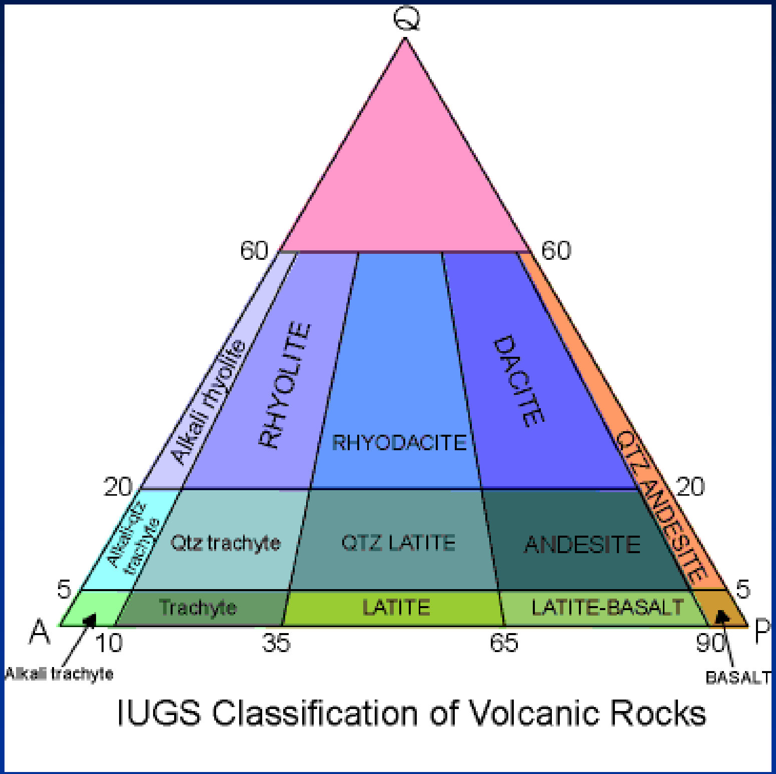


	3. Texture(s) Identify the rock's texture(s).	**4. Rock Name:** Select name below, based on data from steps 1–3.			
INTRUSIVE ORIGIN	Pegmatitic: very coarse-grained	PEGMATITIC GRANITE	PEGMATITIC DIORITE	PEGMATITIC GABBRO	PEGMATITIC PERIDOTITE
INTRUSIVE ORIGIN	Phaneritic: coarse-grained	**GRANITE** (SYENITE, if no quartz)	**DIORITE**	**GABBRO**	**PERIDOTITE**
INTRUSIVE ORIGIN	Phenocrysts[1] in a phaneritic groundmass	PORPHYRITIC GRANITE	PORPHYRITIC DIORITE	PORPHYRITIC GABBRO	PORPHYRITIC PERIDOTITE
EXTRUSIVE ORIGIN	Phenocrysts[1] in an aphanitic groundmass	PORPHYRITIC RHYOLITE	PORPHYRITIC ANDESITE	PORPHYRITIC BASALT	Cannot be distinguished from basalt in hand samples (KOMATITE)
EXTRUSIVE ORIGIN	Aphanitic: fine-grained	**RHYOLITE**	**ANDESITE**	**BASALT**	
EXTRUSIVE ORIGIN	Glassy	OBSIDIAN			
EXTRUSIVE ORIGIN	Vesicular	PUMICE (abundant tiny vesicles–like meringue; very lightweight; white or gray; floats in water)		SCORIA (resembles a sponge) VESICULAR BASALT (has few scattered vesicles)	
EXTRUSIVE ORIGIN	Pyroclastic or Fragmental	VOLCANIC TUFF (fragments ≤ 2 mm) VOLCANIC BRECCIA (fragments > 2 mm)			

Igneous Rock Classification



Granitic Plutonic Rocks



Volcanic Rocks

Ternary Diagrams:

1) Top corner = quartz; Bottom L. corner = K-spar; Bottom R. corner = Plag

2) Fields indicate tri-mineral proportions in terms of percentages totally 100%

Igneous Rock Classification

A Three Step Process

1) Determine Composition

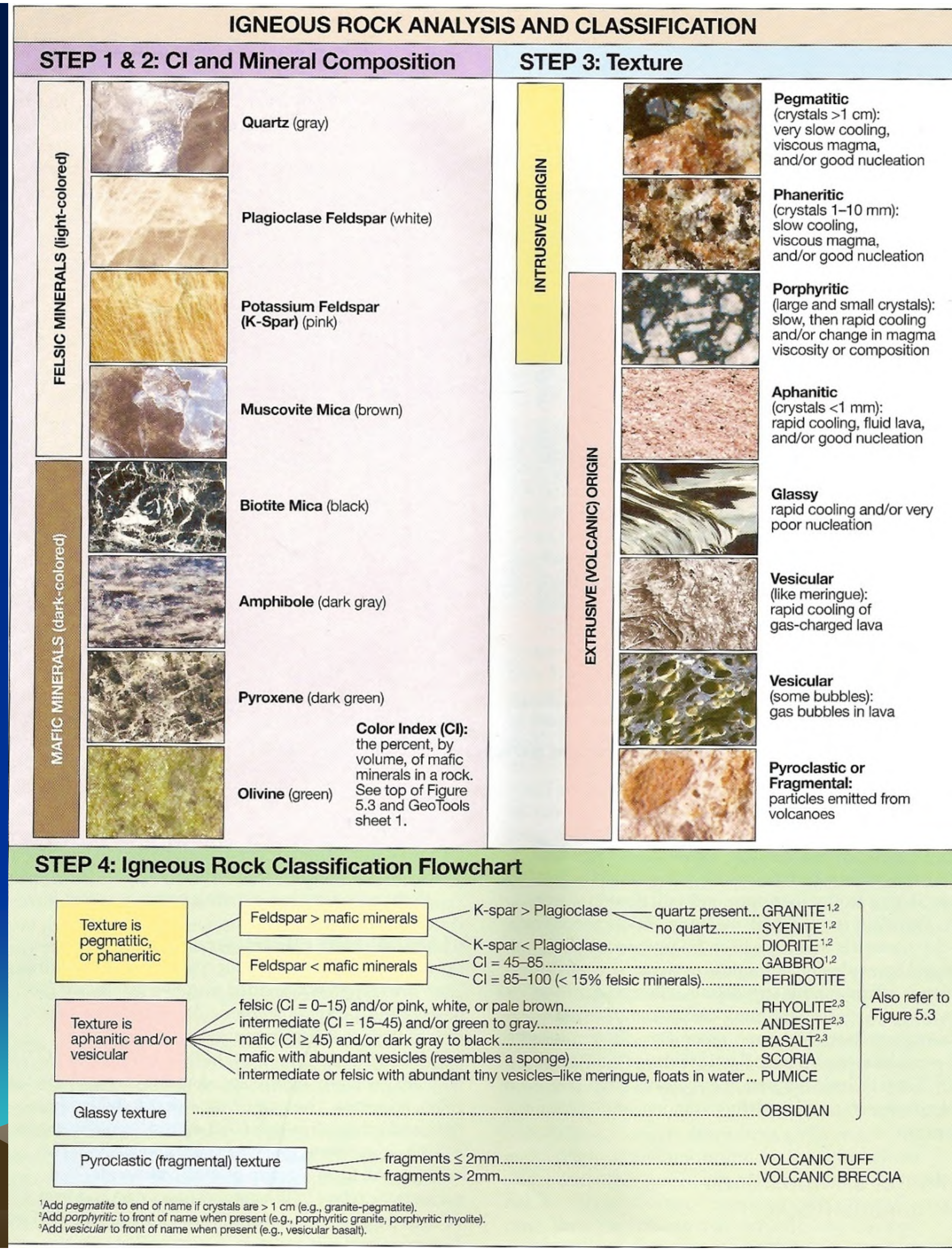
- ✓ Color Index (plutonic only)
- ✓ Color darkness (volcanic)
- ✓ Mineralogy (observable)

2) Determine Texture

- ✓ Specific intrusive texture?
- ✓ Specific extrusive texture?

3) Name the Rock

- ✓ Use Flowchart



Practical Use for Rock?

Igneous Rock Classification

A Three Step Process

1) Determine Composition

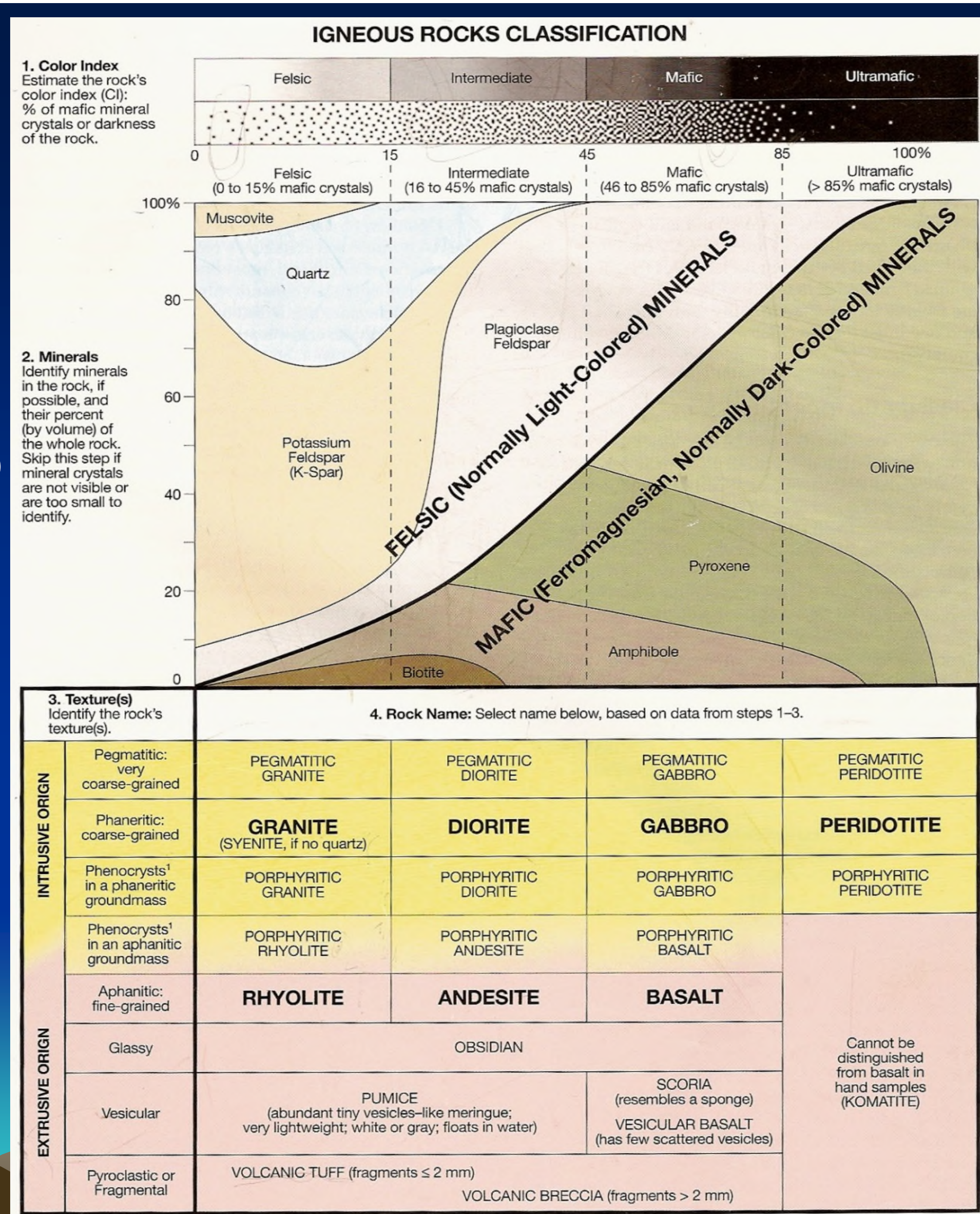
- ✓Color Index min % (plutonic only)
- ✓Color index darkness (volcanic)
- ✓Mineralogy (observable)

2) Determine Texture

- ✓ Specific intrusive texture?
- ✓ Specific extrusive texture?

