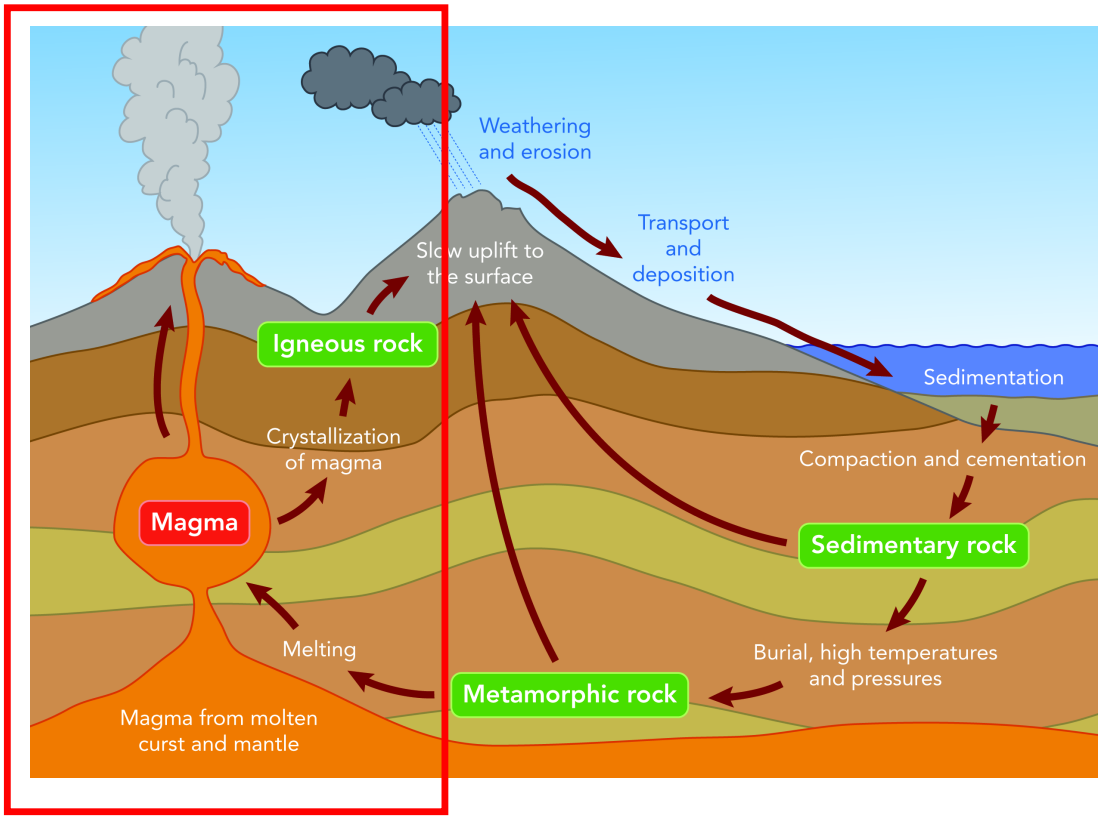
Magmatic rocks

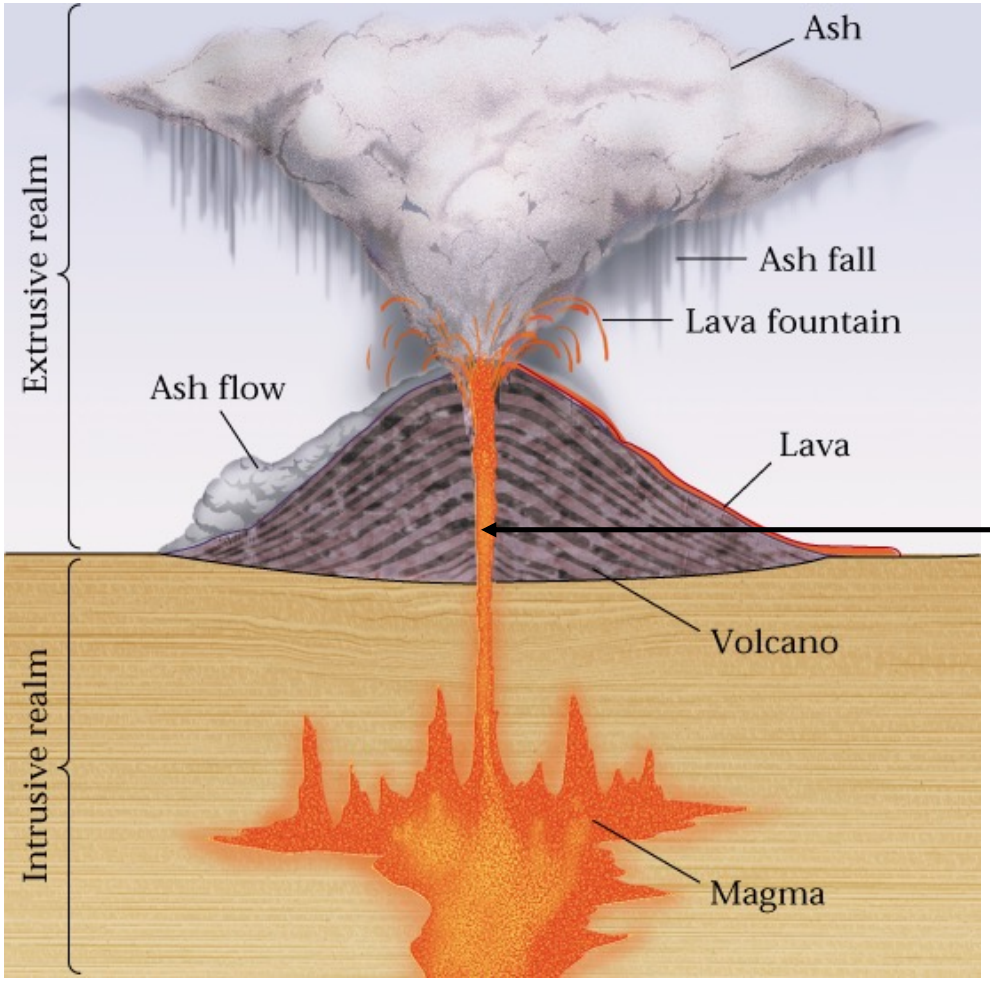
Magmatic Rocks

Magmatic (igneous) rocks are formed from a **melt** that occurs in magma chambers and fractures at depth. The melt can erupt (come up to the surface) during a volcanic event and form lava that crystallizes fast. These are **volcanic rocks (extrusive).**

The melt starts to crystallize minerals at depth and if there is no eruption then the crystallization continuous until no more melt is left. They are called **plutonic rocks (intrusive)**.



Magmatic Rocks: plutonic vs. volcanic



Volcanic rocks cool down fast, yields small crystal sizes, glass

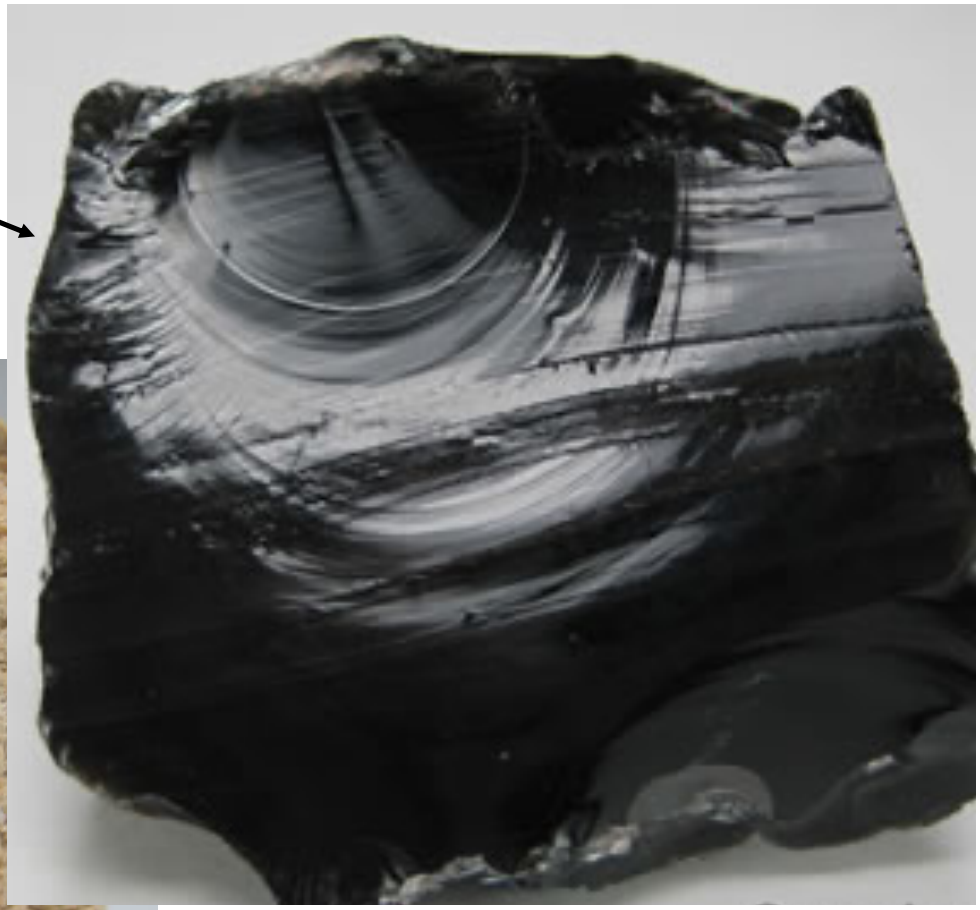
Intermediate cooling rate

Plutonic rocks cool slowly, larger crystal sizes

APHANITIC
TEXTURE

(GLASS)

