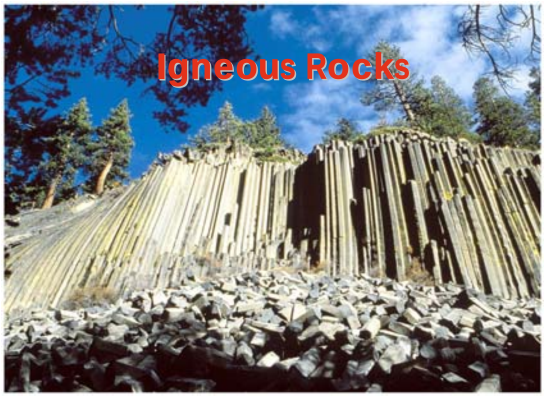


Igneous Rocks

- Earth scientists use the structure, sequence, and properties of rocks, sediments, and fossils to reconstruct events in Earth's history
- Earth's systems continually react to changing influences from geological, hydrological, physical, chemical, and biological processes
- rocks and minerals provide essential metals and other materials

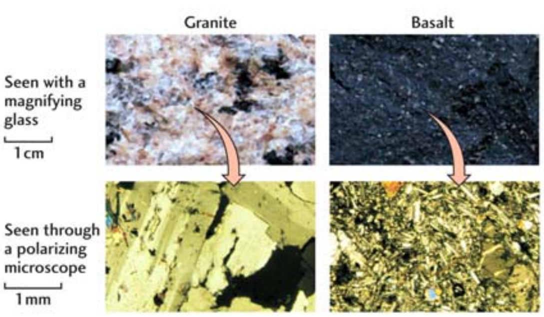


Fig. 5.1

Genetic Classification of Igneous Rocks

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

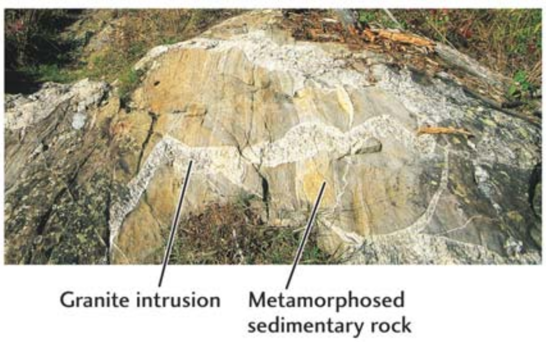


Fig. 5.2

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 (fragmented pieces of magma and material erupted into the air)

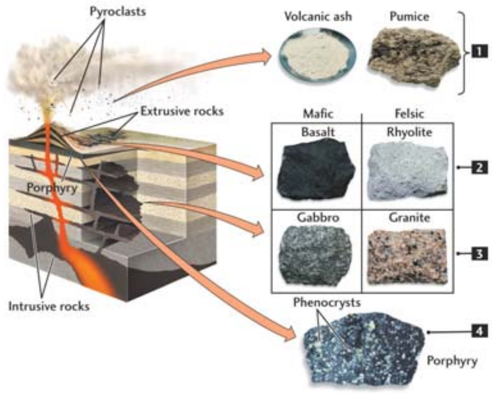


Fig. 5.3

Table 5-1 Common Minerals of Igneous Rocks

Compositional Group	Mineral	Chemical Composition	Silicate Structure
FELSIC	Quartz	SiO_2	Frameworks
	Potassium feldspar	$KAlSi_3O_8$	
	Plagioclase feldspar	$\{NaAlSi_3O_8, CaAl_2Si_2O_8\}$	
	Muscovite (mica)	$KAl_3Si_3O_{10}(OH)_2$	Sheets
MAFIC	Biotite (mica)	K, Mg, Fe, Al $Si_3O_{10}(OH)_2$	
	Amphibole group	Mg, Fe, Ca, Na $Si_8O_{22}(OH)_2$	Double chains
	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

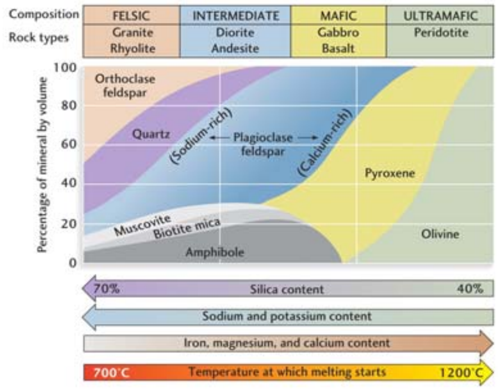


Fig. 4.4

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

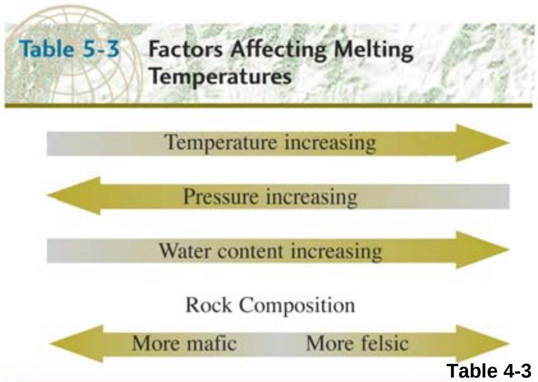
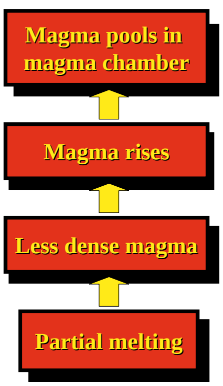