3) Name the Rock

- ✓ Use Flowchart



Texture	Felsic	Intermediate	Mafic	Ultramafic
Pegmatitic: very coarse-grained	PEGMATITIC GRANITE	PEGMATITIC DIORITE	PEGMATITIC GABBRO	PEGMATITIC PERIDOTITE
Phaneritic: coarse-grained	GRANITE (SYENITE, if no quartz)	DIORITE	GABBRO	PERIDOTITE
Phenocrysts[1] in a phaneritic groundmass	PORPHYRITIC GRANITE	PORPHYRITIC DIORITE	PORPHYRITIC GABBRO	PORPHYRITIC PERIDOTITE
Phenocrysts[1] in an aphanitic groundmass	PORPHYRITIC RHYOLITE	PORPHYRITIC ANDESITE	PORPHYRITIC BASALT	Cannot be distinguished from basalt in hand samples (KOMATITE)
Aphanitic: fine-grained	RHYOLITE	ANDESITE	BASALT	
Glassy	OBSIDIAN			
Vesicular	PUMICE (abundant tiny vesicles–like meringue; very lightweight; white or gray; floats in water)		SCORIA (resembles a sponge) VESICULAR BASALT (has few scattered vesicles)	
Pyroclastic or Fragmental	VOLCANIC TUFF (fragments ≤ 2 mm) VOLCANIC BRECCIA (fragments > 2 mm)			

Practical Use for Rock?

Igneous Rock Identification Procedure

Step 1: Observe and record the rock's **TEXTURE**

- ✓ **Pegmatitic**
- ✓ **Phaneritic**
- ✓ **Aphanitic**
- ✓ **Porphyritic**
- ✓ **Fragmental**
- ✓ **Others = vesicular or glassy**

Step 2: IF ***Phaneritic* or *Pegmatitic*-** Identify and record the minerals and the volume % of dark minerals = ***COLOR INDEX***.

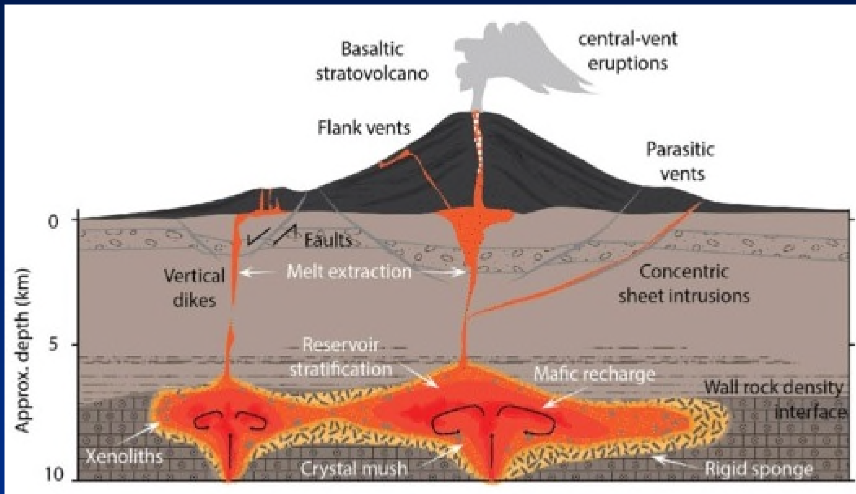
Note: **Color index** applicable for **course-grained rocks** **ONLY**! **OR**

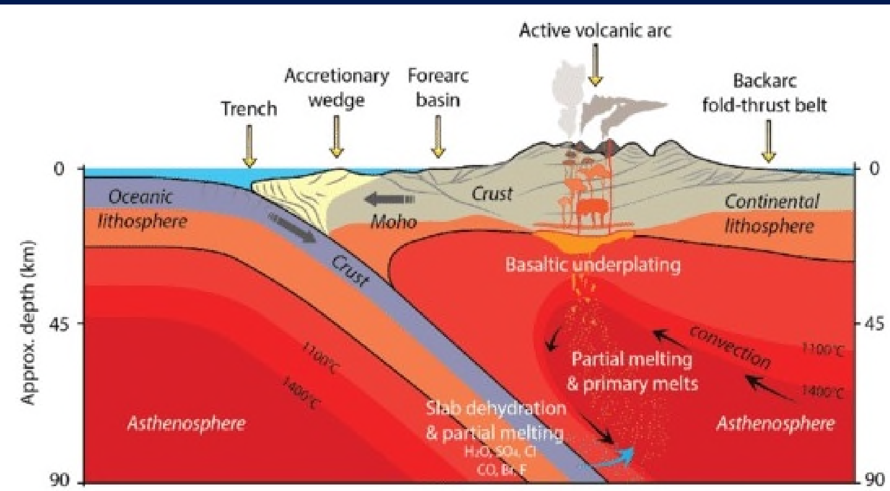
IF ***Aphanitic*** or ***Porphyritic*** = no to some observable minerals, then estimate composition by the **OVERALL ROCK COLOR.**

Note: ("light" = felsic/silisic, "medium" = intermediate, and "dark" = mafic).

Step 3: **NAME the ROCK** – **based on texture/composition combo**

Volcanism


Basaltic stratovolcano
central-vent eruptions
Flank vents
Parasitic vents
Faults
Vertical dikes
Melt extraction
Concentric sheet intrusions
Reservoir stratification
Mafic recharge
Wall rock density interface
Xenoliths
Crystal mush
Rigid sponge
Approx. depth (km)
0
5
10


Active volcanic arc
Trench
Accretionary wedge
Forearc basin
Backarc fold-thrust belt
Oceanic lithosphere
Moho
Crust
Continental lithosphere
Crust
Basaltic underplating
convection
Partial melting & primary melts
Slab dehydration & partial melting
Asthenosphere
Asthenosphere
1100°C
1400°C
Approx. depth (km)
0
45
90

Major Concepts

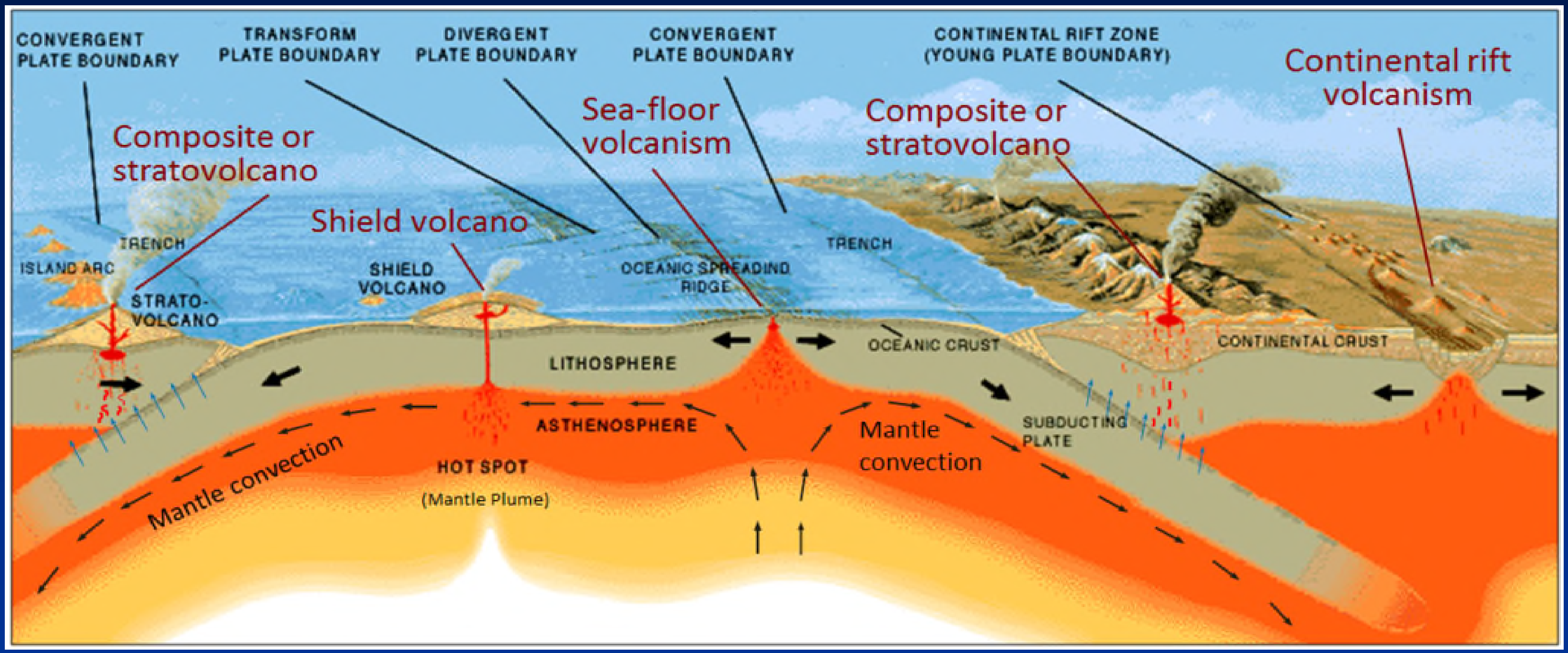
1) Volcanism occurs over places where rocks are melting deep in the Earth
2) Two melting mechanisms are 1) decompression melting and 2) flux melting
3) Three primary tectonic settings of global-scale volcanism are divergent boundaries, subduction-related convergent boundaries, and hot spots.
4) Tectonic environment controls the type of magmas generated, and hence the types of volcanism that occur at specific plate boundaries and hot spots.
5) Magma composition is a function of source rock composition, degree of partial melting, and assimilation and fractionation processes.
6) Magma compositions vary from mafic to intermediate to silicic-felsic.
7) Magma reaching the surface is termed lava, typically forming a volcano.
8) There are different types of volcanoes, with variation due to differences in magma properties and eruption style.
9) There are different types of volcanic eruptions, with variation due to differences in magma properties and volume.
10) Each type of volcanic eruption has a certain explosivity index value, depending on the hazard level.