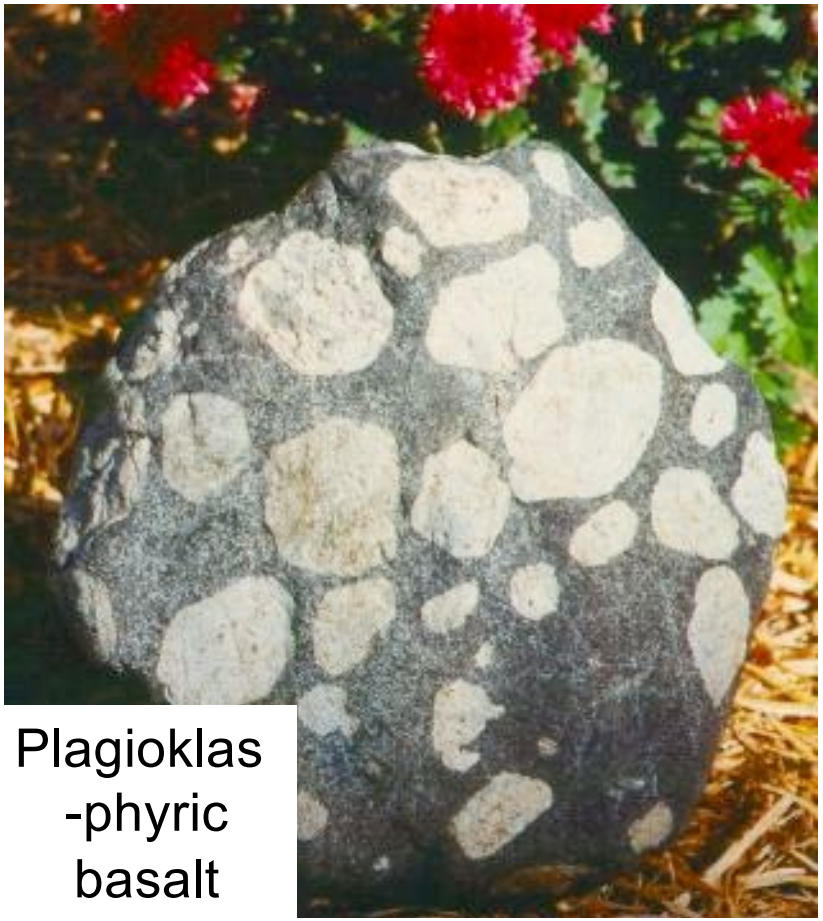
Obsidian



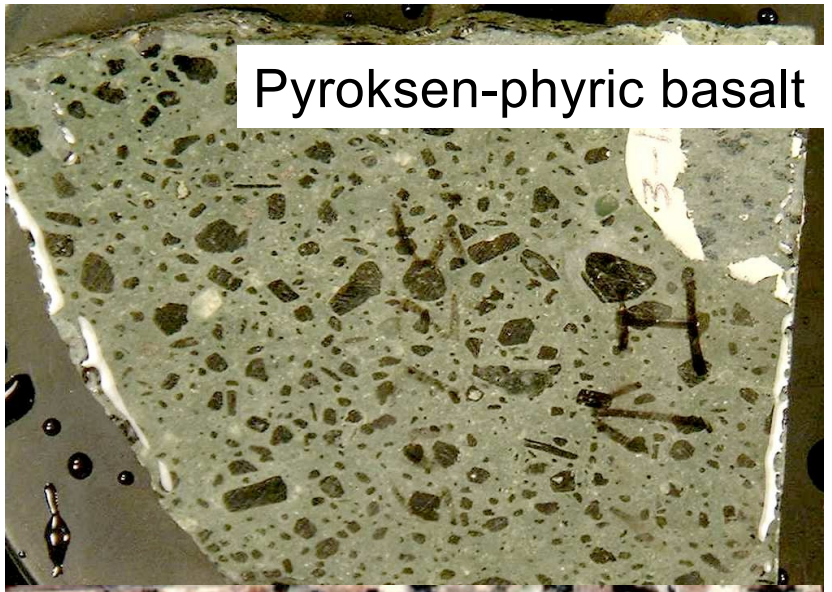
Pumice

The large crystals are PHENOCRYSTALS

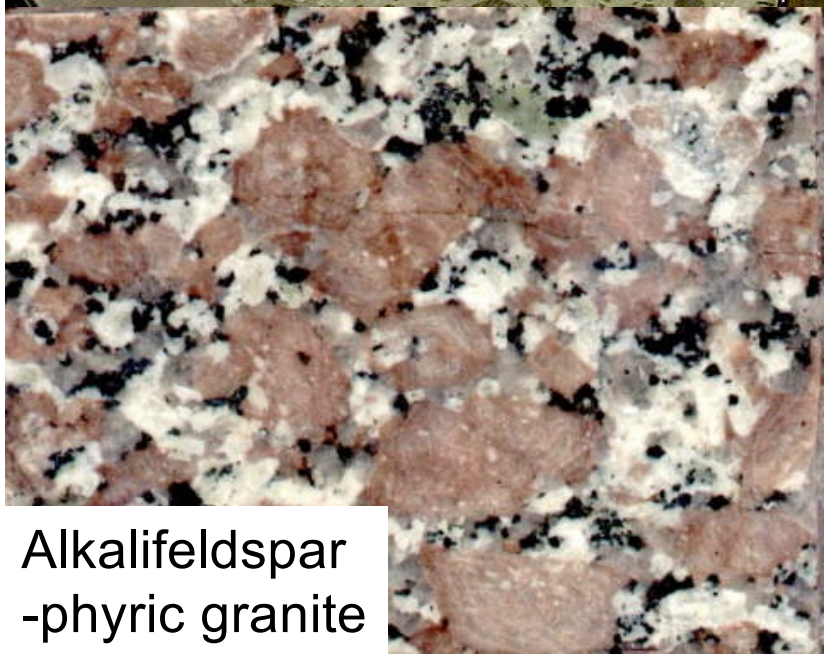
The texture is called PORPHYRIC



Plagioklas -phyric basalt



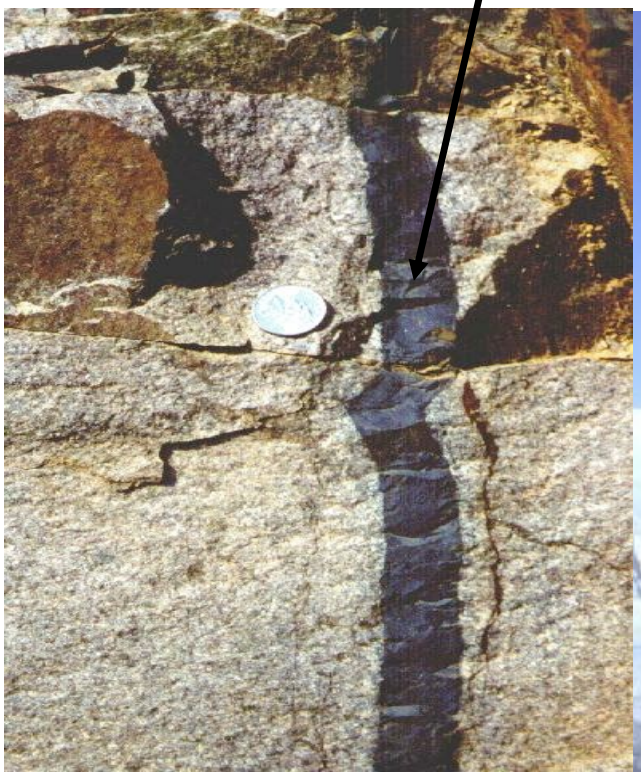
Pyroksen-phyric basalt



Alkalifeldspar -phyric granite

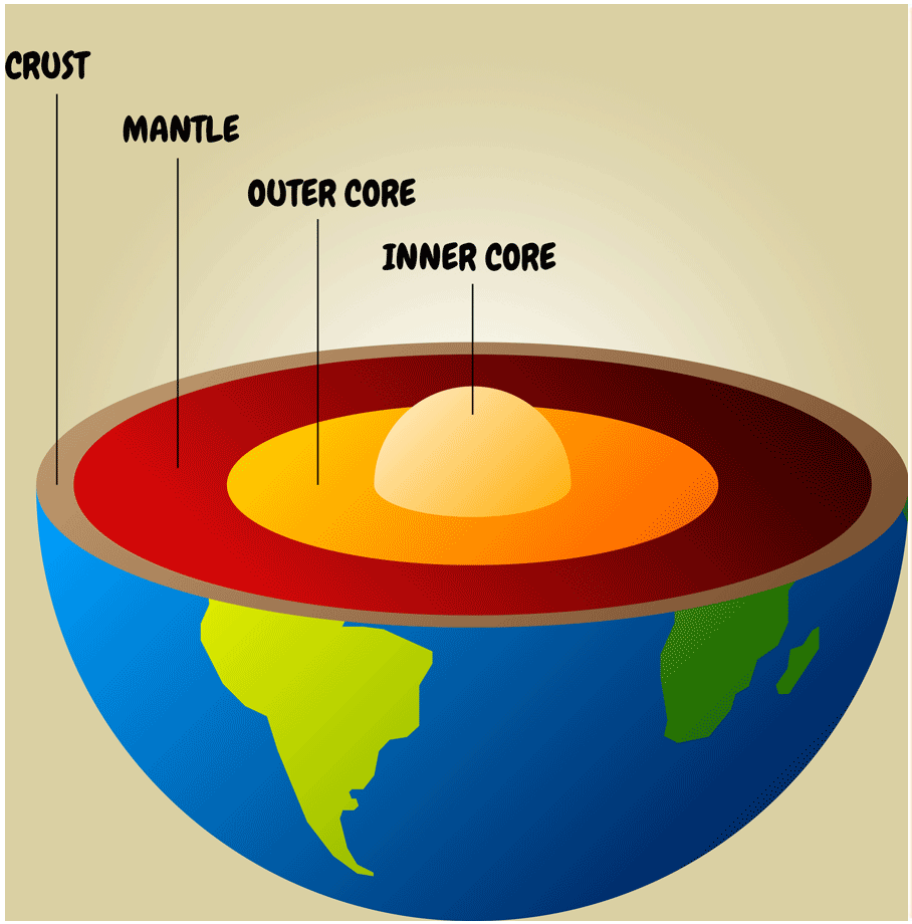
Microgabbro is called
dolerite (eng.) or **diabase** (am.)

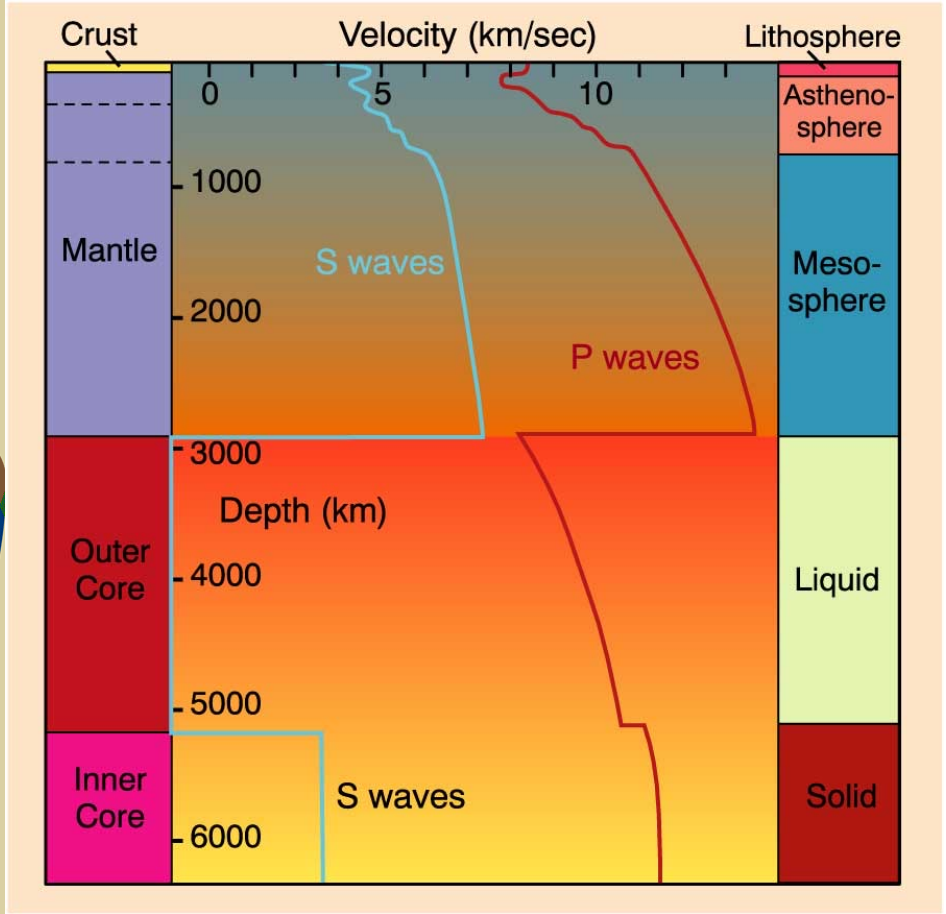
e.g., a dolerite dyke or



diabase sill

Magmatic Rocks: Where does magma come from?



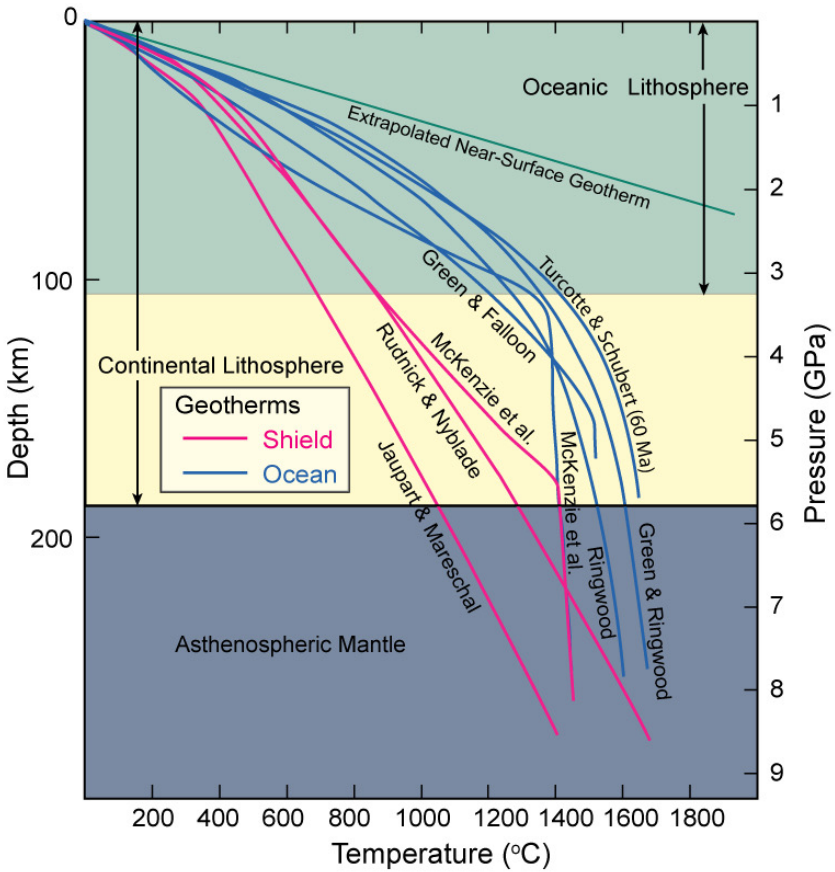


Magmatic Rocks: Where does magma come from?

Normal geotherm does not melt rocks.

Basaltic magma (most abundant) has a temperature of about 1100-1200°C . Generated at a depth of at least 100km.

Partial melting of mantle material (peridotite)



Magmatic Rocks: Where does magma come from?

The temperature of the magma depends on its composition

Basaltic lava ca. 1200° C
Rhyolitic lava ca. 900° C

LIQUIDUS temperature: the first crystals form. The lowest temperature where there is 100% melt.

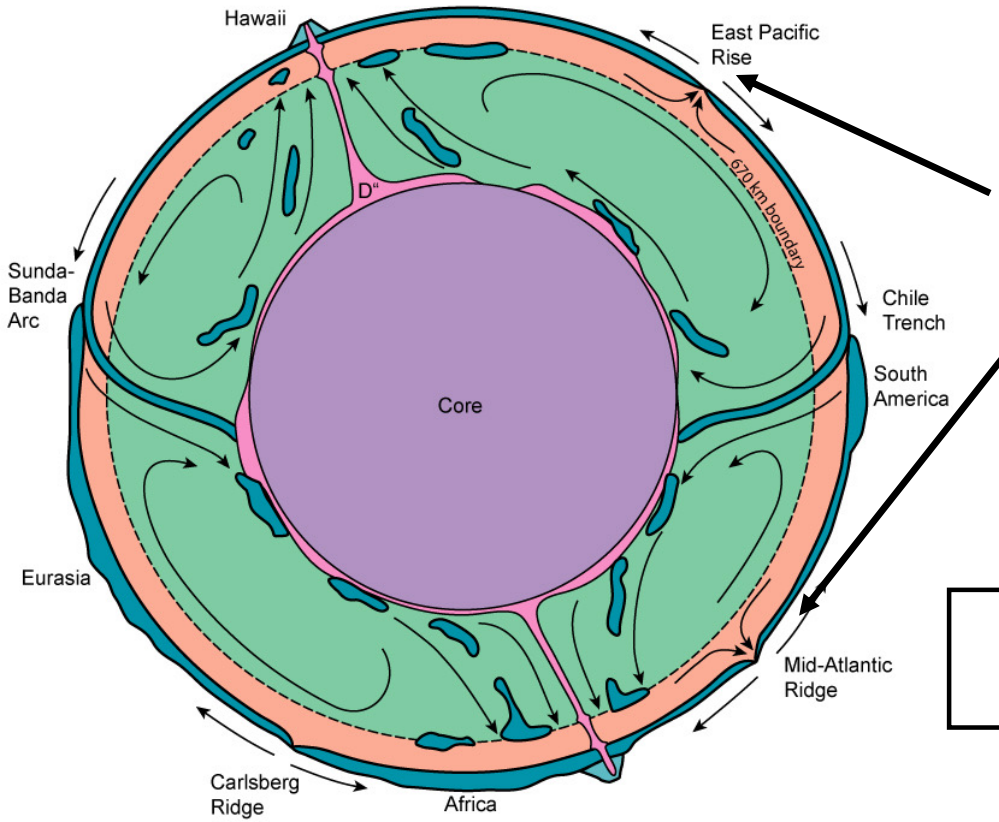
SOLIDUS temperaturen: last drop of melt crystallizes. The highest temperature where 100% is crystallized.