Table 4-3



The Formation of Magma Chambers

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

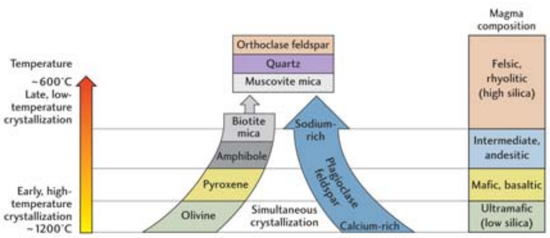


Fig. 4.5

Evidence of Fractional Crystallization in the Palisades Sill

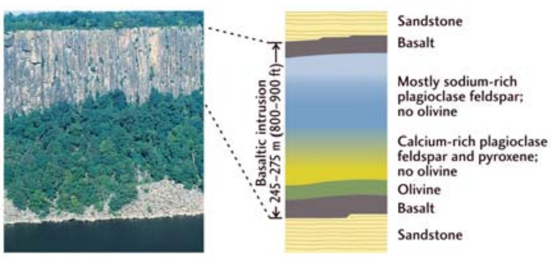


Fig. 4.5

Evidence of Fractional Crystallization in the Palisades Sill

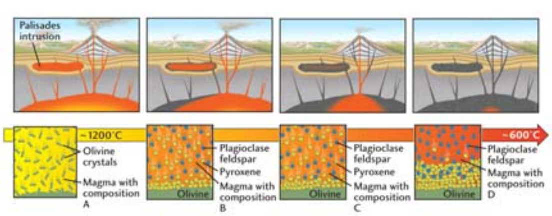
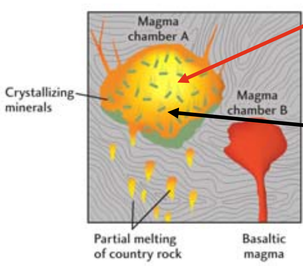


Fig. 4.5

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!

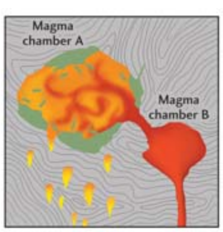
Modern Ideas of Magmatic Differentiation



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

- Batholith: **Massive, discordant intrusive body covering at least 100 km2**
- Stock: **Massive, discordant intrusive body covering less than 100 km2**
- Dike: **Tabular, discordant intrusive body**
- Sill: **Tabular, concordant intrusive body**

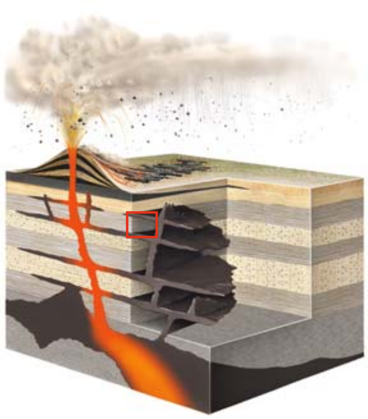
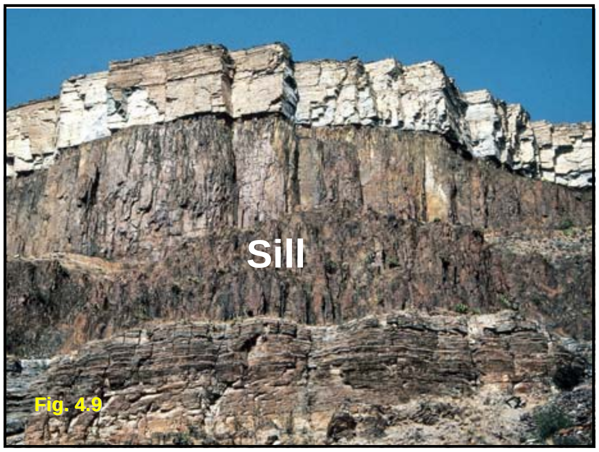