Magma and Lava = Mother Igneous

Magmas and lavas are the result of partial melting of a source rock deep within the Earth – mainly in the upper mantle where temperatures are high enough for rock to melt

There are two principle mechanisms deep in the Earth that cause rocks to melt: 1) decompression and 2) water fluxing

Tectonic Environments for Volcanism

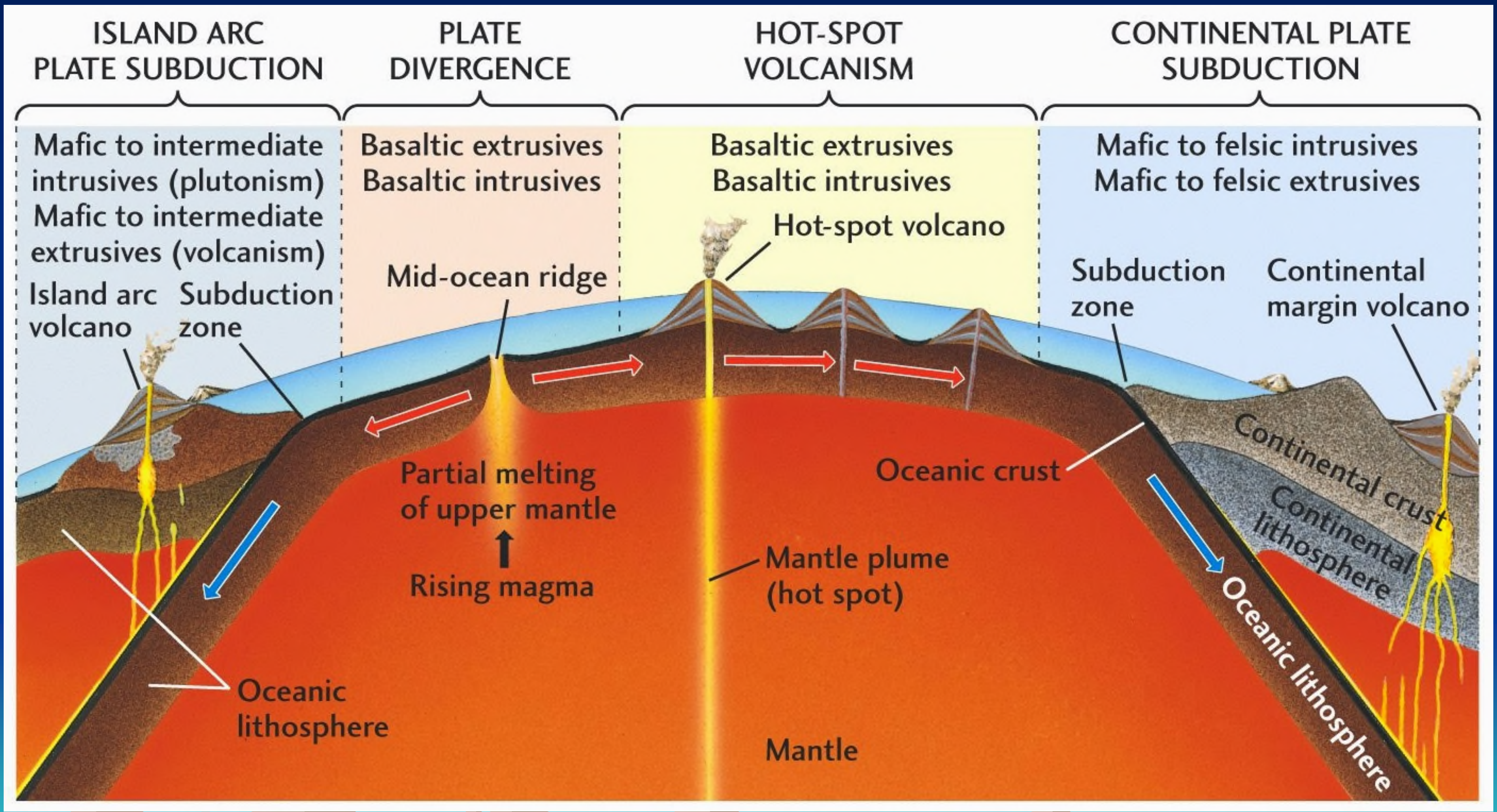


Specific regions in the upper mantle and base of the crust have the proper conditions for rocks to substantially melt: principally at convergent and divergent plate boundaries

Decompression melting mechanism occurs at divergent boundaries and hot spots where overheated, ascending asthenosphere rises to a shallow-enough level (lowered pressure) to spontaneously melt

Water-fluxing, or hydrous melting mechanism occurs at convergent plate boundaries with subduction where dewatering of the downgoing slab lowers the melting temperature of rocks in slab and the overlying mantle wedge

Predominant Magma Types at Specific Plate Tectonic Settings



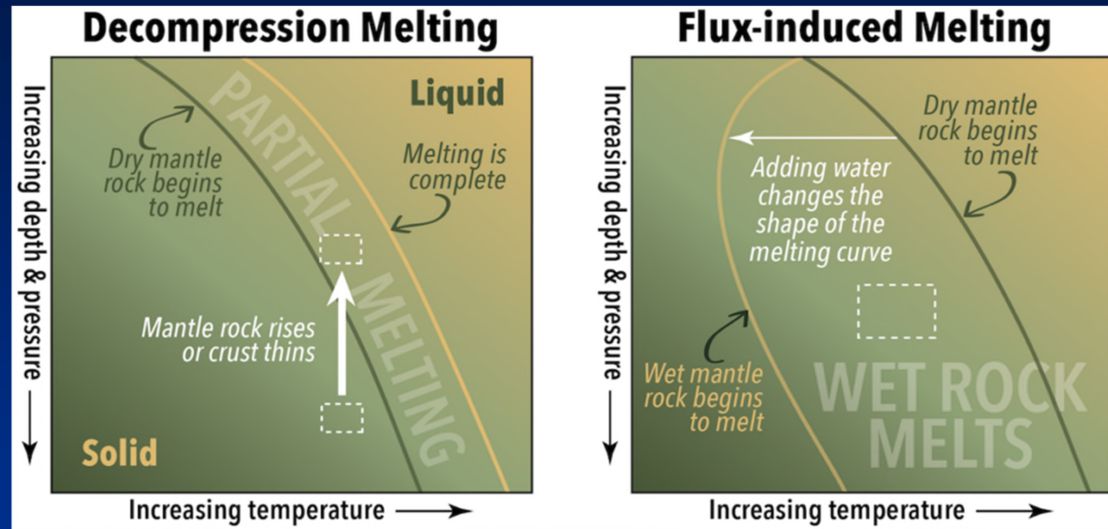
Two Mechanisms That Melt Rocks

Mechanism #1

Decompression Melting

Hot asthenosphere rises to shallow depth - or where crust is greatly thinned - the lowered confining pressure lowers melting temperature and initates melting

Sites of decompression melting are crustal rift zones and hot spots

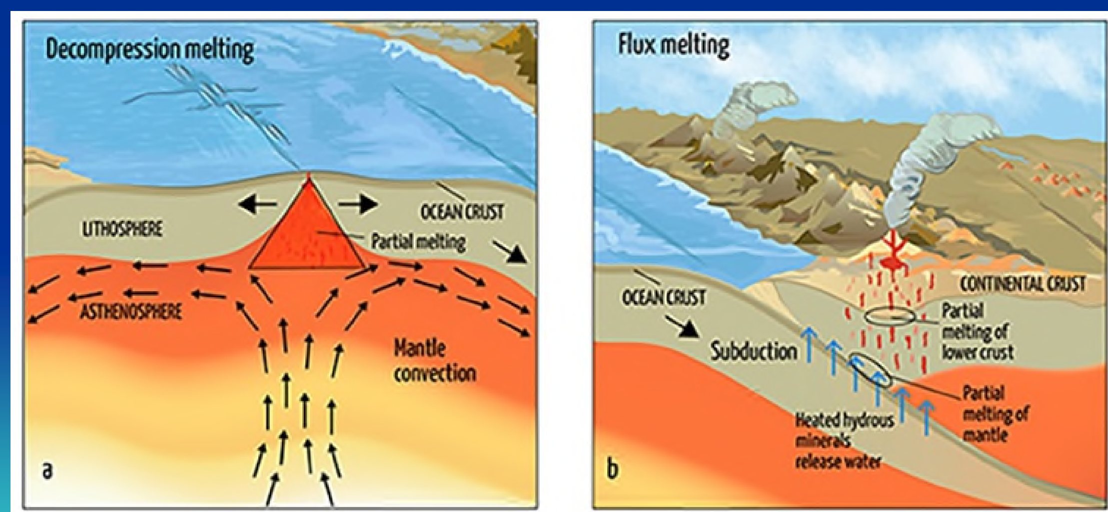


Mechanism #2

Water Flux Melting

Addition of water to source rock acta as a flux, which lowers the melting temperature of the source material, and initates melting

Sites of water-flux melting are subductions zones



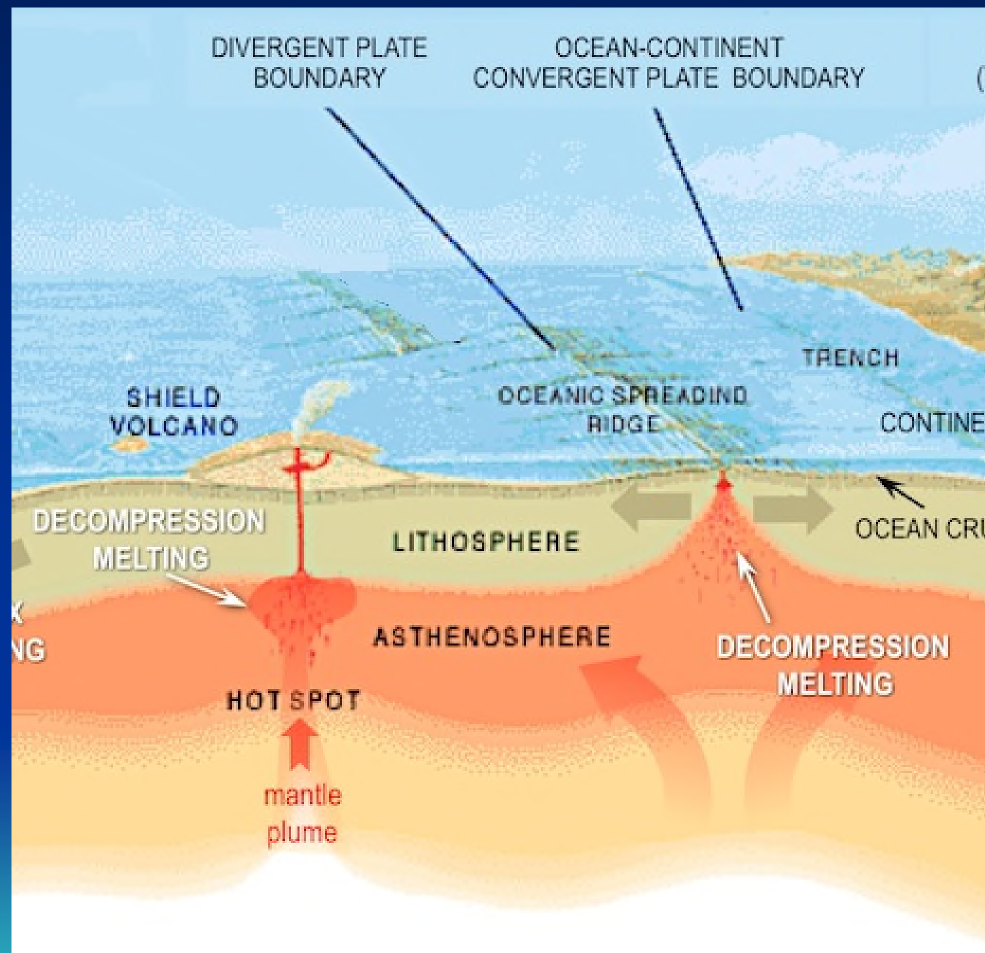
Decompression Melting Mechanism at Rift Zones and Hot Spots

Rising, overheated asthenosphere reaches a shallower depth under lowered confining pressure

Lower confining pressure lowers the melting temperature of rock

At a shallow enough depth,the rising asthenosphere peridotite rock will spontaneously start to melt to form relatively dry, tholiietic basaltoc magma

The generated basaltic magma rises into the overlying crust to eventually form new oceanic crust



Sites include seafloor spreading ridges and rises, hot spots, and continental rift zones.