Magma crystallizes over a temperature interval

Basalt liquidus ca. 1200° C; solidus ca. 990° C

Rhyolit solidus ca. 900° C; solidus ca. 750° C

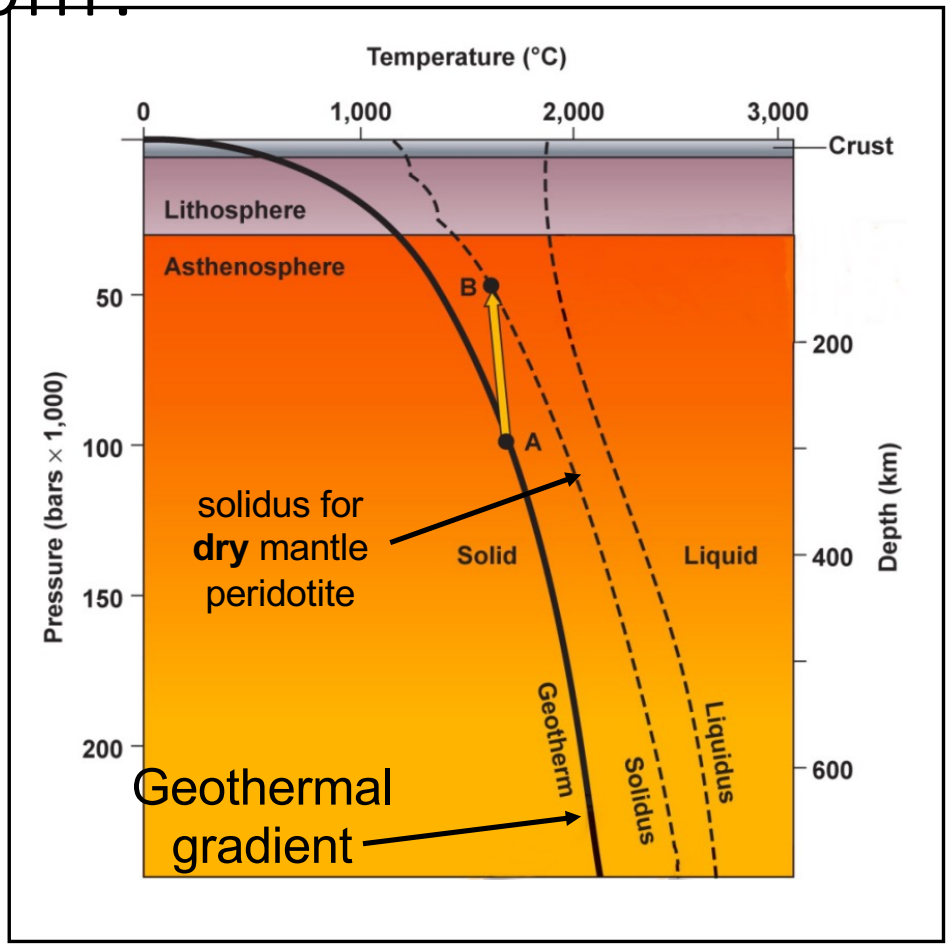
Magmatic Rocks: Where does **basaltic** magma come from?



Convection drives peridotite up into a region where it can melt due to **pressure decrease**.

This happens at Mid-Ocean Ridges (MOR)

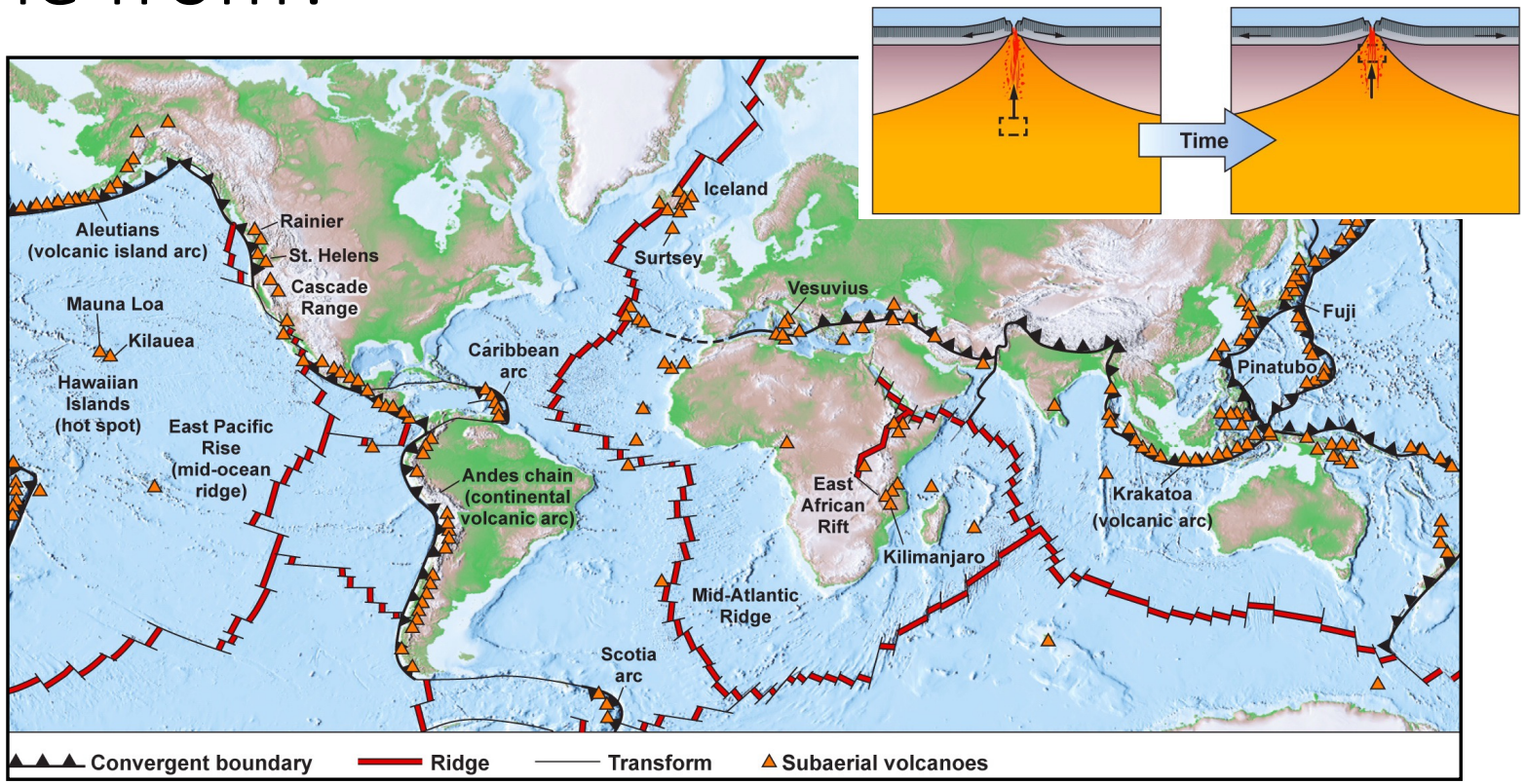
Magmatic Rocks: Where does **basaltic** magma come from?



Partial melting requires that the temperature is higher than the SOLIDUS temperatur

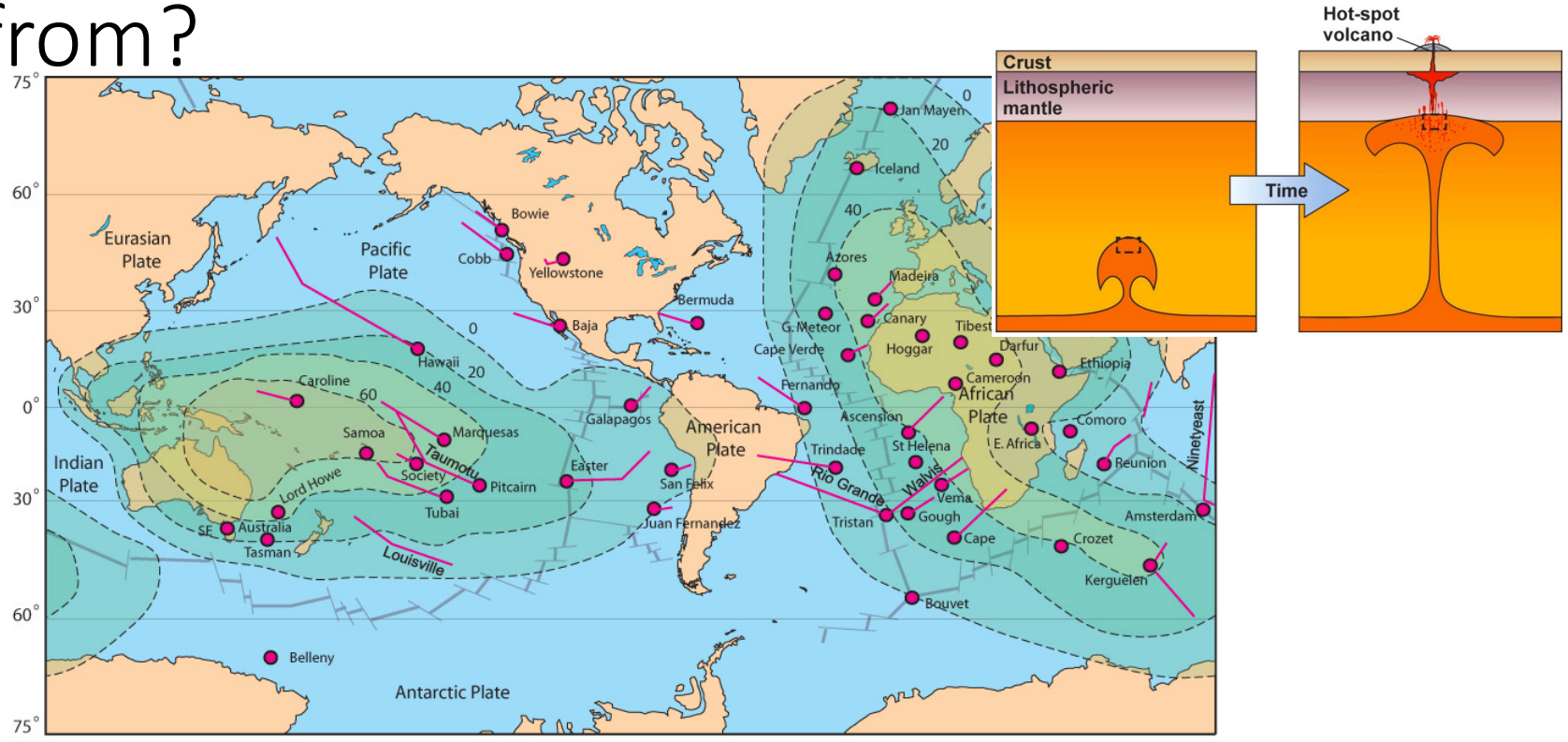
Partial melting can occur due to decompression (A → B)

Magmatic Rocks: Where does **basaltic** magma come from?



Basaltic magma comes to the surface at ”mid-ocean ridges” (**divergent plate boundaries**)

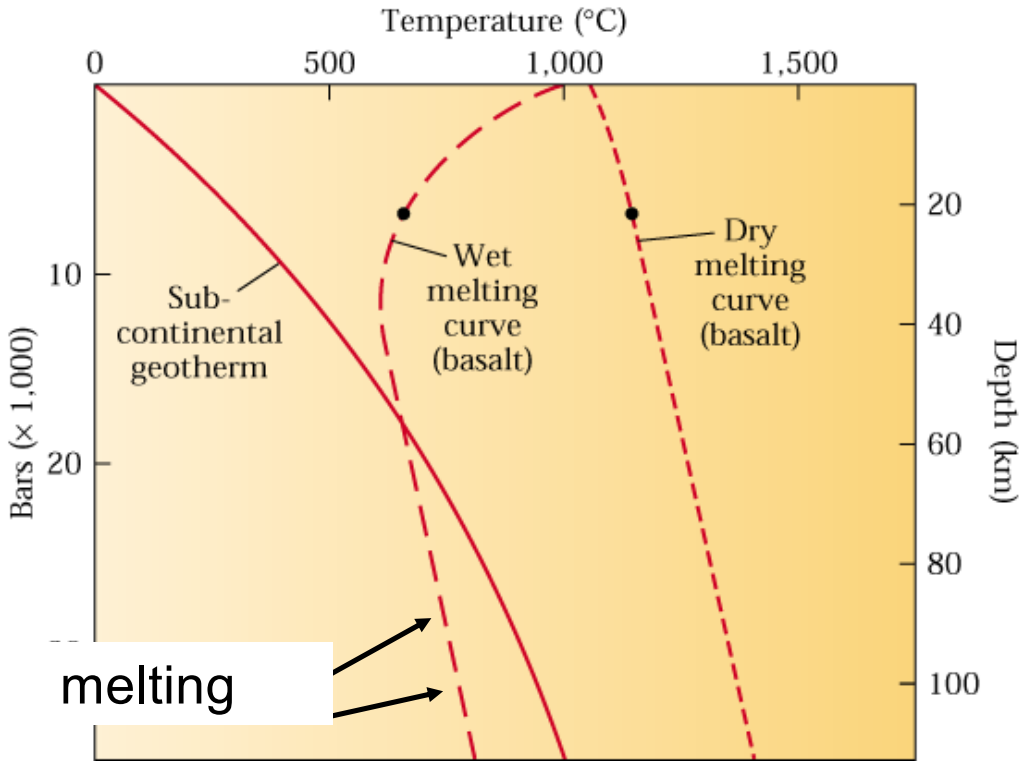
Magmatic Rocks: Where does **basaltic** magma come from?



Map of hotspots and their traces (oceanic island chains).

HOTSPOTS occur among others under Hawaii, Iceland, Canary Islands

Magmatic Rocks: Where does **basaltic** magma come from?

