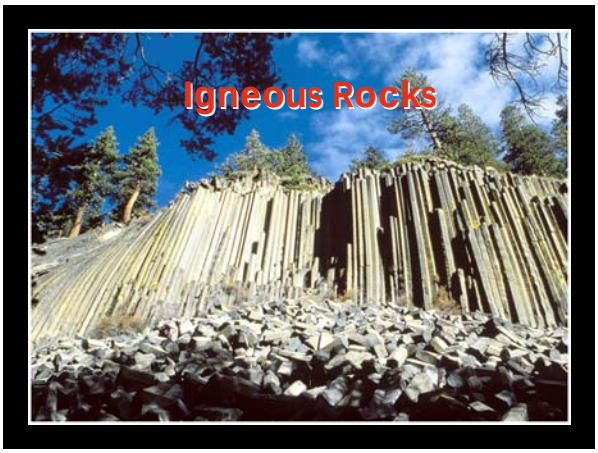


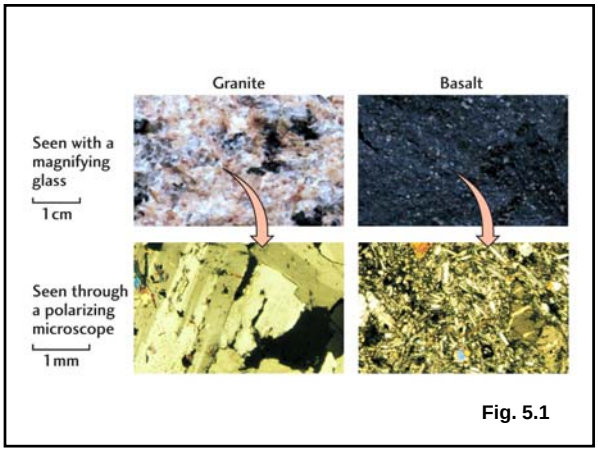




Fig. 5.1

## Genetic Classification of Igneous Rocks

- **Intrusive**: crystallized from slowly cooling magma intruded within the Earth's crust; e.g. granite, gabbro

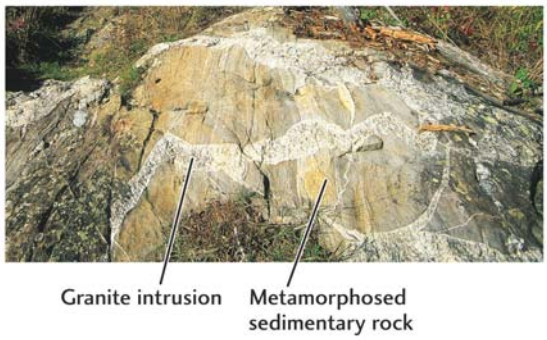



Fig. 5.2

## Genetic Classification of Igneous Rocks

- **Extrusive**: crystallized from rapidly cooling magma extruded on the surface of the Earth as lava or erupted as pyroclastic material.

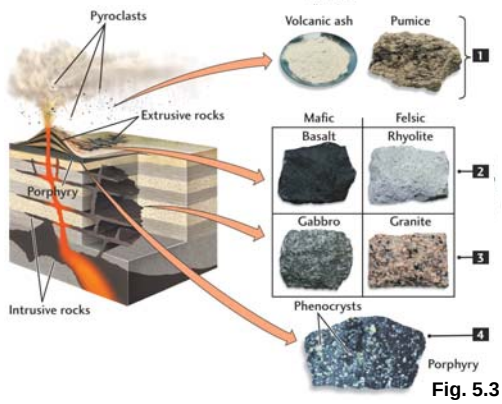



Fig. 5.3

## Extrusive Igneous Rocks Include:

- rocks formed from the cooling of *lavas*
- rocks formed by the cooling of *pyroclastic* material, i.e. fragmented pieces of magma and material erupted into the air