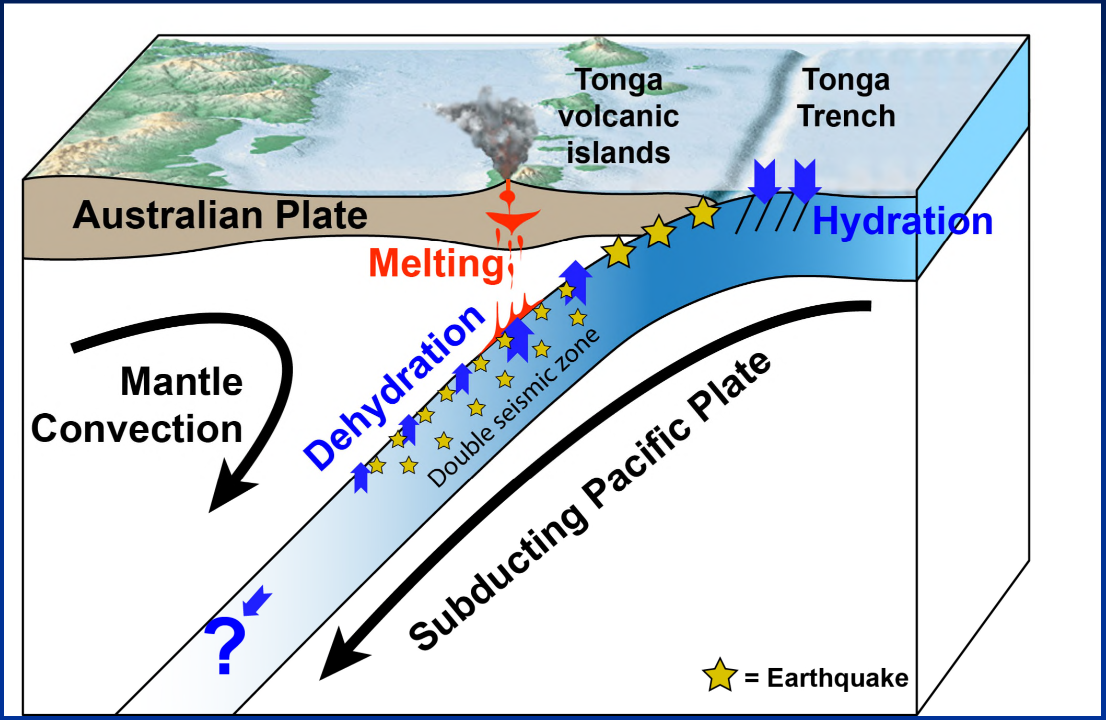
Flux (Dehydration) Melting Mechanism at Subduction Zones

Ocean-hydrated subducting slab (oceanic tectonic plate) brings water deep into the mantle

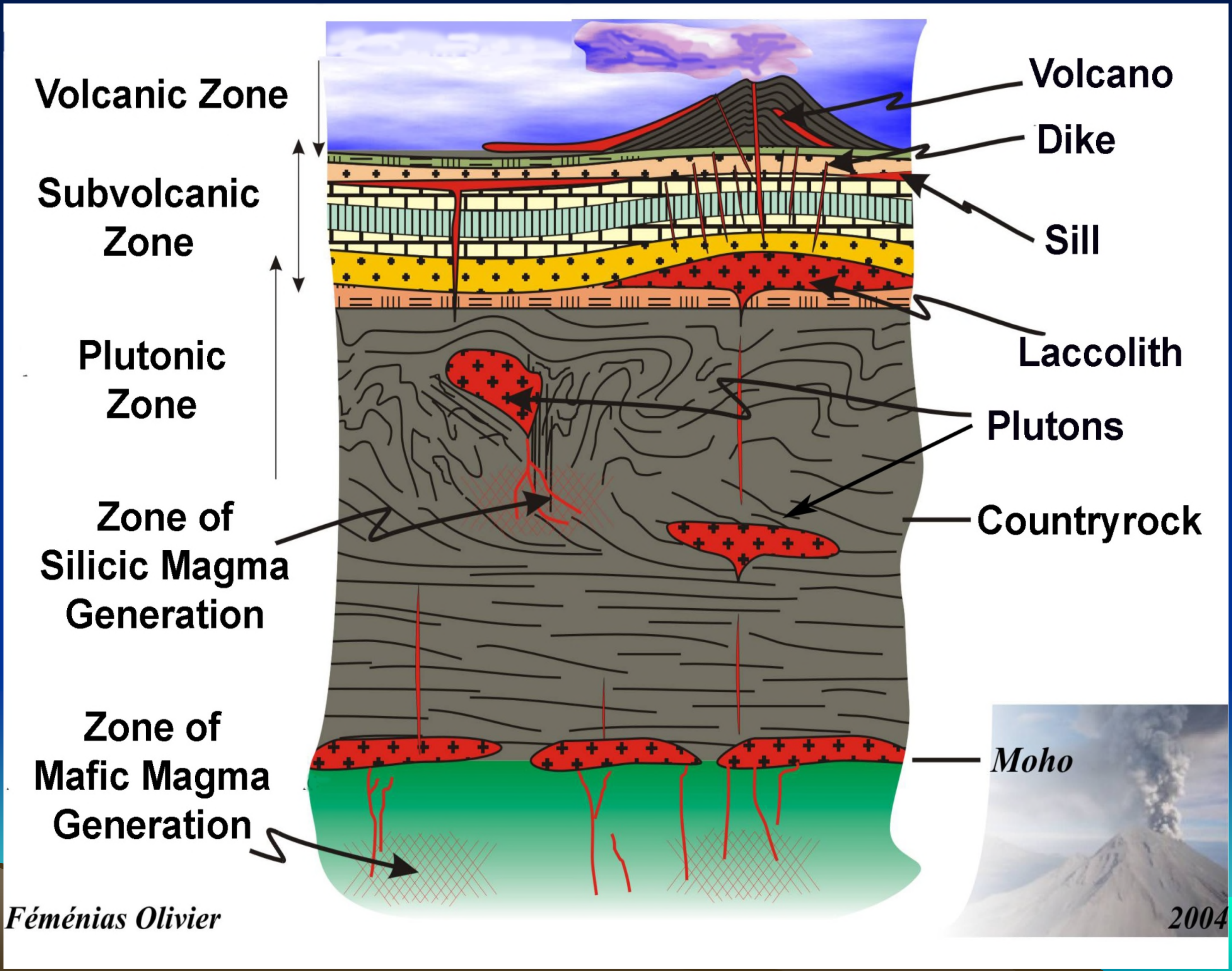
Increasing temperature and pressure with increasing depth causes dehydration of the slab – release of water locked in the subducting sediment and minerals

Released fluids migrate up into the overlying mantle, fluxing the rocks, lowering melting temperature, and causing rocks to melt.

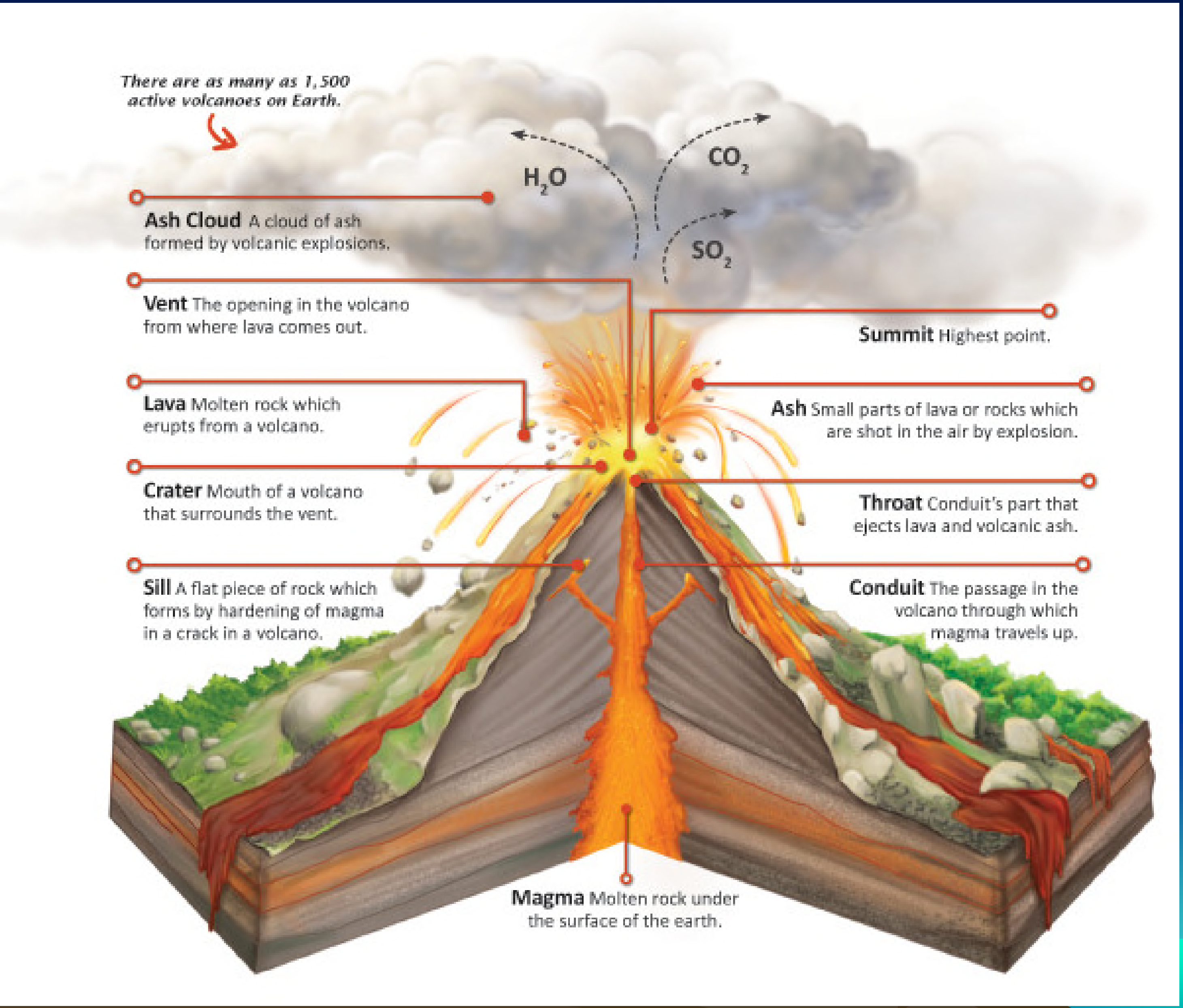
Hydrous basaltic and andesitic magmas are generated in the mantle wedge that feed an overlying volcanic arc



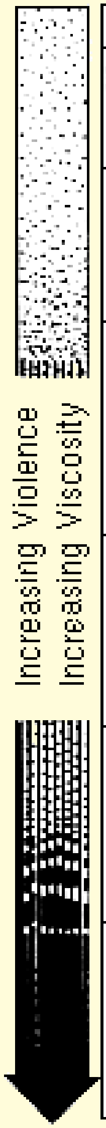
The Volcanic Zone

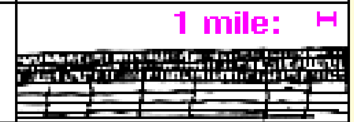
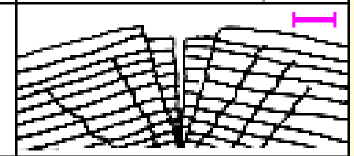
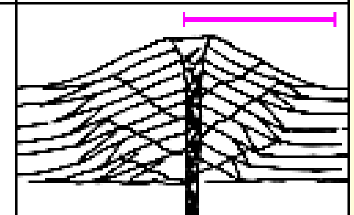
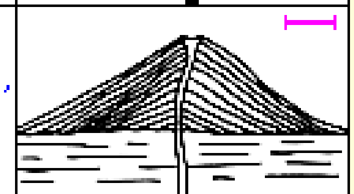
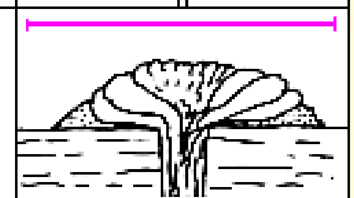
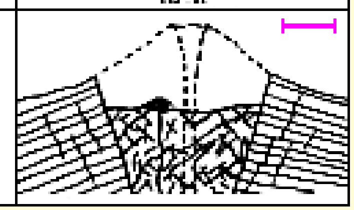