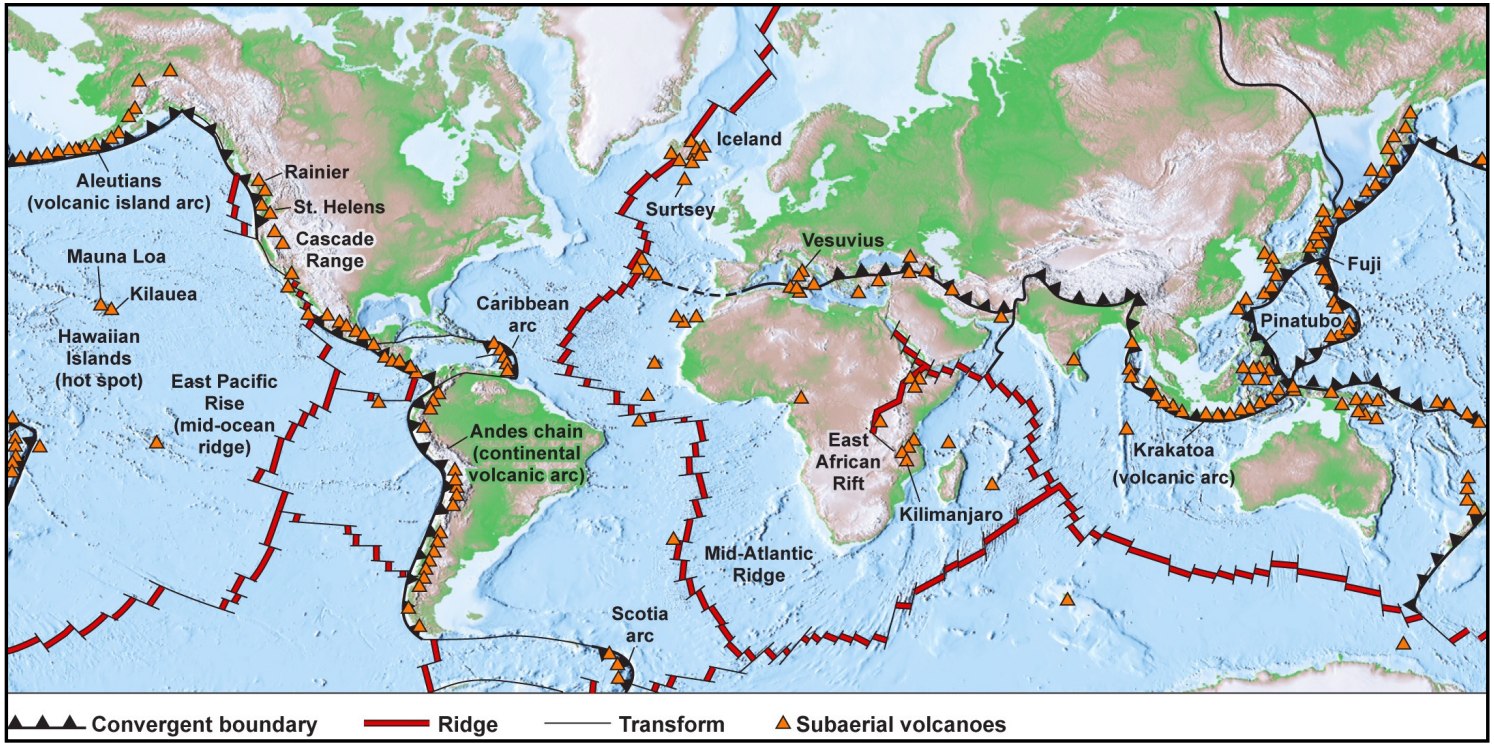


Partial melting of the mantle can also happend if **water** is present.

Water lowers the solidus temperature

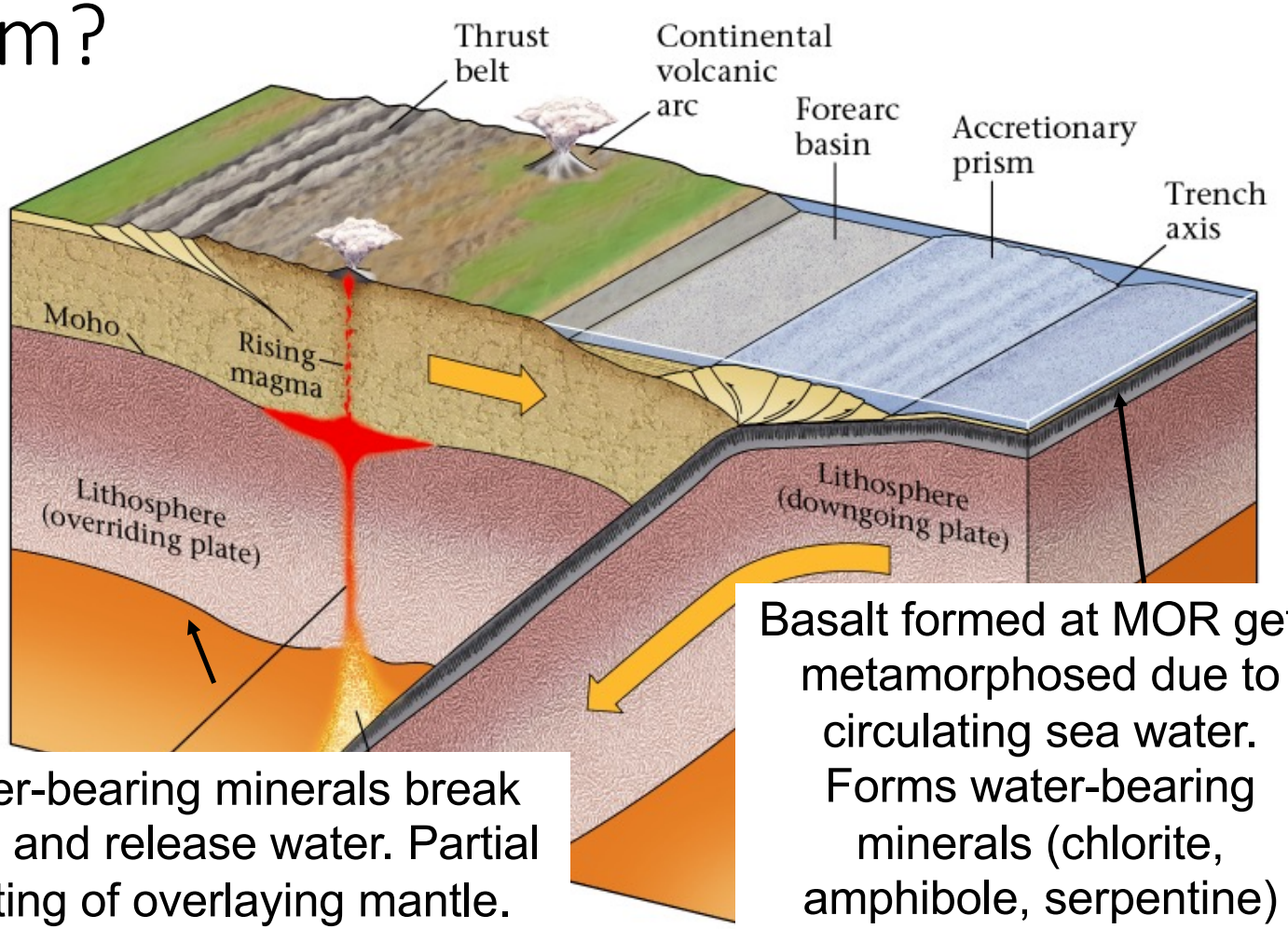
Water gets to the mantle by SUBDUCTON

Magmatic Rocks: Where does **andesitic** magma come from?



SUBDUCTION and related magma formation occurs at **konvergent plate boundaries**

Magmatic Rocks: Where does **andesitic** magma come from?



Water-bearing minerals break down and release water. Partial melting of overlaying mantle.

Basalt formed at MOR gets metamorphosed due to circulating sea water. Forms water-bearing minerals (chlorite, amphibole, serpentine)

Magmatic Rocks: Where does **rhyolitic** magma come from?

Rhyolitic magma can form in two ways:

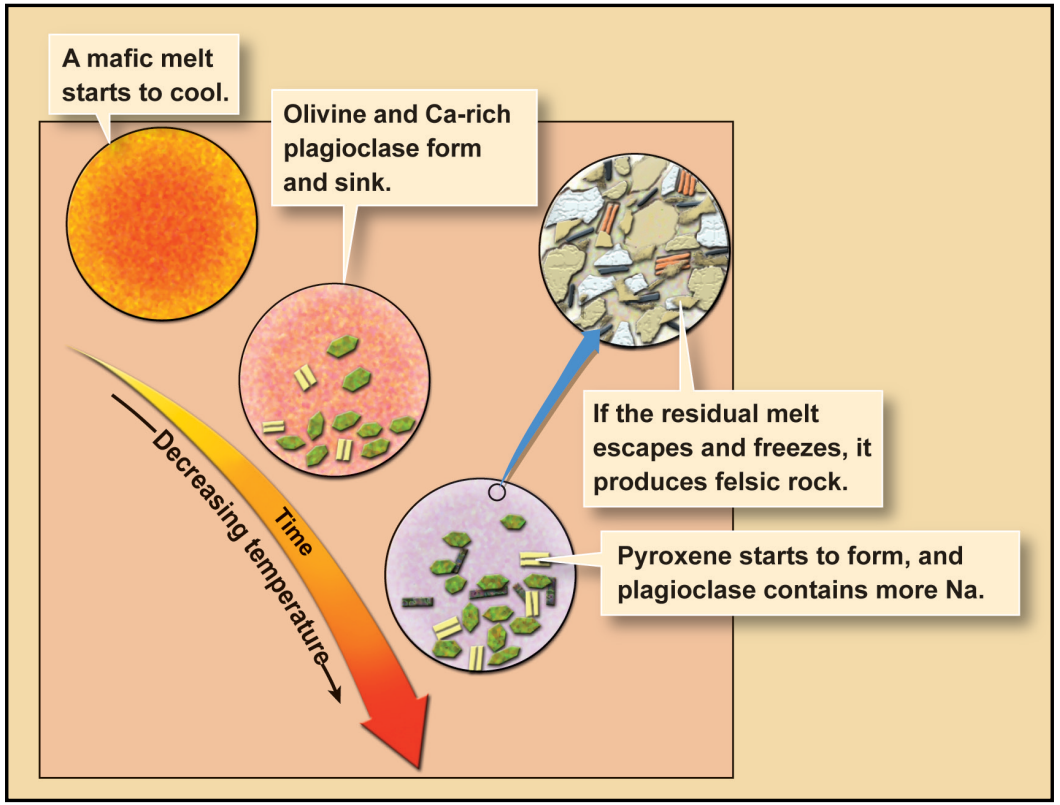
- **Partial melting of the continental crust** (e.g., heating due to mafic intrusion)

- **Fractional crystallization**

Magmatic Rocks: Fractional crystallization

Fractional crystallization

During fractional crystallization the first (mafic) crystals are ‘removed’ from the melt and are not in equilibrium with the melt. This results in a change in the magma composition. In the end, the melt has a granitic composition (SiO_2-rich)



‘Last minute’ paper

Write down what was difficult to understand

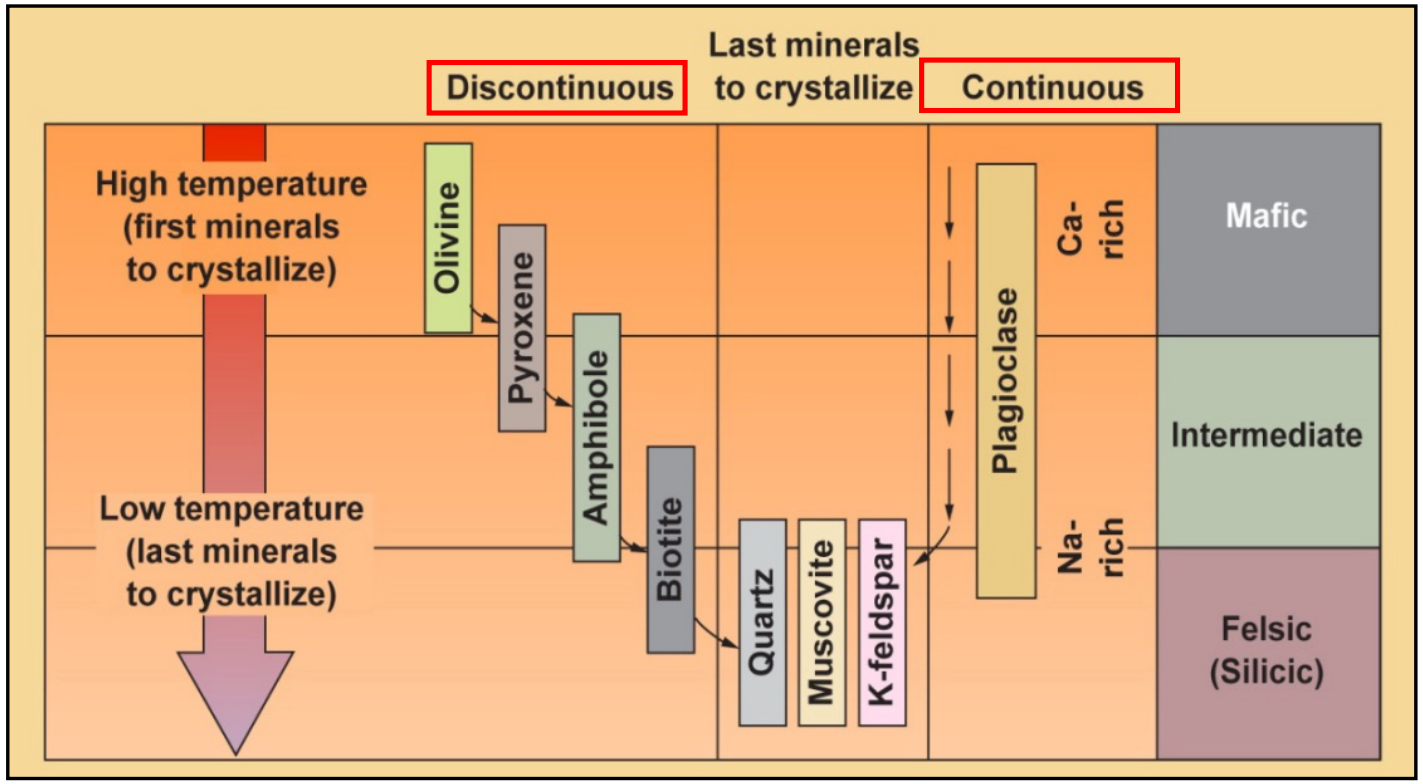
Write down what was easy to understand

Magmatic Rocks: Plutonic rocks: Bowen's series

Plutonic rocks crystallize slowly at depth. With decreasing temperature, new minerals start to crystallize (**Bowen's reaction series**). **Fractional crystallization**