Table 5.1 Common Minerals of Igneous Rocks

| Compositional Group | Mineral | Chemical Composition | Silicate Structure |
|---|---|---|---|
| | Quartz | $SiO_2$ | Frameworks |
| | Potassium feldspar | $KAlSi_3O_8$ | |
| FELSIC | Plagioclase feldspar | $NaAlSi_3O_8$ / $CaAl_2Si_2O_8$ | |
| | Muscovite (mica) | $KAl_2Si_3O_{10}(OH)_2$ | Sheets |
| | Biotite (mica) | K, Mg, Fe, Al — $Si_3O_{10}(OH)_2$ | |
| | Amphibole group | Mg, Fe, Ca, Na — $SiO_{22}(OH)_2$ | Double chains |
| MAFIC | Pyroxene group | Mg, Fe, Ca, Al — $SiO_3$ | Single chains |
| | Olivine | $(Mg,Fe)_2SiO_4$ | Isolated tetrahedra |

**Table. 5.1**

## Composition and Classification of Igneous Rocks

- **Chemistry:** e.g. % $SiO_2$
- **Mineralogy:** e.g.
  - Felsic
  - Intermediate
  - Mafic
  - Ultramafic

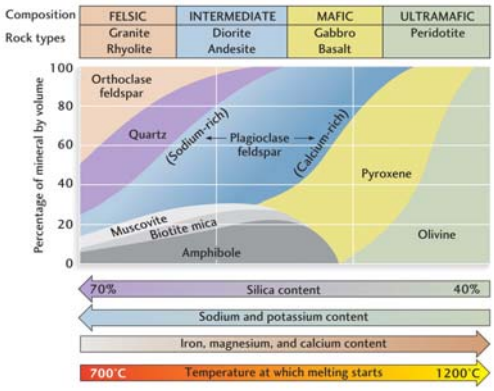


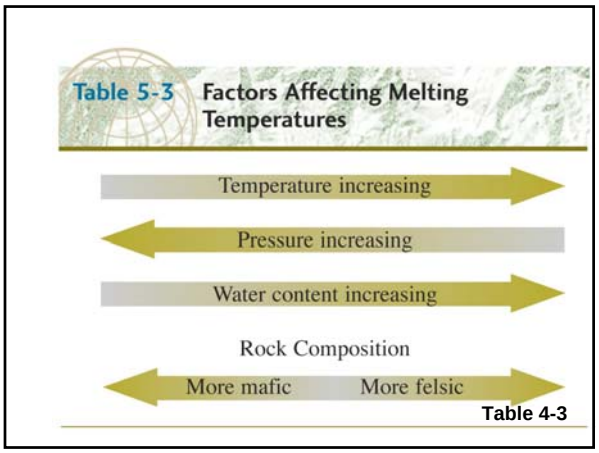

Fig. 4.4

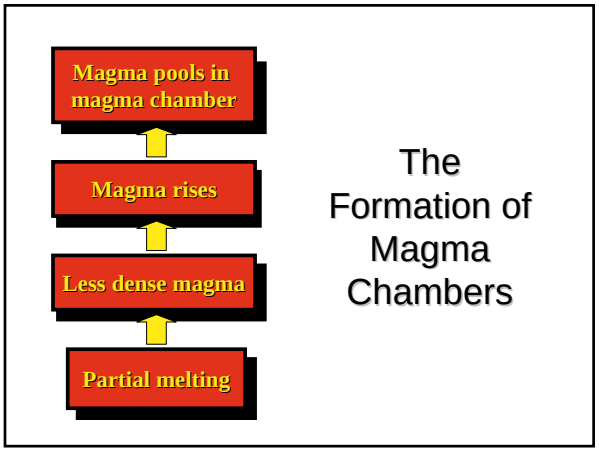
## How do magmas form?

When rocks melt (or partially melt).