Volcano Anatomy



Types of Volcanoes



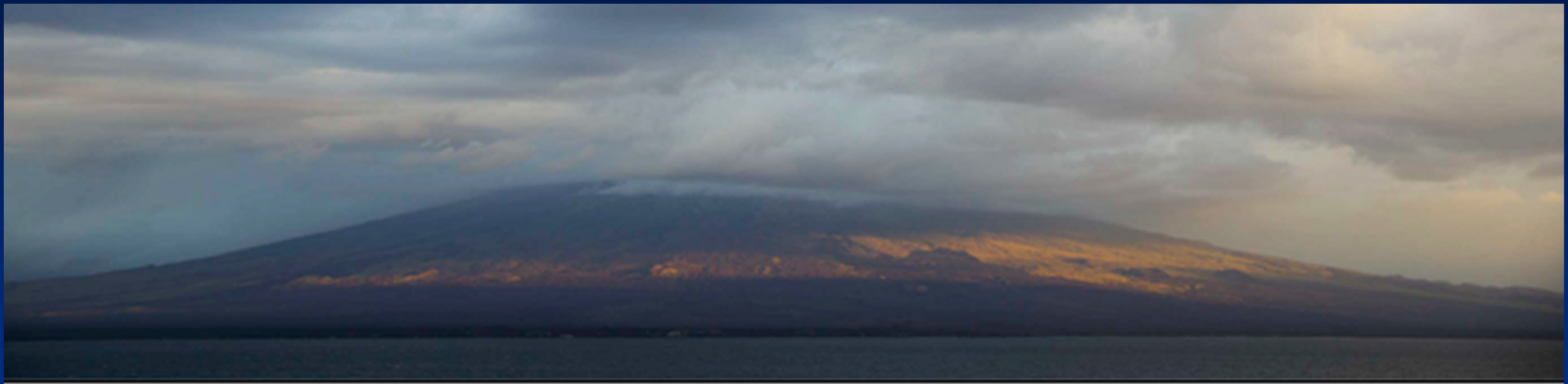
Volcano Type	Characteristics	Examples	Simplified Diagram
Flood or Plateau Basalt	Very liquid lava; flows very widespread; emitted from fractures	Columbia River Plateau	
Shield Volcano	Liquid lava emitted from a central vent; large; sometimes has a collapse caldera	Larch Mountain, Mount Sylvania, Highland Butte, Hawaiian volcanoes	
Cinder Cone	Explosive liquid lava; small; emitted from a central vent; if continued long enough, may build up a shield volcano	Mount Tabor, Mount Zion, Chamberlain Hill, Pilot Butte, Lava Butte, Craters of the Moon	
Composite or Stratovolcano	More viscous lavas, much explosive (pyroclastic) debris; large, emitted from a central vent	Mount Baker, Mount Rainier, Mount St. Helens, Mount Hood, Mount Shasta	
Volcanic Dome	Very viscous lava; relatively small; can be explosive; commonly occurs adjacent to craters of composite volcanoes	Novarupta, Mount St. Helens Lava Dome, Mount Lassen, Shastina, Mono Craters	
Caldera	Very large composite volcano collapsed after an explosive period; frequently associated with plug domes	Crater Lake, Newberry, Kilauea, Long Valley, Medicine Lake, Yellowstone	

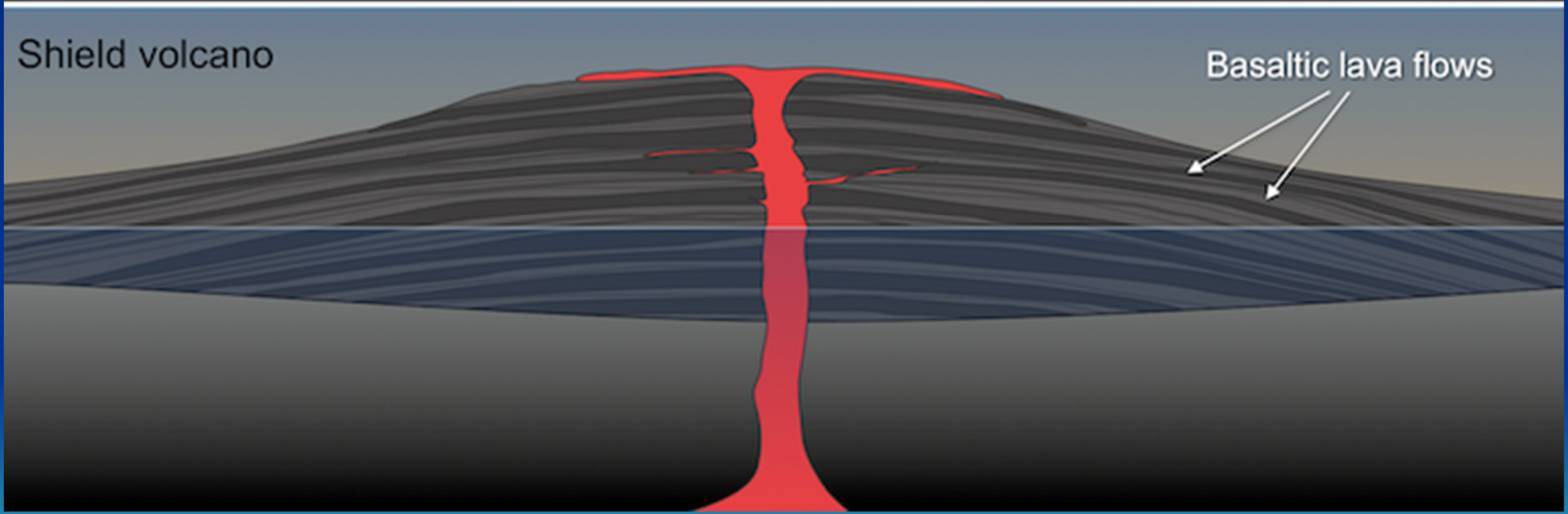
USGS

Topinka, USGS/CVO, 1997, Modified from: Allen, 1975, Volcanoes of the Portland Area, Oregon, Ore-Bin, v.37, no.9

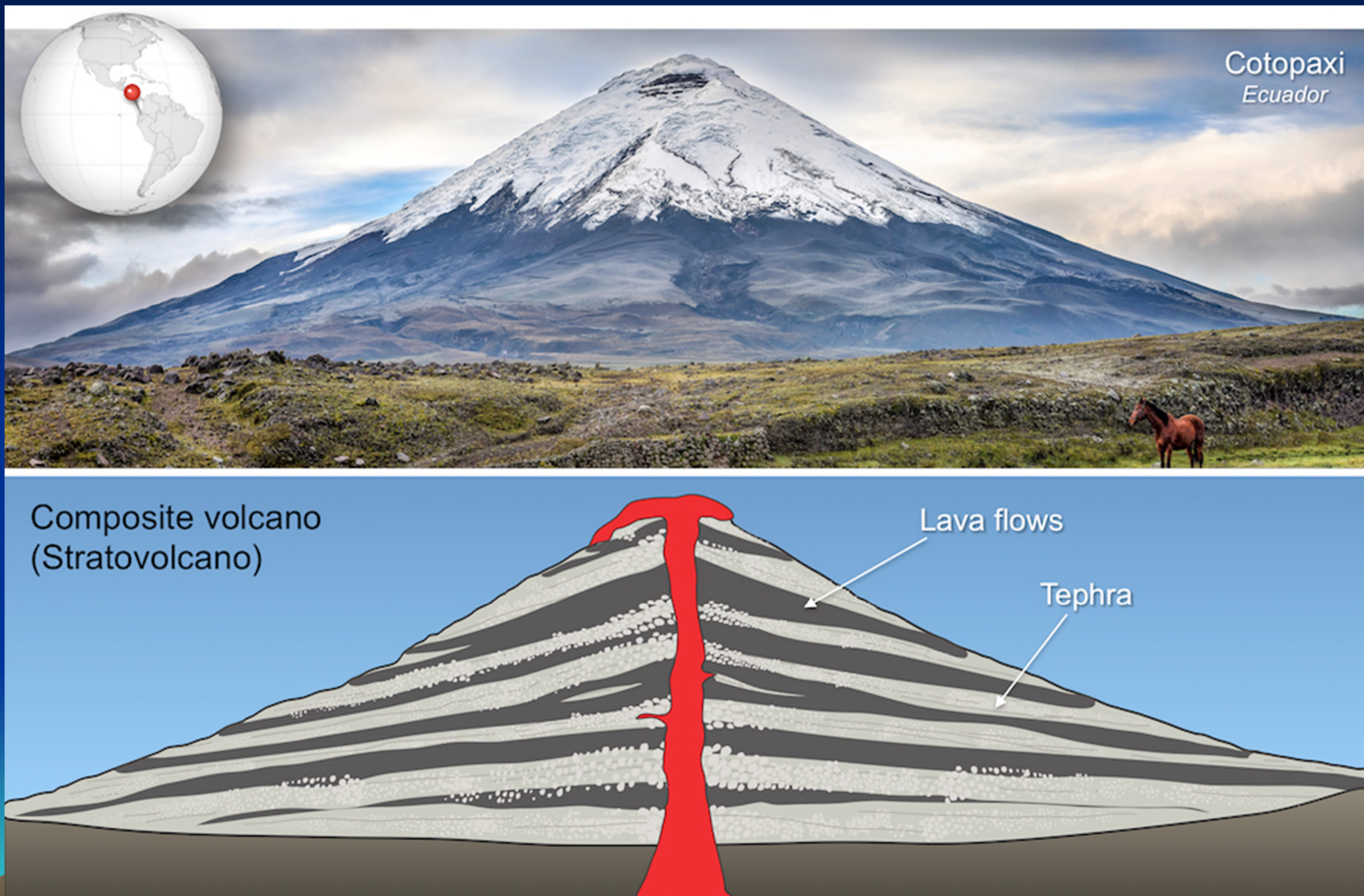

Five Major Types of Volcanoes
Caldera
Crater Lake
Caldera – a large depression created by the collapse of a volcano
USGS Photo by W.E.Scott
Lava Butte
Cinder Cone
Cinder Cone – a simple volcano built from blobs of lava ejected from a single vent
USGS Photo by Lyn Topinka
USGS
Shield Volcano
Shield Volcano – built from countless outpourings of fluid lava flows
USGS Photo by Tom Casadevall
Mauna Loa
Stratovolcano
Stratovolcano – built of layers of lava, ash, and volcanic debris
Mount Rainier
USGS Photo by Lyn Topinka
Lava Dome
Lava Dome – mound formed when viscous lava piles up around vent
USGS Photo by Lyn Topinka
Mount St. Helens
1. Caldera
2. Cinder Cone
3. Shield Volcano
4. Stratovolcano
5. Lava Dome
Lyn Topinka, USGS/CVO, 1998