Felsic minerals: quartz, feldspars, felspathoids, muscovite

Mafic minerals: olivine, pyroxenes, amphiboles, biotite



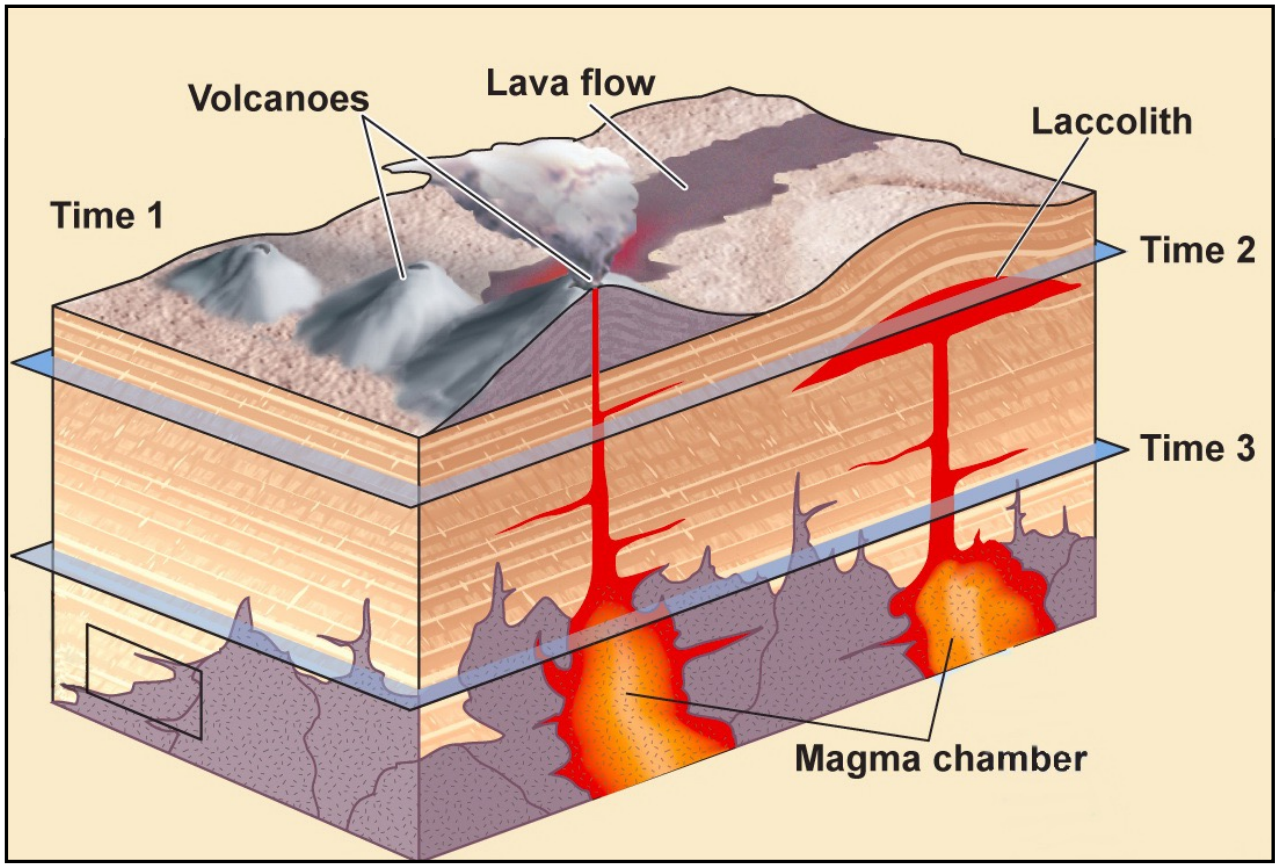
Magmatic Rocks: Plutonic rocks: Fractional crystallization

	BASALT	ANDESITE	DACITE	RHYOLITE
SiO_2	49.60	57.94	65.01	72.82
TiO_2	1.84	0.95	0.58	0.28
Al_2O_3	15.84	16.67	15.91	13.47
Fe_2O_3	3.79	2.50	2.43	1.48
FeO	7.13	4.92	2.70	1.11
MnO	0.20	0.12	0.09	0.06
MgO	6.99	3.91	1.58	0.39
CaO	9.70	6.78	4.32	1.14
Na_2O	2.91	3.54	3.79	3.65
K_2O	0.51	1.76	2.17	4.50
P_2O_5	0.95	0.29	0.15	0.07
H_2O	0.35	1.15	1.20	1.10
Total	99.81	99.94	99.93	100.07
MgO/FeO	0.98	0.79	0.59	0.35
CaO/Na_2O	3.33	1.92	1.14	0.31

Magmatic Rocks: Plutonic rocks

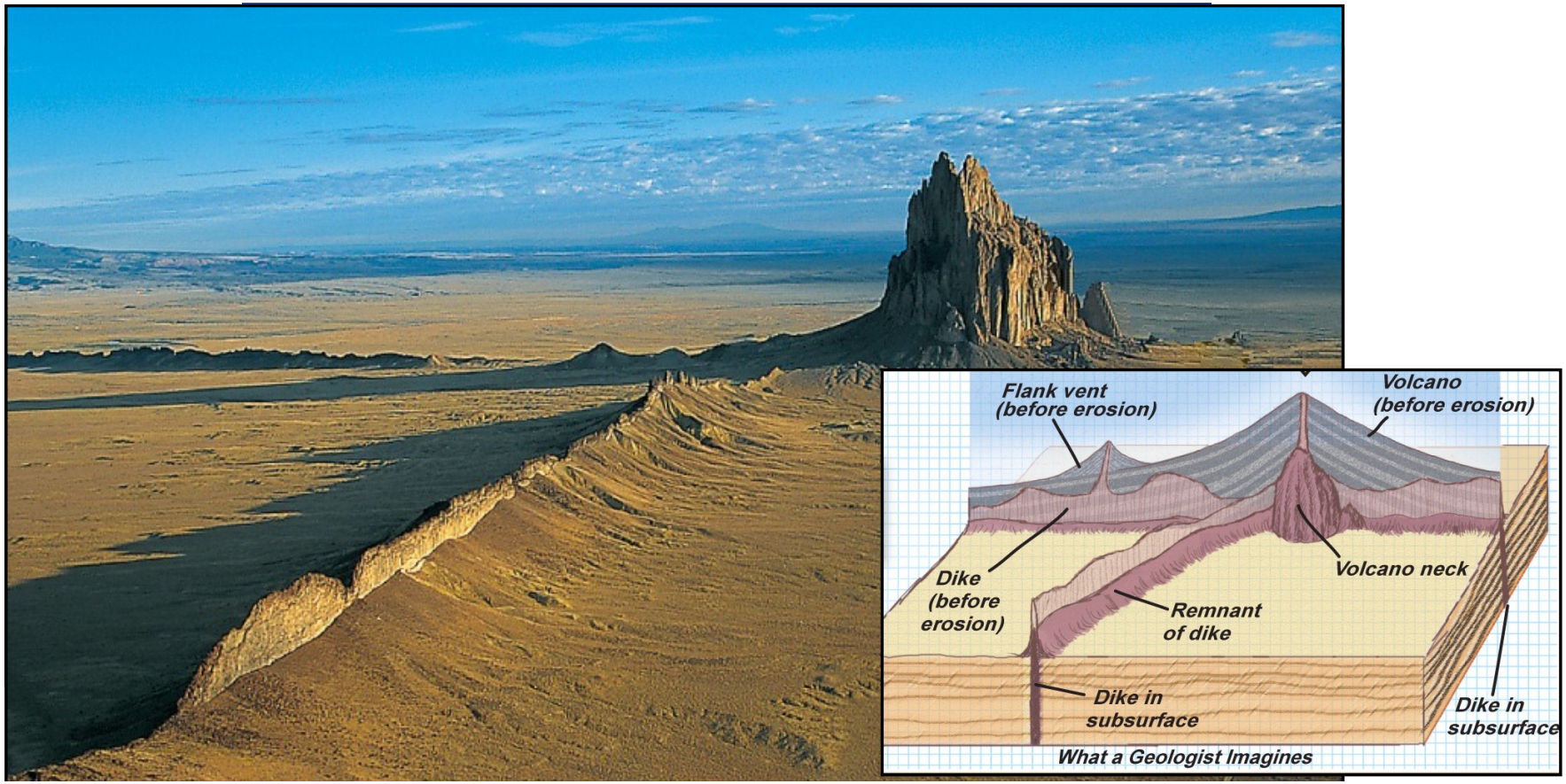
Magma forms **plutonic rocks** when it raises and crystallizes slowly at depth. They can form different shapes:

- **Pluton (magma chamber)**
- **Dyke**
- **Laccolith**
- **Sills**



Magmatic Rocks: Plutonic rocks

After strong erosion, former magma chambers or fractures (dykes) are exposed

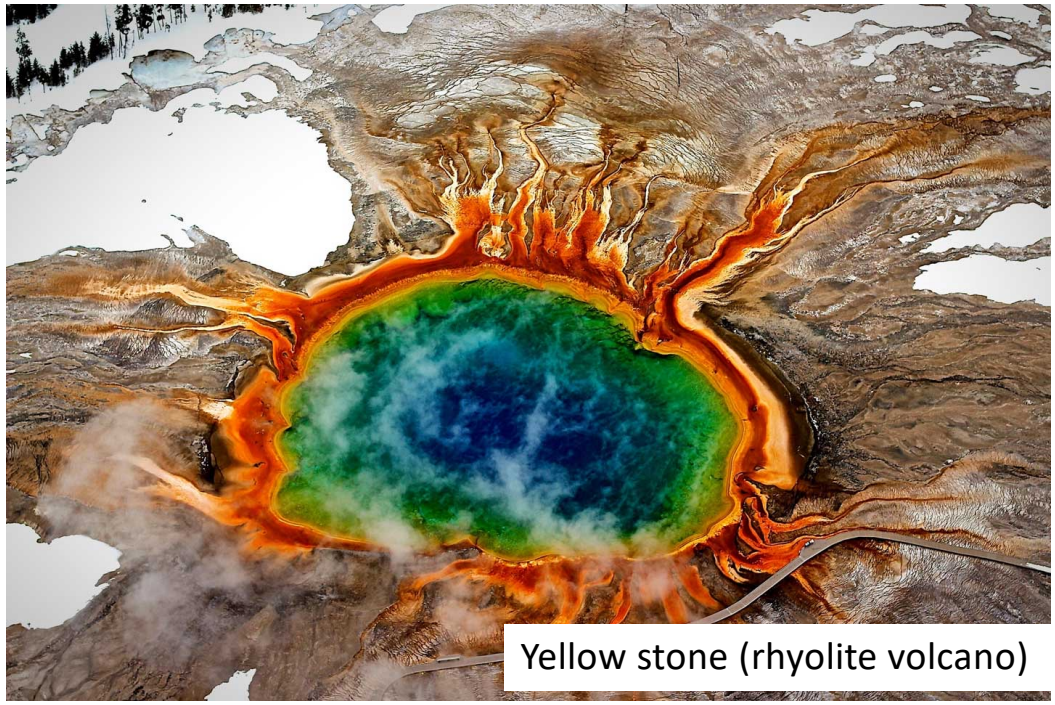


Magmatic Rocks: Plutonic rocks: Layering, Gabbro

When basaltic magma crystallizes it forms gabbro and can form layers due to crystal settling

Magmatic Rocks: Plutonic rocks: Granite

When rhyolitic magma crystallizes it forms granite
Rhyolitic melt is more viscous than basaltic melt. Consequently, there are more granite intrusions than rhyolitic volcanoes.



Yellow stone (rhyolite volcano)

Magmatic Rocks: Plutonic rocks: Pegmatites

If the magmatic rocks are very coarse-grained they are called **pegmatites.**

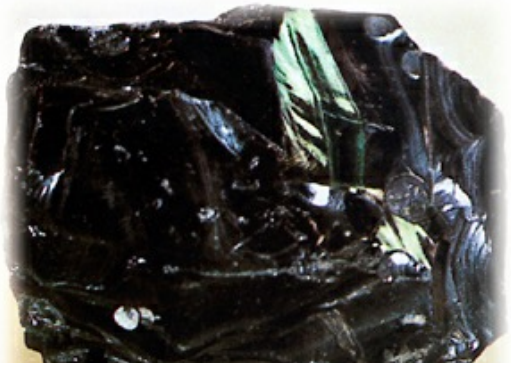
They consist mostly of quartz and alkalifeldspar. Many other minerals may occur however (muscovite, biotite, tourmaline, fluorite, beryl, ….

The characteristic feature of pegmatites is their very large grain (up to several meters!)

Magmatic Rocks: Volcanic rocks

Volcanic rocks form due to the eruption of melt (lava) on the Earth surface or submarine. The lava cools very quickly and consequently, volcanic rocks have a very fine-grained (aphanitic) or glassy groundmass. Classification is therefore difficult based on their mineralogy.

In porphyric rocks the phenocrysts and the Streckeisen diagram are used to classify the rocks.