## Partial Melting

Occurs when some of the minerals forming a rock melt at lower temperatures than other minerals within the same rock




## Magma Differentiation

**The process by which rocks of various compositions can arise from a uniform parent magma**

## Magma Differentiation

Occurs because different minerals crystallize at different temperatures

(i.e., the opposite of partial melting)

## Fractional Crystallization

The process by which crystals forming in a cooling magma are segregated from the remaining liquid

## Bowen's Reaction Series

Experimental sequence of crystallization of minerals from a gradually cooling mafic (basaltic) magma

## Bowen's Reaction Series

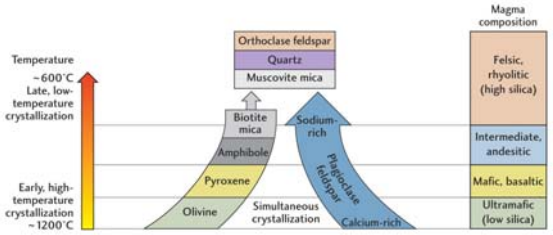



Fig. 4.5

## Evidence of Fractional Crystallization in the Palisades Sill

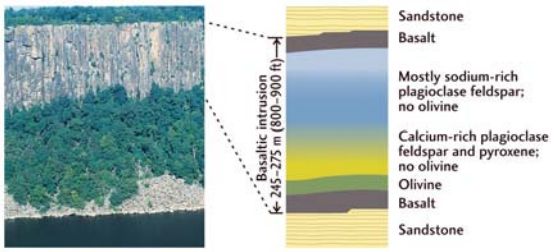



Fig. 4.5

## Evidence of Fractional Crystallization in the Palisades Sill

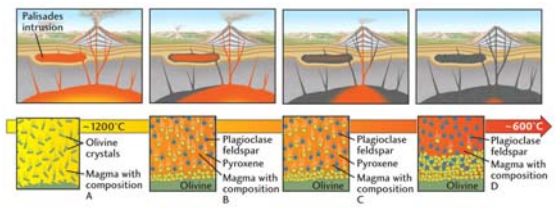
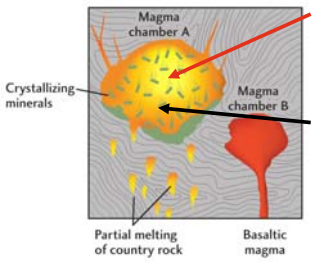



Fig. 4.5

**Can fractional crystallization of a primitive basaltic (mafic) magma generate a granitic (felsic ) magma?**

Yes, but not in the amounts present in the continental crust!

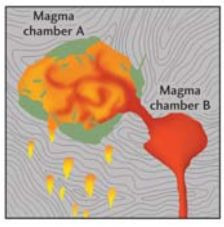
## Modern Ideas of Magmatic Differentiation




1. Partial melting creates magma of specific composition
2. Cooling causes minerals to form and settle

**Fig. 4.6**

## Modern Ideas of Magmatic Differentiation




3. Basaltic magma breaks through, causing turbulence
4. Crystals are mixed and deposited on chamber walls
5. Mixing of two magmas produces an andesitic magma

**Fig. 4.6**

## Partial Melting and the Origin of Magmas

| | | |
|---|---|---|
| Partial melting of upper mantle: e.g. at divergent spreading centers | → | **Mafic** Magmas |
| Partial melting of sedimentary rocks and mafic lithosphere: e.g. in subduction zones | → | **Intermediate** Magmas |
| Partial melting of continental crustal rocks | → | **Felsic** Magmas |

## Plutons

**Large igneous bodies formed at depth in the Earth's crust**

## Types of Plutons

- **Batholith:** Massive, discordant intrusive body covering at least 100 $km^2$
- **Stock:** Massive, discordant intrusive body covering less than 100 $km^2$
- **Dike:** Tabular, discordant intrusive body
- **Sill:** Tabular, concordant intrusive body