Shield Volcano

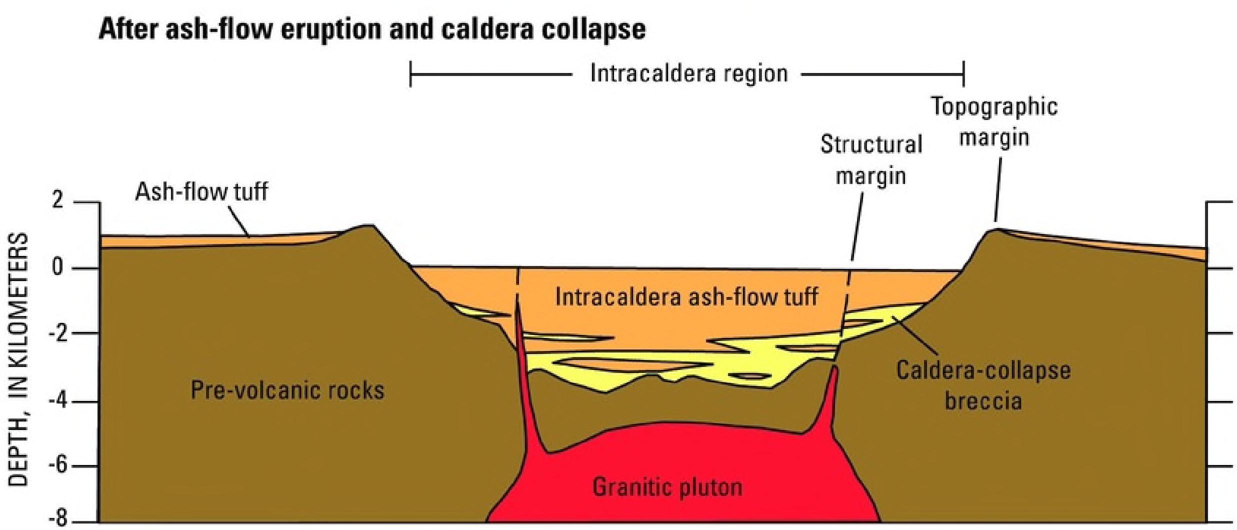




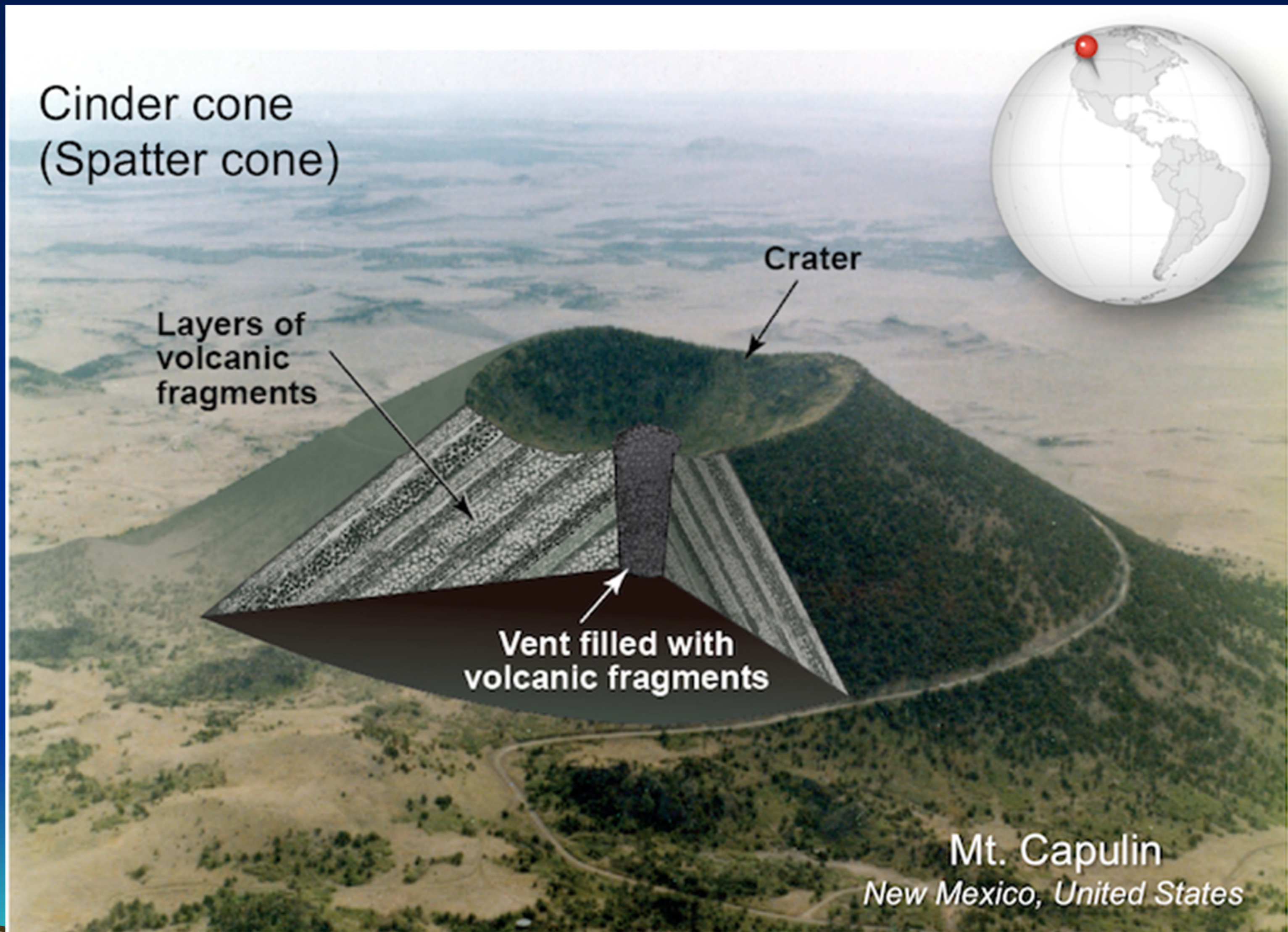
Composite (Strato)Volcano



Caldera Volcano

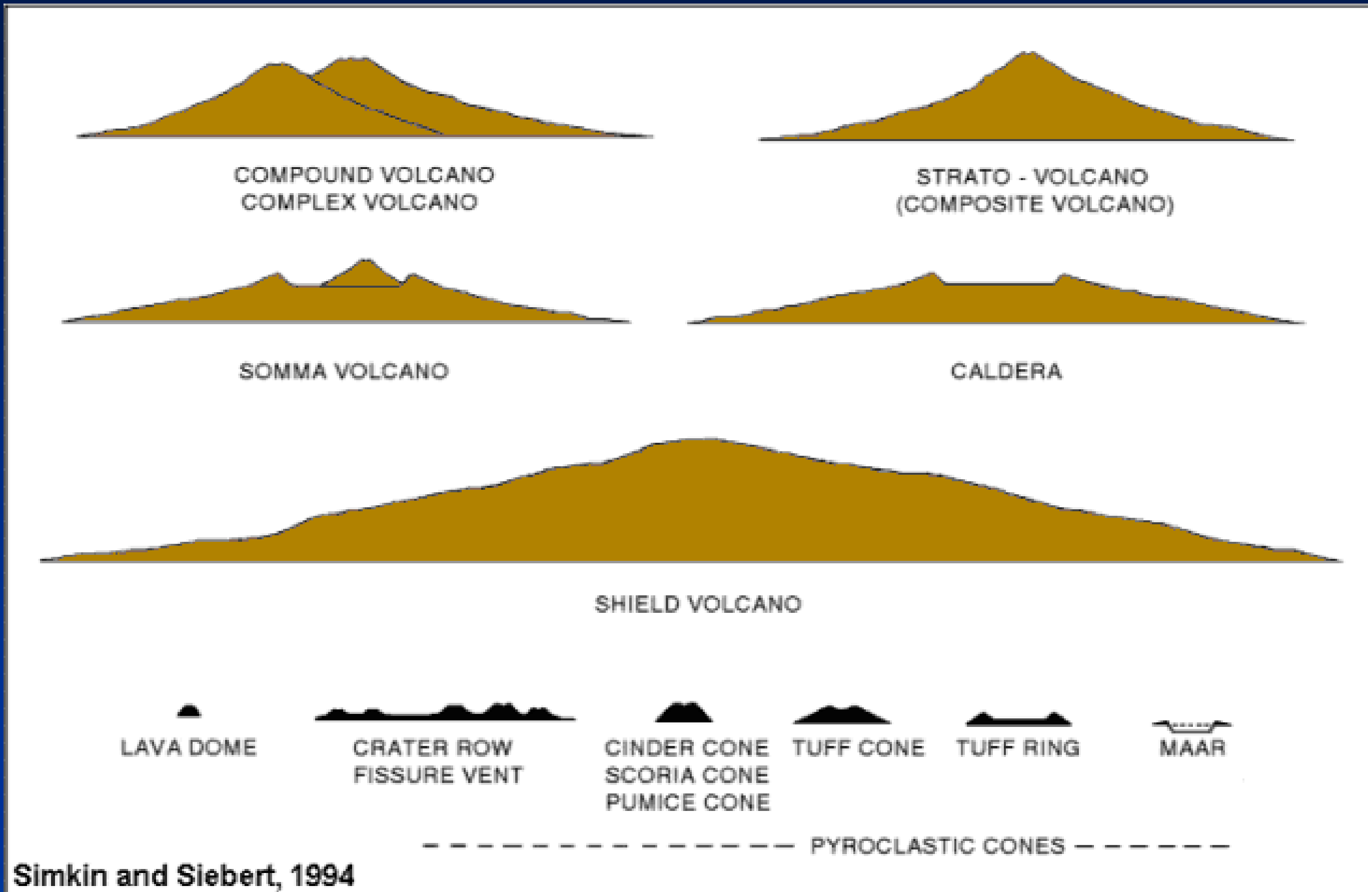


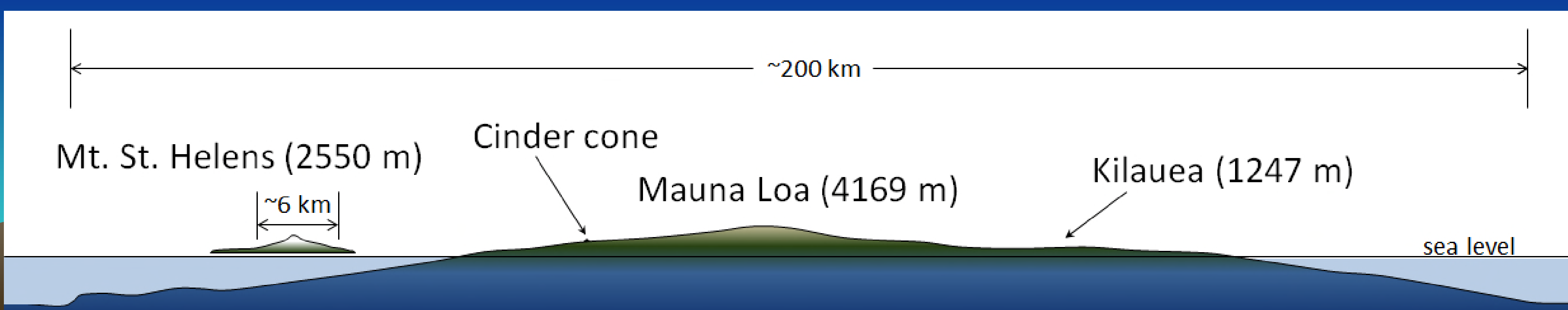
Cinder Cone



Cinder cone
(Spatter cone)
Crater
Layers of
volcanic
fragments
Vent filled with
volcanic fragments
Mt. Capulin
New Mexico, United States

Size Variation of Volcano Types





Volcanic Eruptions

What Causes Volcanic Eruptions?