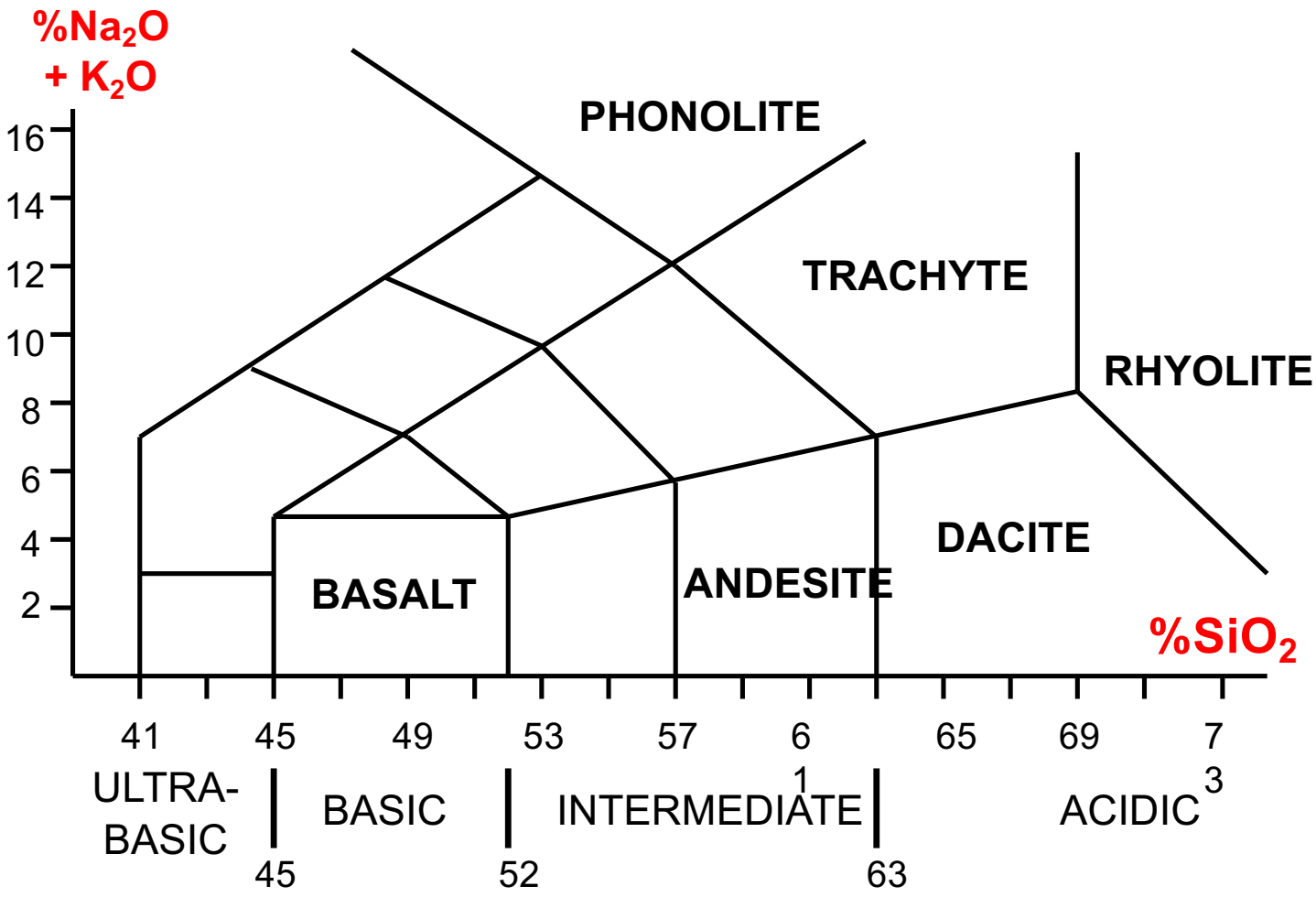


Volcanic glass: obsidian, has a rhyolitic composition

Volcanic rocks with phneocrystsd and a fine-grained groundmass

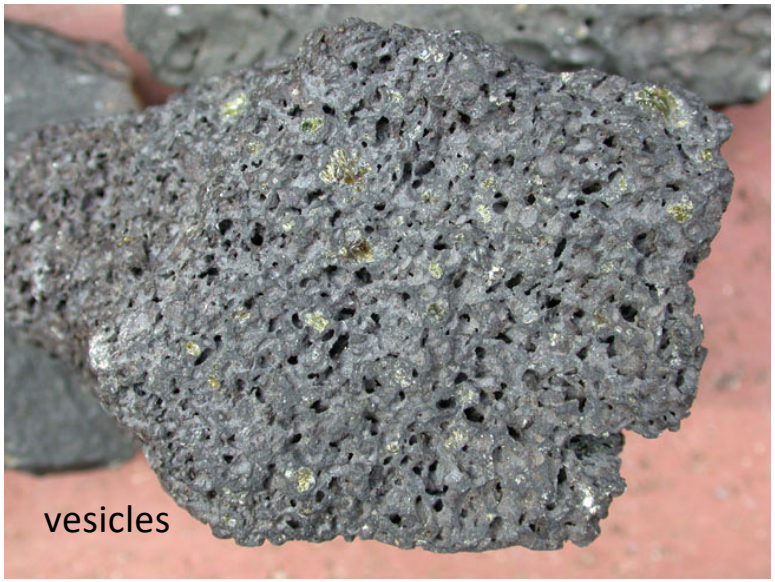
Magmatic Rocks: Volcanic rocks: Classification

Total alkalis vs. SiO_2 (TAS)-diagram is based on the whole rock chemistry of the rock



Magmatic Rocks: Volcanic rocks

Many volcanic rocks have ‘holes’ (vesicles). These represent former gas bobbles.
Magma contains dissolved gasses (H_2O, CO_2, SO_2, etc) and when the pressure decreases, the gas slips out of the melt.
Compare to sparkling water in a bottle.



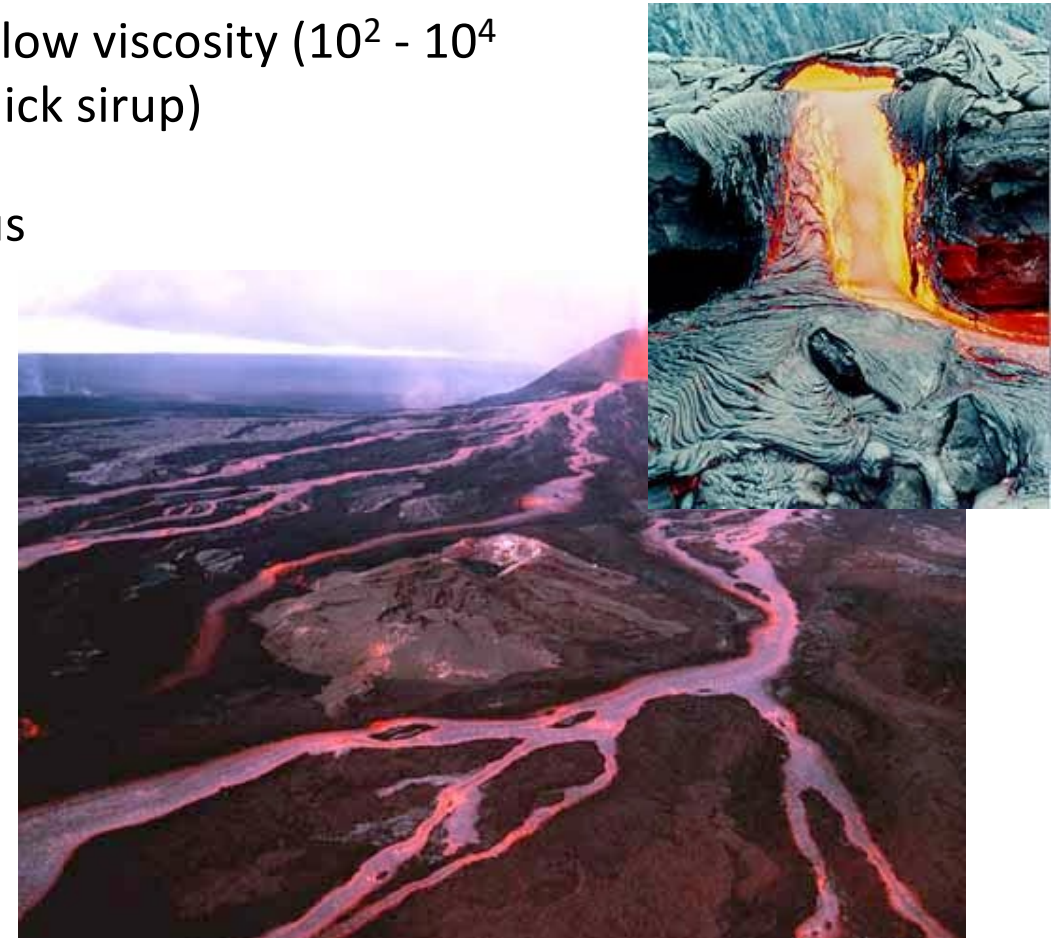
MAGMATIC GAS

Magmatic Rocks: Volcanic rocks: Viscosity

Basaltic magma has a relatively low viscosity (10^2 - 10^4 poise; similar to thick sirup)

Rhyolitic magma is highly viscous (10^5 - 10^{15} poise)

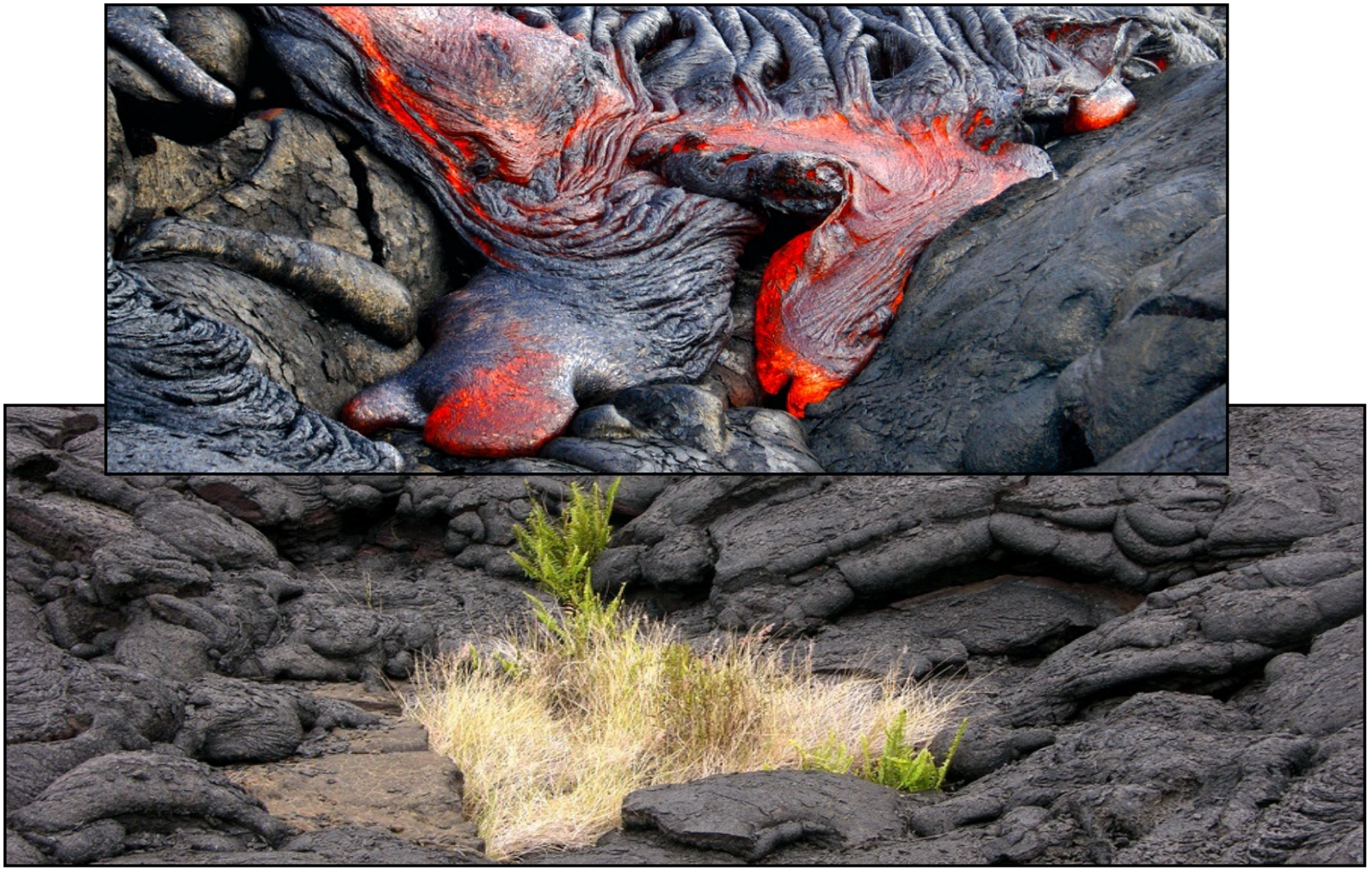
The viscosity is controlled by the composition (including volatiles) of the lava, which determines what type of volcanic eruption occurs (explosive vs. effusive).