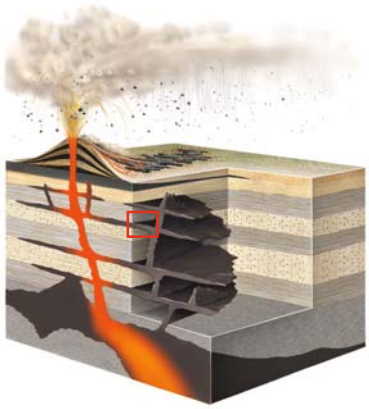


Fig. 4.9

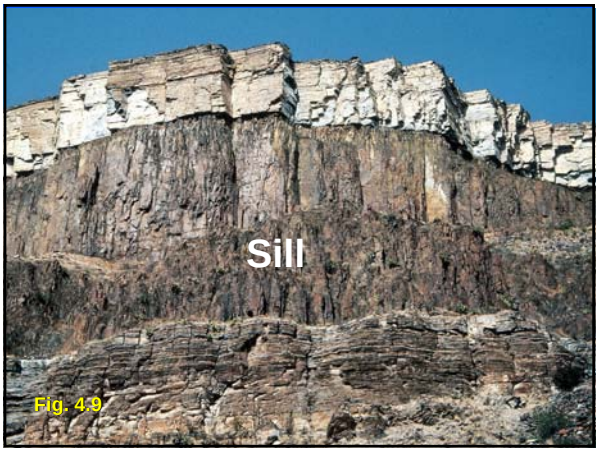



Fig. 4.9

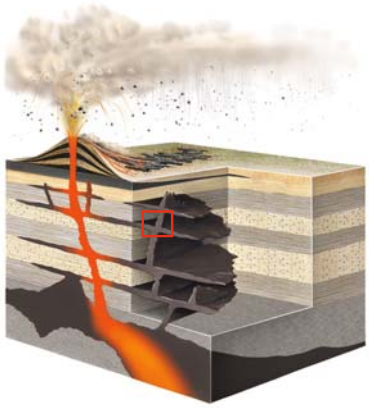


Fig. 4.9

Fig. 4.9

Fig. 4.10

**Where do most magmas form?**

- Divergent Plate Margins
- Convergent Plate Margins
- Mantle Plumes/Hot Spots

## Plate Divergence
## e.g. Mid-Atlantic Ridge

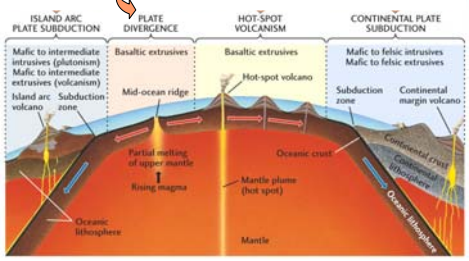



Fig. 4.11

## Island Arc
## Plate Subduction
## e.g. Java, Indonesia

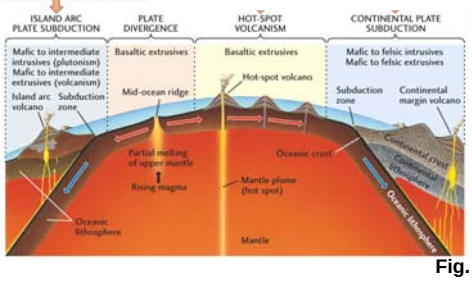




Fig. 4.11

## Continental
## Plate Subduction
## e.g. Mt Ranier

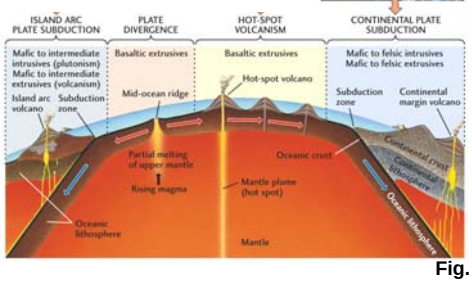




Fig. 4.11

## Hot Spot Volcanism e.g., Hawaii Yellowstone

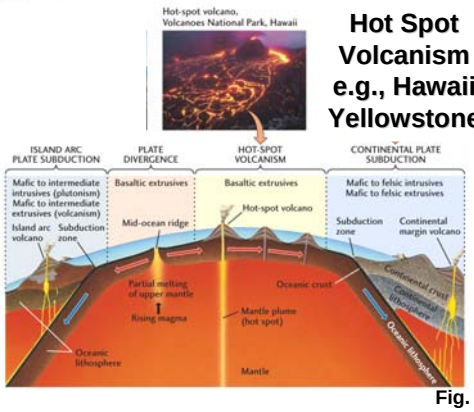



Fig. 4.11

## Idealized Section of an Ophiolite Suite

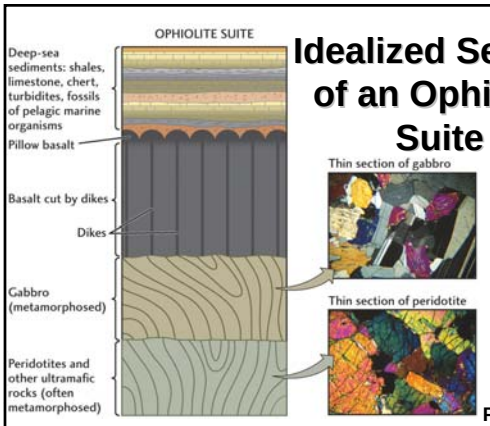



Fig. 4.12