Multiple factors capable of triggering a volcanic eruption:

1) Buoyancy of the magma

2) Pressure from the exsolving gases in the magma

3) Injection of a new batch of magma into an already filled magma chamber

4) Catastrophic collapse of volcanic cone leading to depressurizing of underlying magma

5) Contact between magma and groundwater

6) Massive earthquake in the vicinity of a dormant volcano

Controls on Volcanic Eruptions

1) Silica Content of Magma

2) Temperature of the Magma

3) Dissolved Gas Content in the Magma

4) Confining Pressure over the Magma

5) Volume and Depth of Magma Reservoir

6) Design of Volcano's Plumbing System

Volcanic Eruption Types

Magmatic Eruptions

1. Hawaiian
2. Strombolian
3. Vulcanian
4. Peléan
5. Plinian

Phreatomagmatic Eruptions

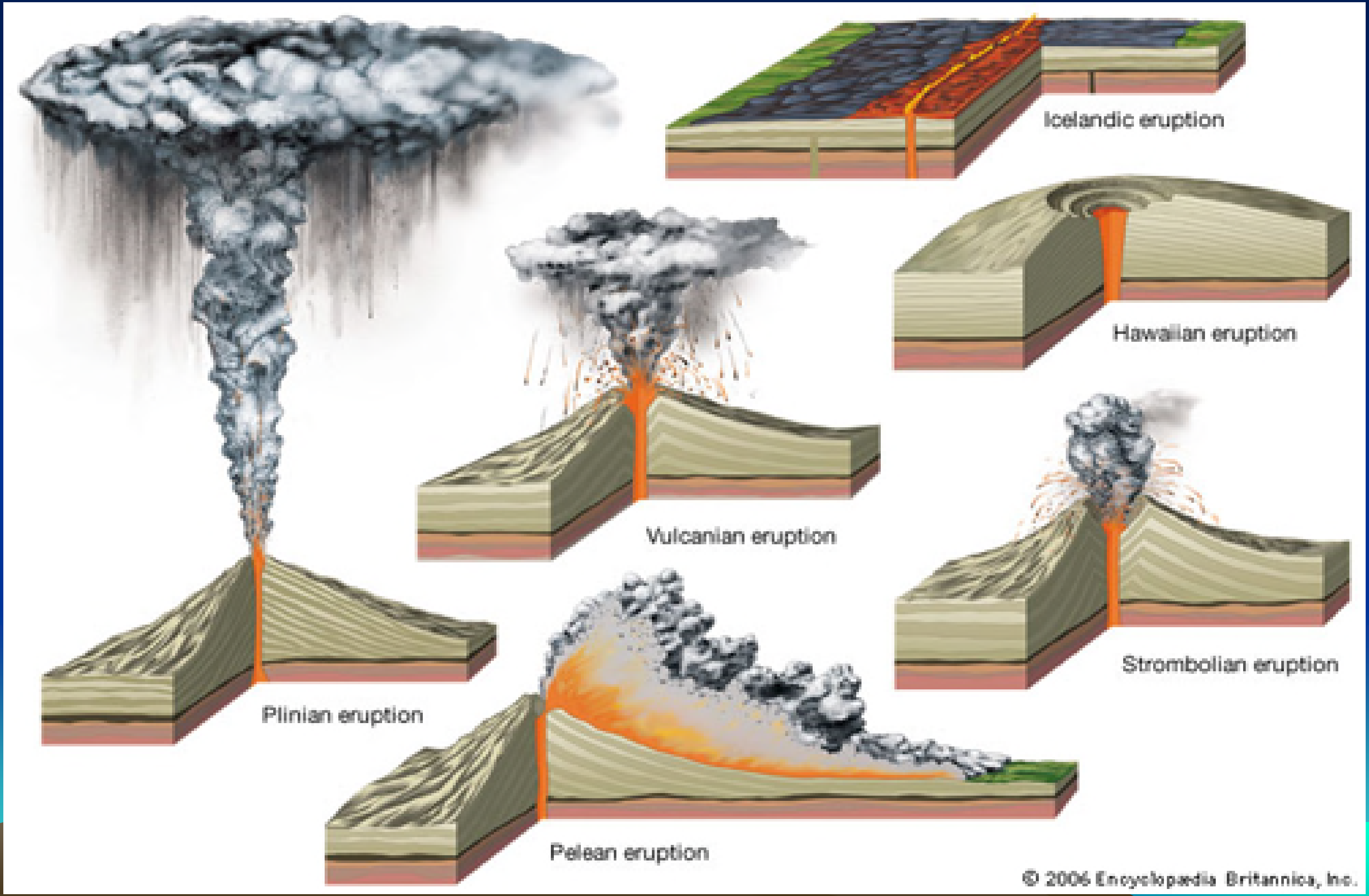
1. Surtseyan
2. Submarine
3. Subglacial

Phreatic Eruptions

Basaltic Volcanic Eruptions

Andesitic Volcanic Eruptions

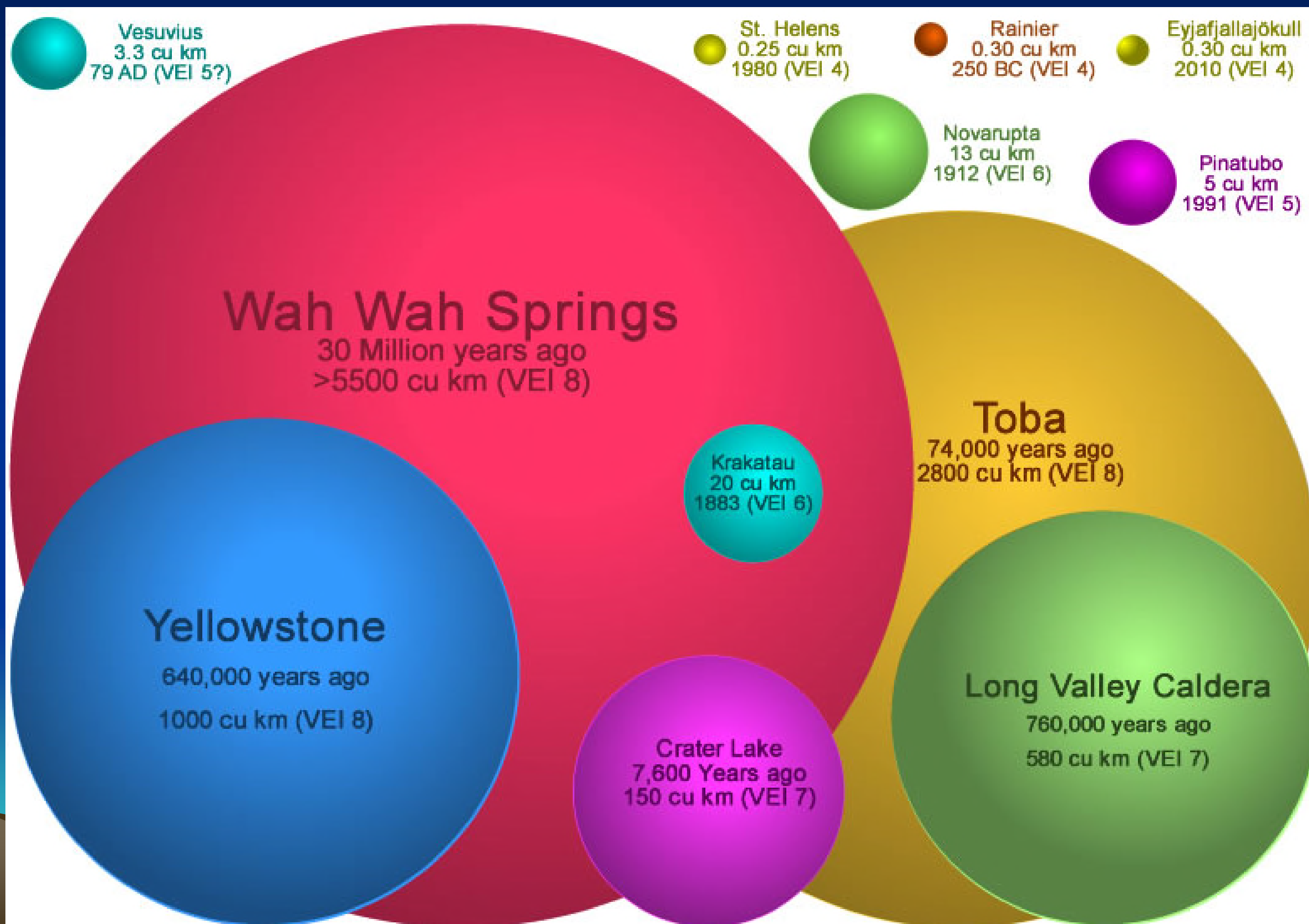
Types of Volcanic Eruptions



Volcano Explosivity Index - VEI

VEI	Plume height	Eruptive volume *	Eruption type	Frequency	Example
0	<100 m (330 ft)	1,000 m^3 (35,300 cu ft)	Hawaiian	Continuous	Kilauea
1	100–1,000 m (300–3,300 ft)	10,000 m^3 (353,000 cu ft)	Hawaiian/Strombolian	Months	Stromboli
2	1–5 km (1–3 mi)	1,000,000 m^3 (35,300,000 cu ft) ‡	Strombolian/Vulcanian	Months	Galeras (1992)
3	3–15 km (2–9 mi)	10,000,000 m^3 (353,000,000 cu ft)	Vulcanian	Yearly	Nevado del Ruiz (1985)
4	10–25 km (6–16 mi)	100,000,000 m^3 (0.024 cu mi)	Vulcanian/Peléan	Few years	Eyjafjallajökull (2010)
5	>25 km (16 mi)	1 km^3 (0.24 cu mi)	Plinian	5–10 years	Mount St. Helens (1980)
6	>25 km (16 mi)	10 km^3 (2 cu mi)	Plinian/Ultra Plinian	1,000 years	Krakatoa (1883)
7	>25 km (16 mi)	100 km^3 (20 cu mi)	Ultra Plinian	10,000 years	Tambora (1815)
8	>25 km (16 mi)	1,000 km^3 (200 cu mi)	Ultra Plinian	100,000 years	Lake Toba (74 ka)

Comparison of the Magnitude of Famous Volcanic Eruptions



Volcanic Eruption Products and Hazards

1) Tephra (ash)