Magmatic Rocks: Volcanic rocks: Basalt

Basaltic lava fountains due to gas slip

Magmatic Rocks: Volcanic rocks: Basalt

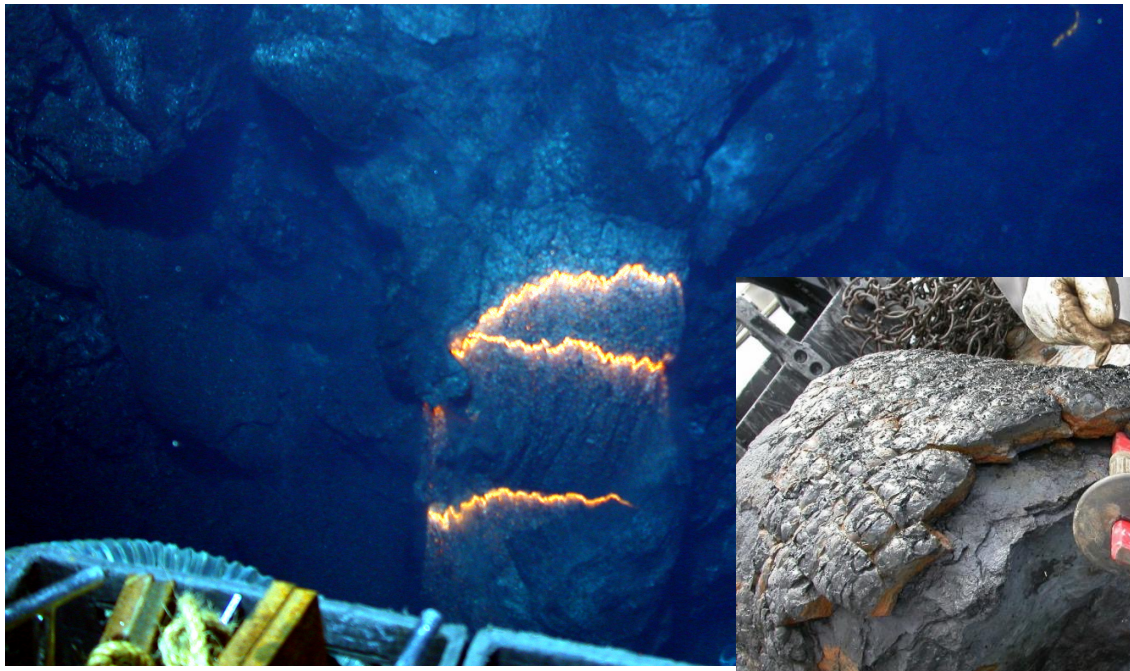


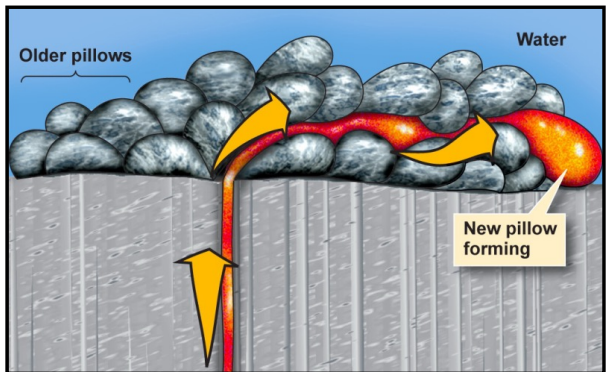
Magmatic Rocks: Volcanic rocks: Basalt

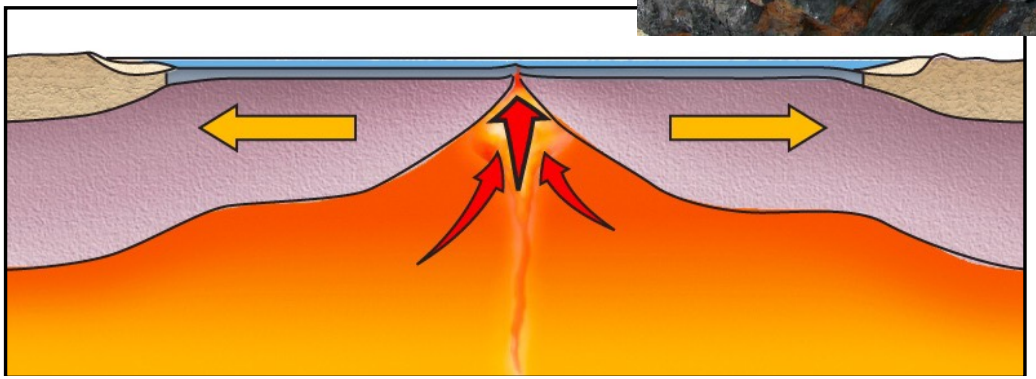
AA (block lava)

Magmatic Rocks: Volcanic rocks: Basalt

Most basaltic eruptions occur submarine art mid-ocean ridges (spreading zones). The fast cooling results in **pillows** with glassy rims

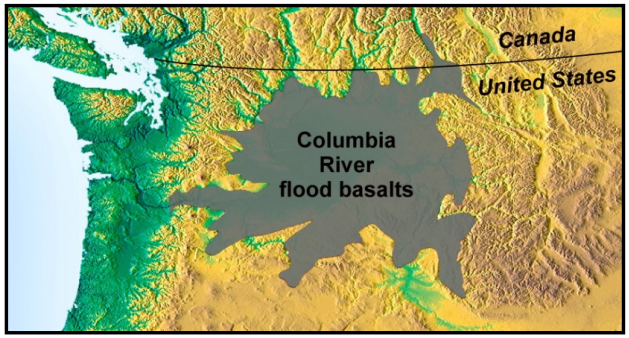


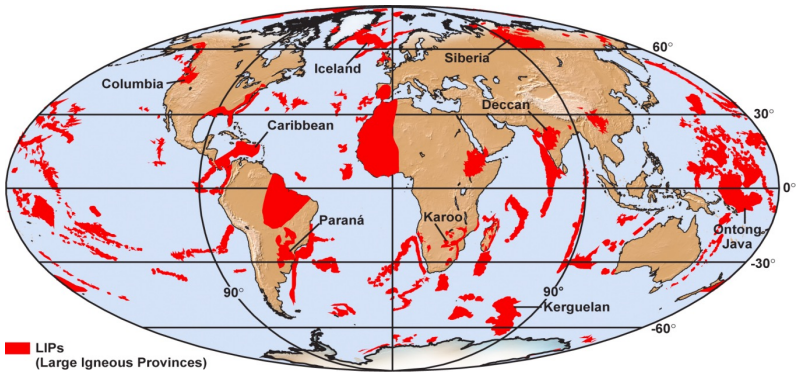




Magmatic Rocks: Volcanic rocks: Flood Basalt

Some of the largest eruptions (volume of lava erupted) occured in rifts during e.g., opening of oceans formed **flood basalts**



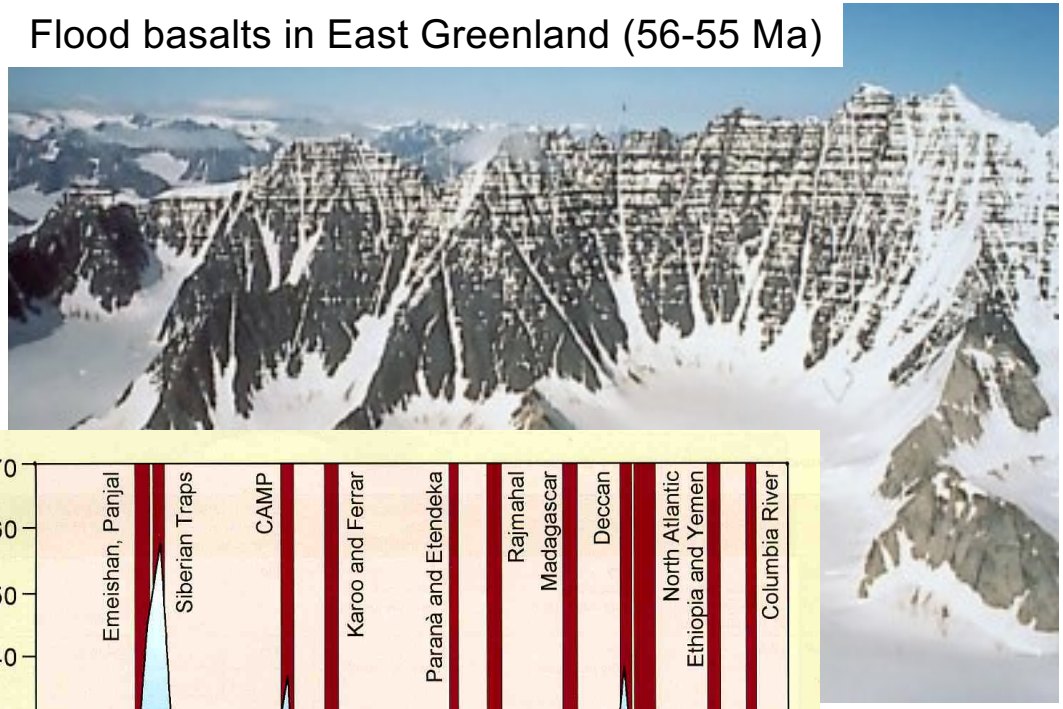


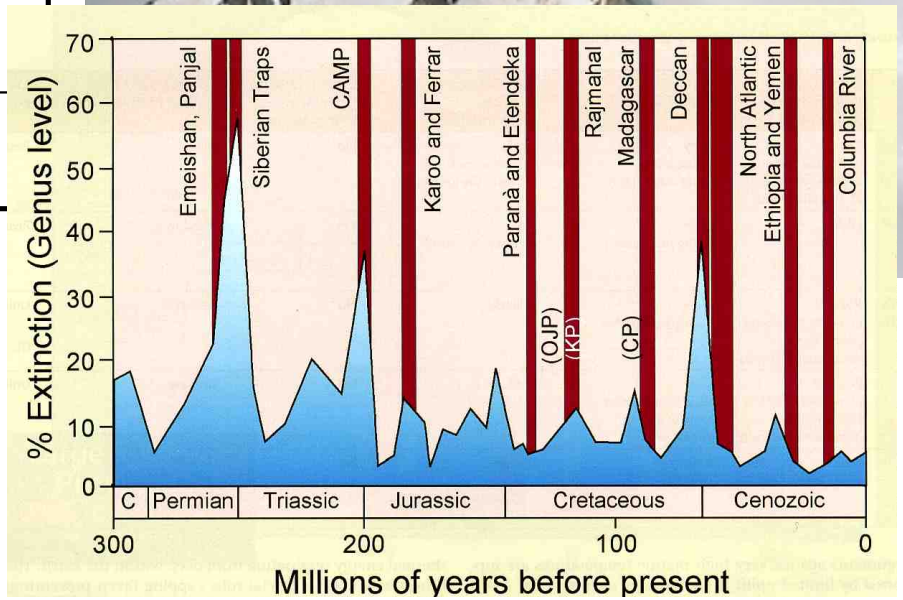
E.g., Columbia River basalts in the USA
area 163.000 km^2; volume 174300 km^3

Magmatic Rocks: Volcanic rocks: Flood Basalt

Province	Age	Area (km^2)
Columbia River	Miocene	163.000
Deccan (India)	Eocene	500.000
Parana (Brasil)	Cretaceous	2.000.000
Karoo (South Africa)	Jurassic	2.000.000
Siberia	Permo-Triassic	2.500.000

Flood basalts in East Greenland (56-55 Ma)



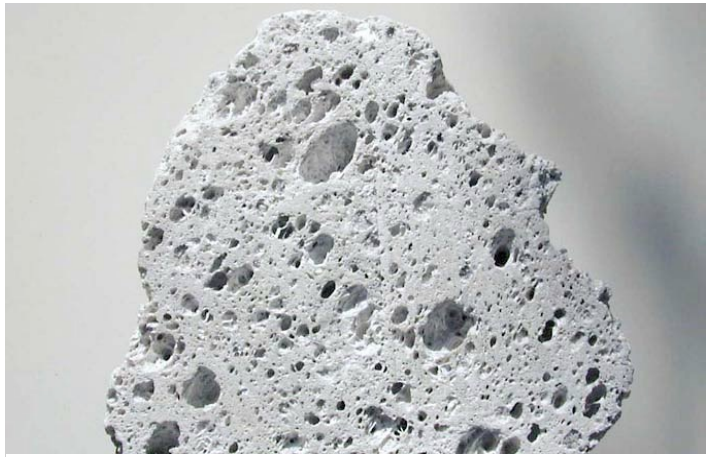


Mass extinctions and volcanism

Magmatic Rocks: Volcanic rocks: Rhyolite

High viscosity and high volatile content in the magma lead to explosive eruptions. Ash clouds to up to 45km heights and can spread several 100km.

The gasses cannot continuously escape, but increase the pressure in the melt until an explosion occurs. Famous eruptions: Mt St. Helens, Mt Pinatubo



Highly vesicular rhyolitic rock (pumice). Floats on water

Magmatic Rocks: Volcanic rocks: Tephra

During explosive eruptions differently sized fragments are produces
They are called **Pyroclastics**: pyro: hot, clastic: fragment).

When they are deposited they form volcanic sediment (**Tephra**)

TEPHRA fragments are classified according to their grain sizes:

<2mm	2-64mm	>64mm
ASH	LAPILLI	BLOCKS and BOMBS

Magmatic Rocks: Volcanic rocks: Tephra

Magmatic Rocks: Volcanic rocks: Pyroclastic flows

Pyroclastic flows are one of the most dangerous volcanic events. They are hot (several 100C) clouds of ash, glass, gas, running down a volcano with high velocity (up to 200km/h). They form rocks called **ignimbrite.**

Sequence of 3 mins
Montserrat eruption 2002

Magmatic Rocks: Different types of volcanoes

Again depending on the magma viscosity and eruption type (explosive vs. effusive), there are different types/shapes of volcanoes.

Shield volcanoes

Hawaii

Tephra cones

Strato volcanoes

Mt Fuji

Magmatic Rocks: Classification

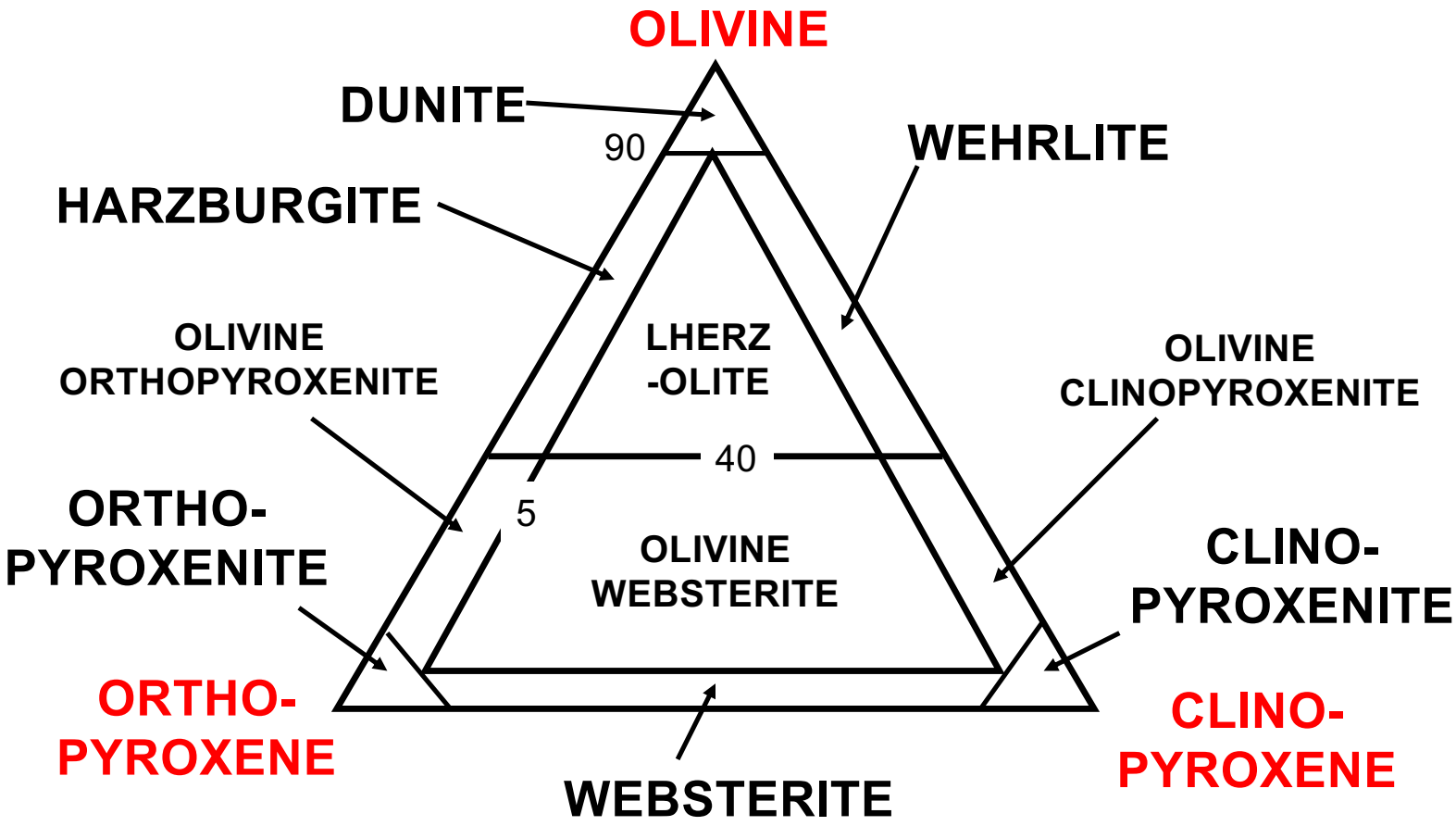
Magmatic rocks are classified based on their mineralogy (modal composition).