## Generation of Magmas at Divergent Plate Margins

- Partially melted asthenosphere (Peridotite) rises at spreading centers, causing ***decompression melting*** of up to 15% of the rock to form mafic magma.

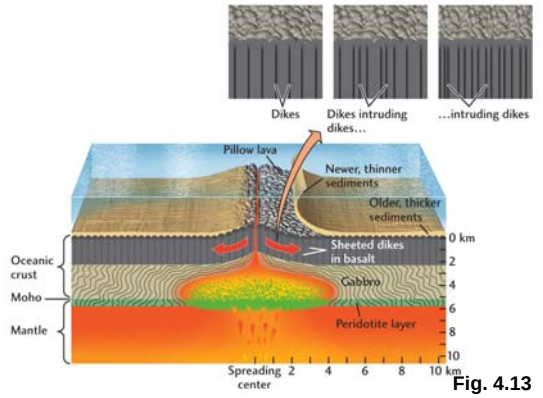



Fig. 4.13

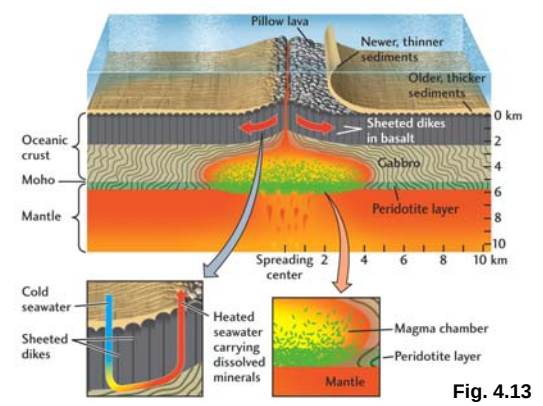



Fig. 4.13

## Generation of Magmas at Convergent Plate Margins

- **Subduction drags oceanic lithosphere (including a veneer of "wet" sediments) beneath the adjacent plate**

## Generation of Magmas at Convergent Plate Margins

- The release of volatiles lowers the melting point of the adjacent mantle, causing ***fluid-induced melting*** to form a mafic magma, which becomes more intermediate in composition as it rises through the overlying crust

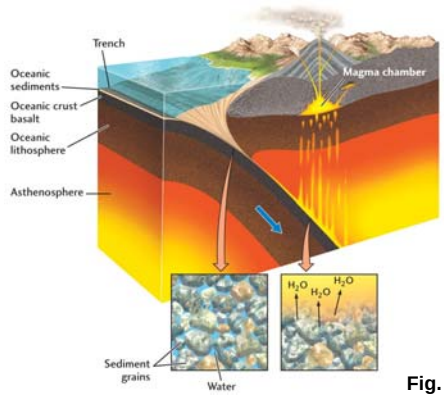



Fig. 4.14

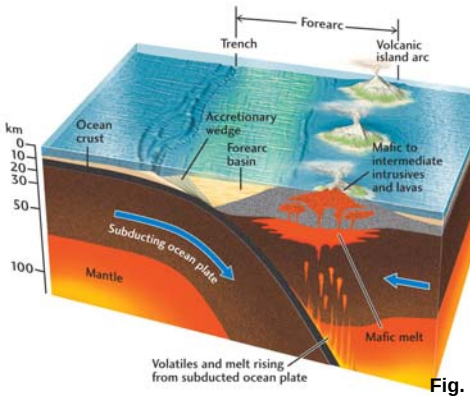



Fig. 4.14