2) Lava

3) Pyroclastic Flow

4) Bombs

5) Gases

6) Lahar

7) Heat

8) Acid Rain

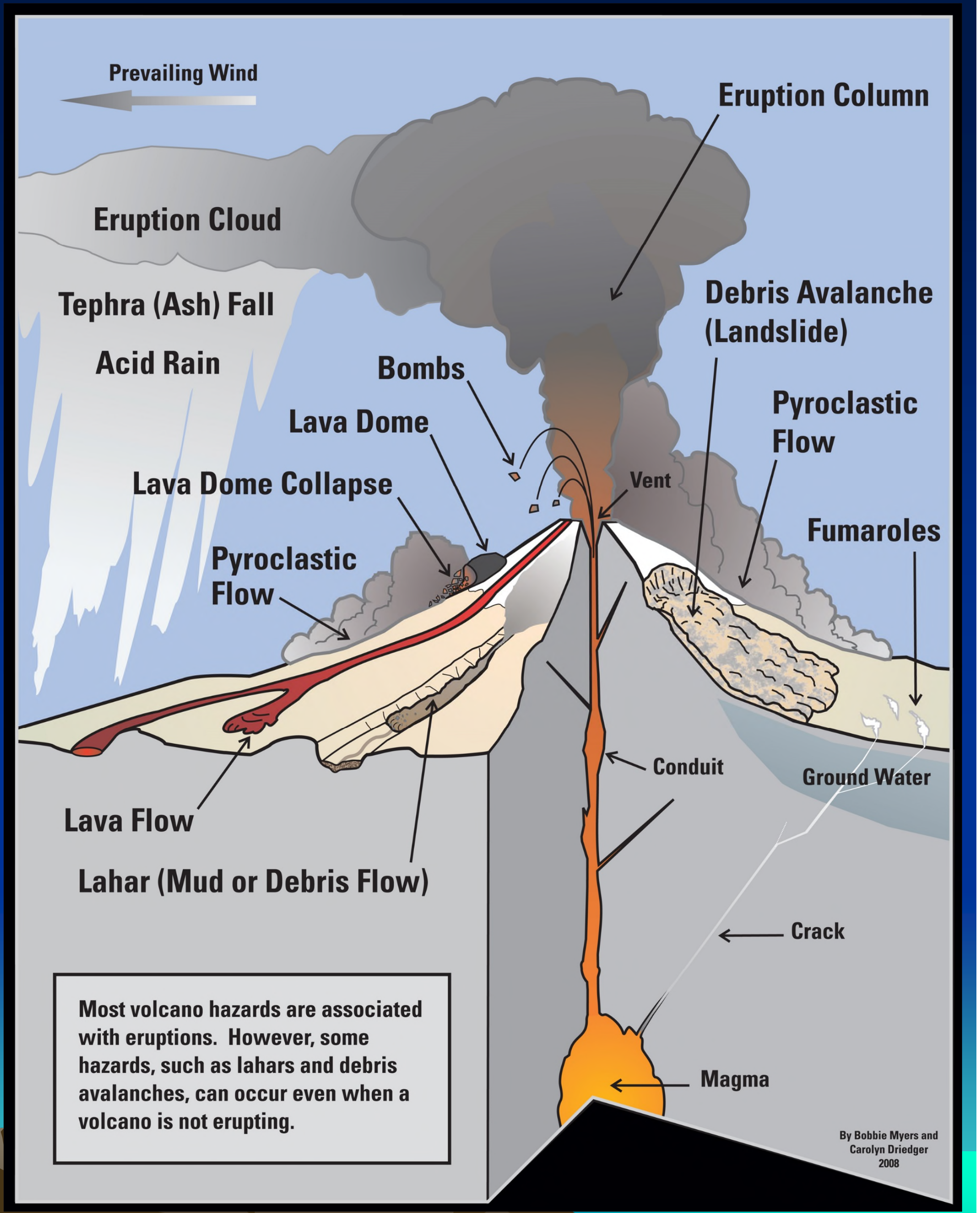


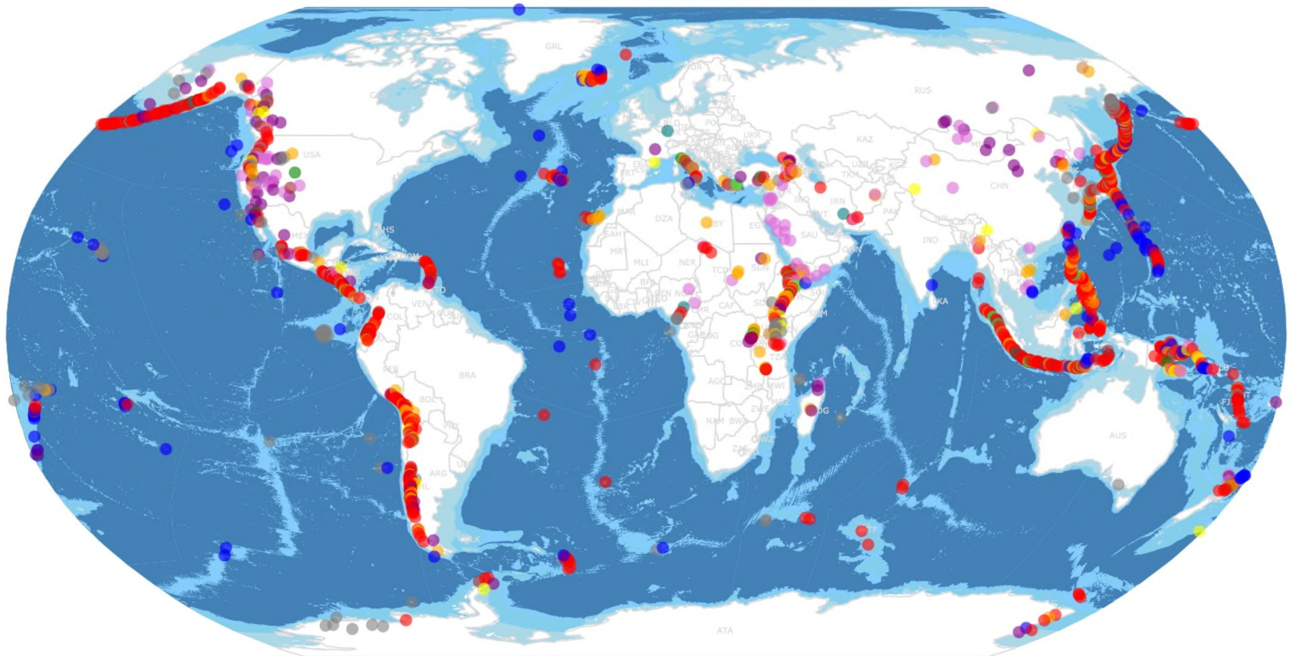
Image Gallery of Volcanic Materials

Active Volcanoes Around the World

Most of Earth's active volcanoes are found along plate boundaries

The map to the right shows the location and type of active volcano

Note that most of the strato volcanoes (red dots) are associated with subduction zones



Volcano Types in this Map

Shield Volcano	Strato Volcano	Caldera	Cinder Cone
Pyroclast	Explosion	Complex volcano	Lava
Maars	Fumarole	Submarine	Volcanic
Other	https://databayou.com/volcano/map.html		

javascript:void

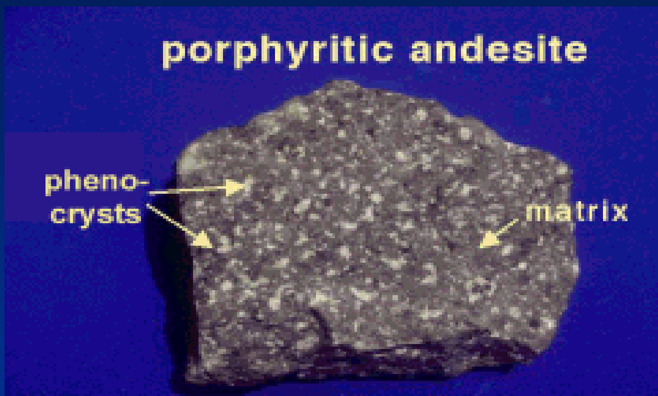
https://volcano.si.edu/

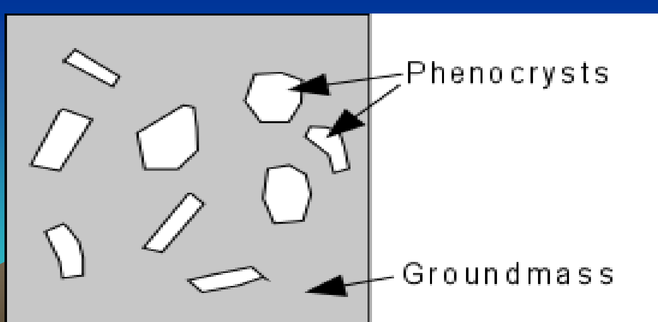
Most Active Volcanoes in 2020

PEDAL CHILE

Volcanic Lava Rock Textures

Porphyritic





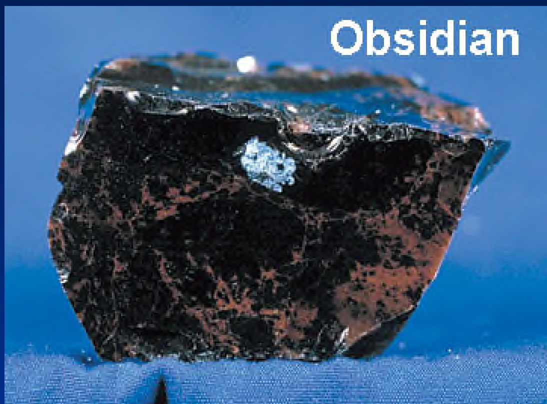
Aphanitic

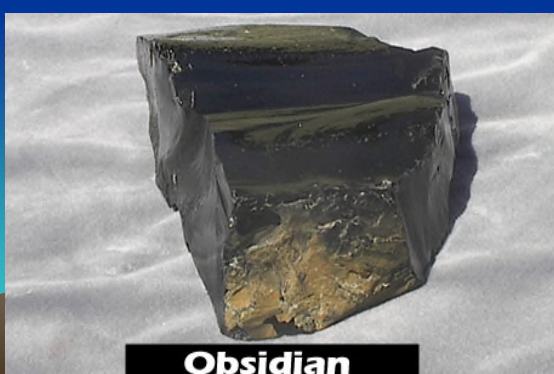
- ✓ Extrusive -Volcanic
- ✓ Fine-grained
- ✓ Cooled Rapidly

- ✓ Combo Plutonic -Volcanic
- ✓ Coarse-grained phenocrysts in a fine-grained groundmass
- ✓ First cooled Slow, then Fast

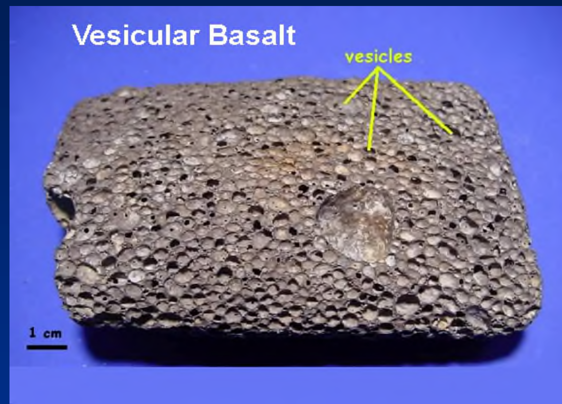
Other Volcanic Rock Textures

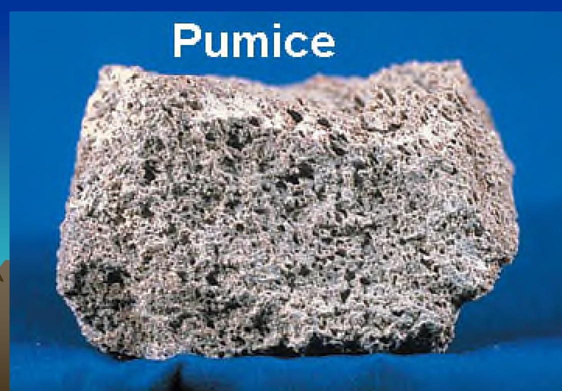
Glassy



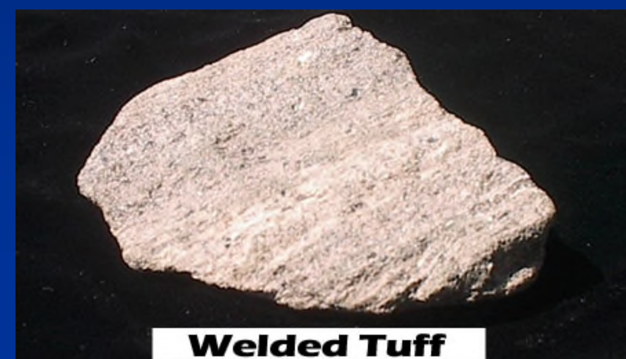


Vesicular





Fragmental



Recommended Volcano Sites

https://courses.lumenlearning.com/wmopen-geology/chapter/outcome-volcano-types/

Igneous Rock References

http://www.rockhounds.com/rockshop/rockkey/index.html

http://earthsci.org/education/teacher/basicgeol/igneous/igneous.html#KindsofIgneousRocks

http://www.cobweb.net/~bug2/mineral.htm

http://www.rockhounds.com/rockshop/rockkey/index.html

http://www.union.edu/PUBLIC/GEODEPT/COURSES/geo-10/mineral.htm

- http://academic.brooklyn.cuny.edu/geology/grocha/mineral/mineral.html