5 minerals are important: **quartz (Q), plagioclase (P), alkali-feldspar (A), feldsphatoids (F), mafic (dark) minerals (M)**

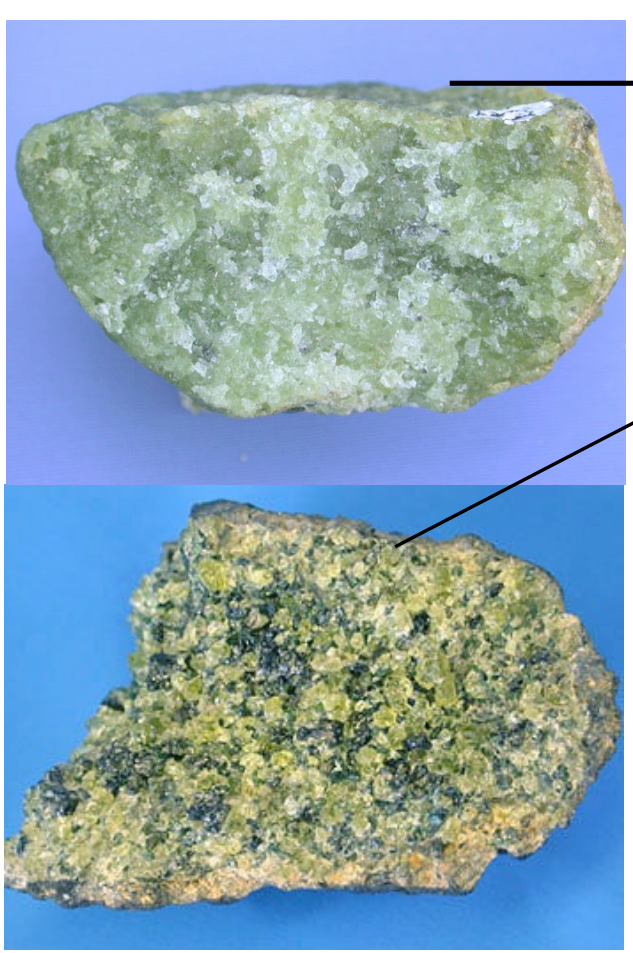
M>90%: ultramafic rocks (e.g., mantle peridotite)

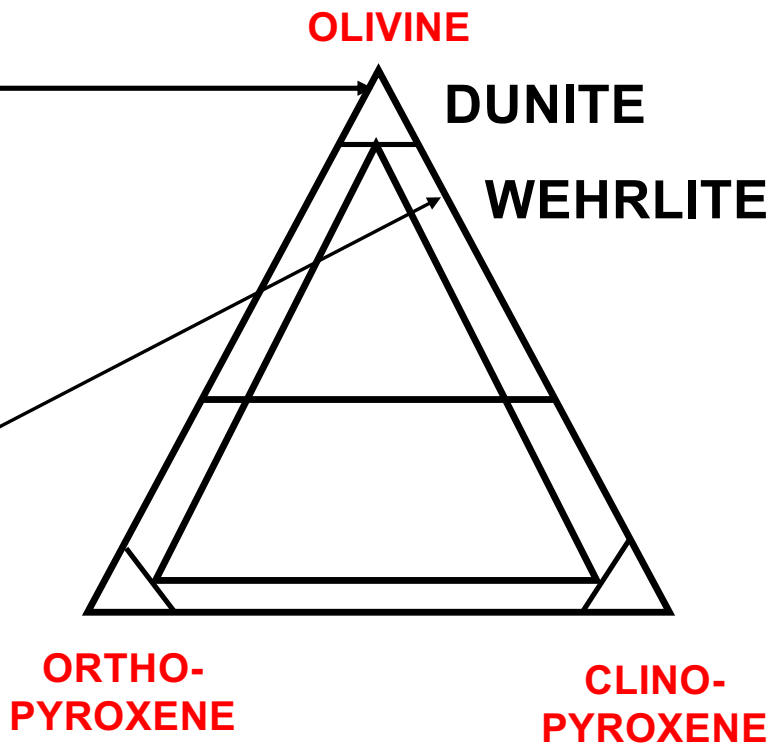
M<90%: mafic and felsic rocks

Magmatic Rocks: Classification: Ultramafic rocks



Magmatic Rocks: Classification: Ultramafic rocks

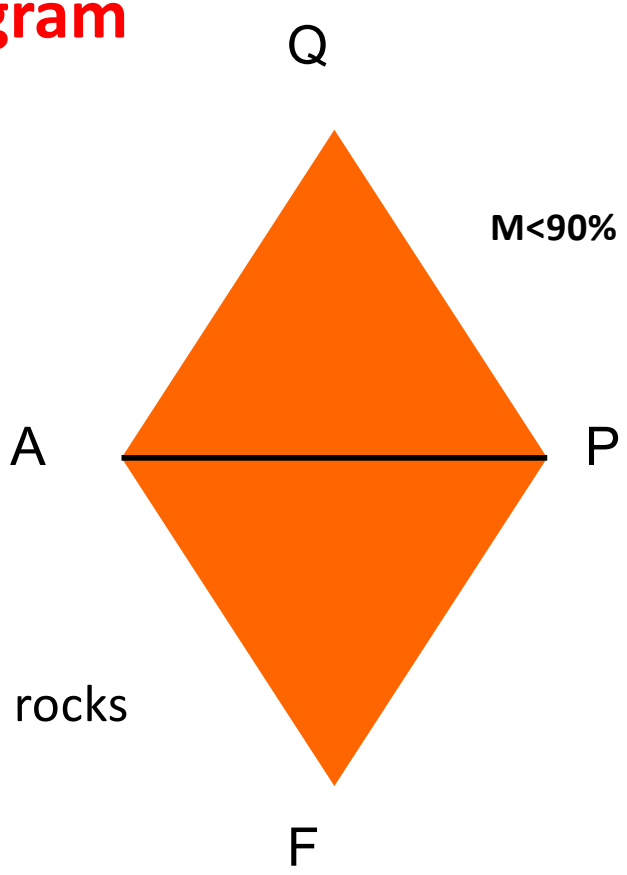




Magmatic Rocks: Classification

Double triangular diagram

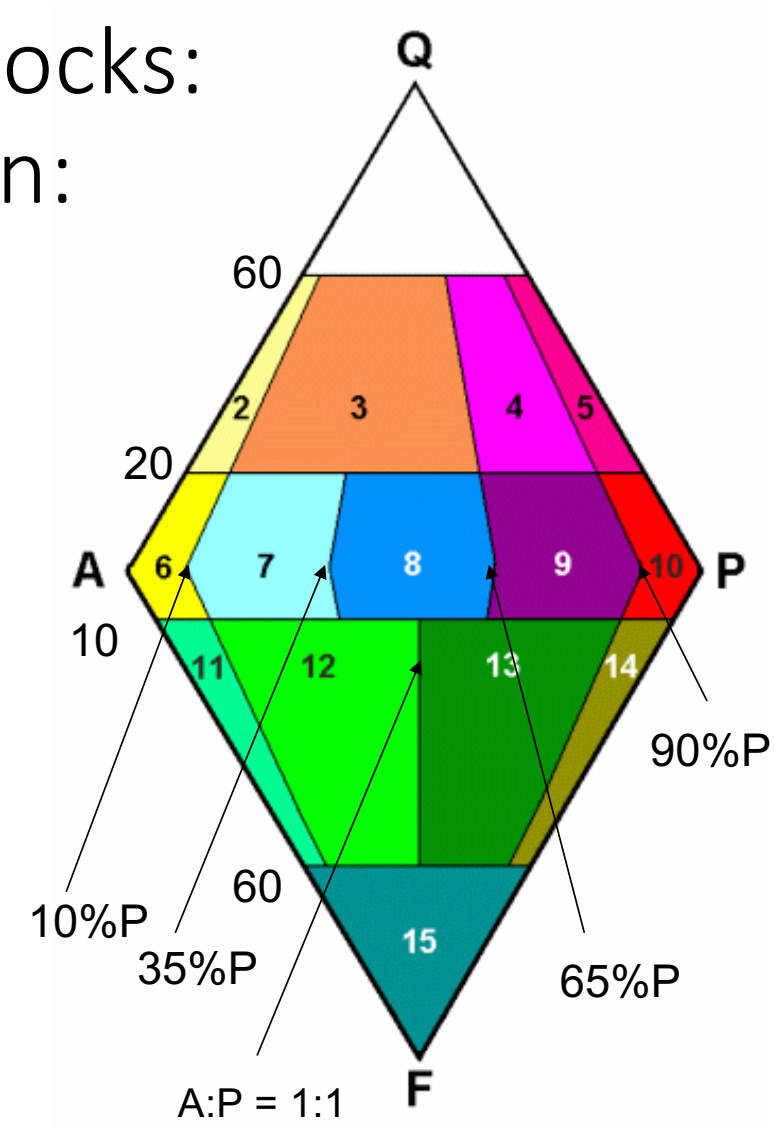
Streckeisen 1973



M: olivine, pyroxene, biotite, amphibole,…

Both for plutonic and volcanic rocks

Magmatic Rocks: Classification: **Plutonic**



2 = alkali feldspar granite

3 = granite

4 = granodiorite

5 = tonalite

6 = alkali feldspar syenite

7 = syenite

8 = monzonite

9 = monzogabbro/monzodiorite

10 = gabbro/diorit/anorthosite

11 = foid syenite

12 = foid monzosyenite

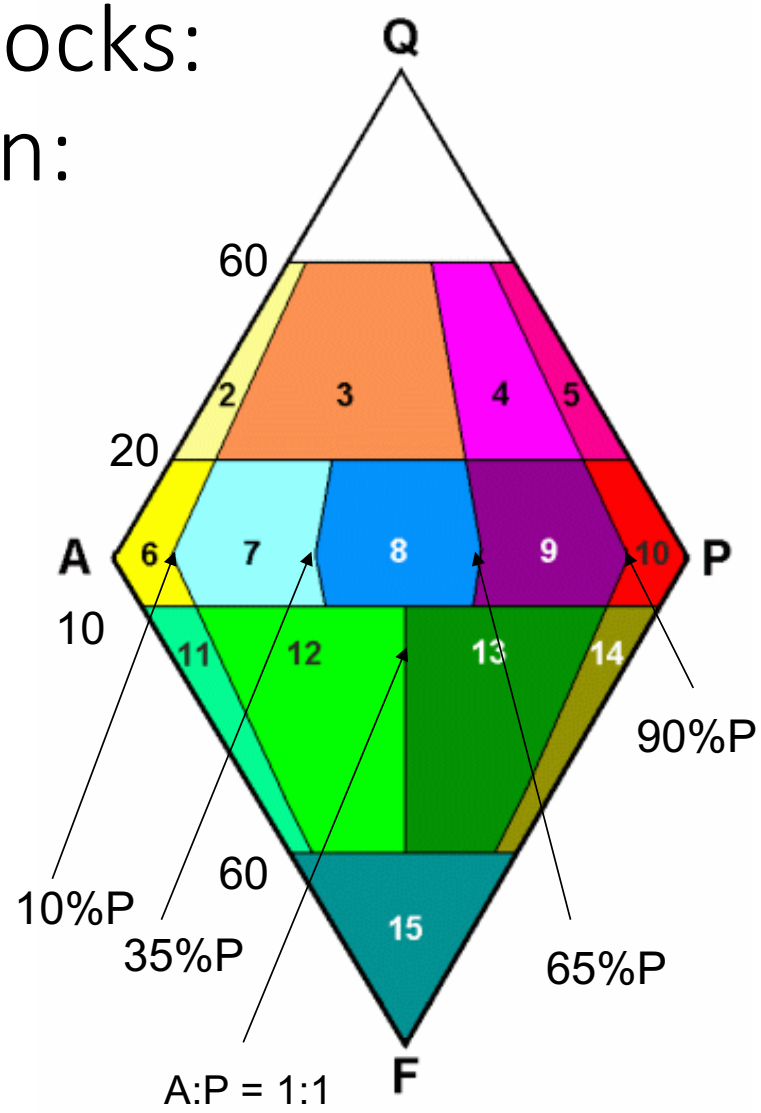
13 = foid monzogabbro/foid monzodiorite

14 = foid gabbro/foid diorite

15 = foidolite

Magmatic Rocks: Classification: **Volcanic**

This is based on the phenocrysts!



2 = alkalifeldspat rhyolite

3 = rhyolite

4 + 5 = dacite

6 = alkalifeldspar trachyte

7 = trachyte

8 = latite

9 + 10 = basalt/andesite

11 = phonolite

12 = tephritic phonolite

13 = phonolitic basanite/tephrite

14 = basanite/tephrite

15 = foidite

Magmatic Rocks: Equivalent plutonic and volcanic rocks

PLUTONIC		**VOLCANIC**
GRANITE	=	RHYOLITE
TONALITE	=	DACITE
SYENITE	=	TRACHYTE
MONZONITE	=	LATITE
DIORITE	=	ANDESITE
GABBRO	=	BASALT
FOID SYENITE	=	PHONOLITE

‘Last minute’ paper

Write down what was difficult to understand

Write down what was easy to understand