Fig. 4.9


Sill
Fig. 4.9

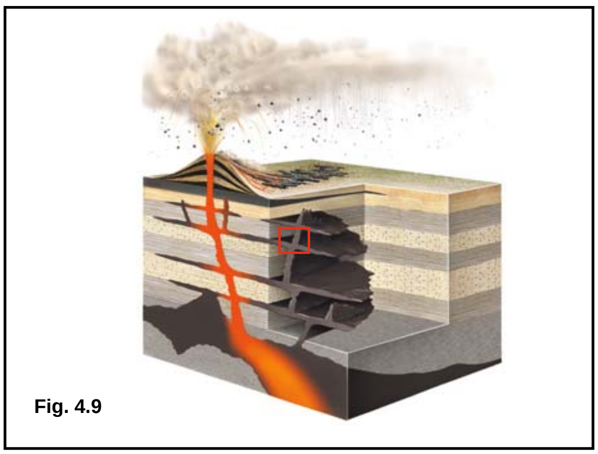
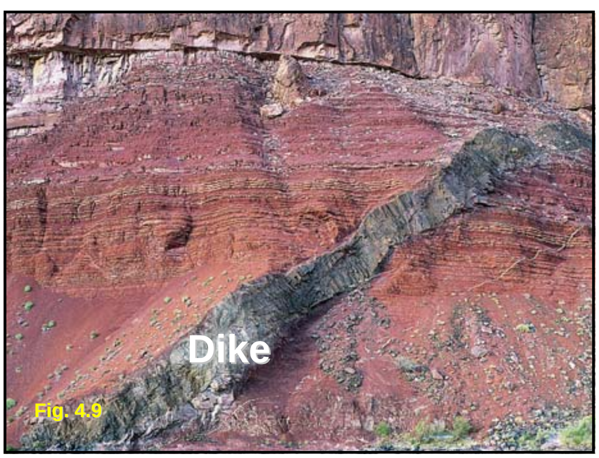


Fig. 4.9


Dike
Fig. 4.9

Granite Pegmatite

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

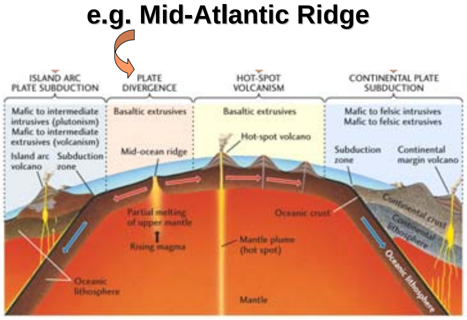


Fig. 4.11

Island Arc Plate Subduction e.g. Java, Indonesia

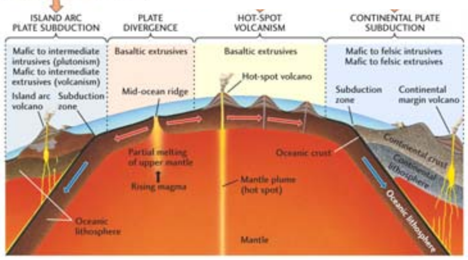


Fig. 4.11

Continental Plate Subduction e.g. Mt Ranier

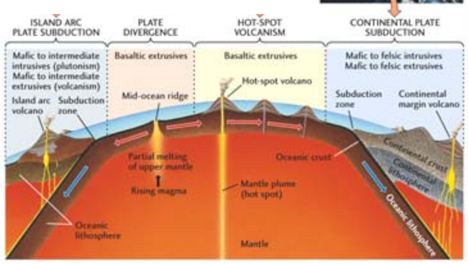


Fig. 4.11

Hot Spot Volcanism e.g., Hawaii Yellowstone

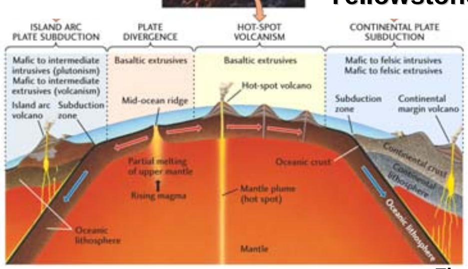


Fig. 4.11

Idealized Section of an Ophiolite Suite

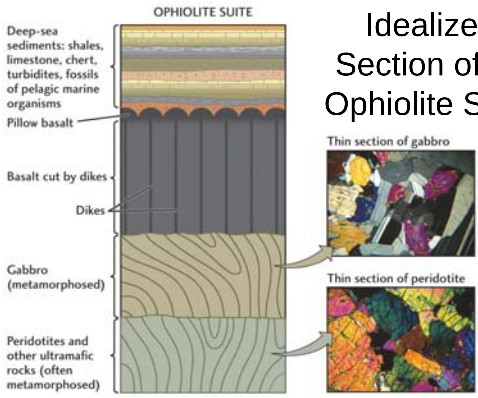


Fig. 4.12

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.

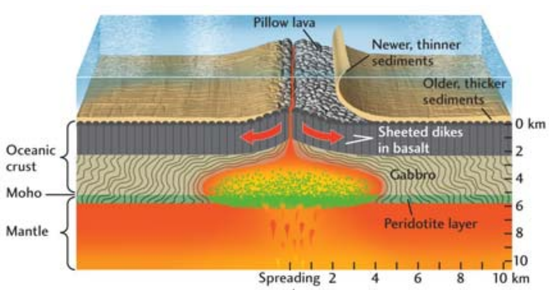


Fig. 4.13

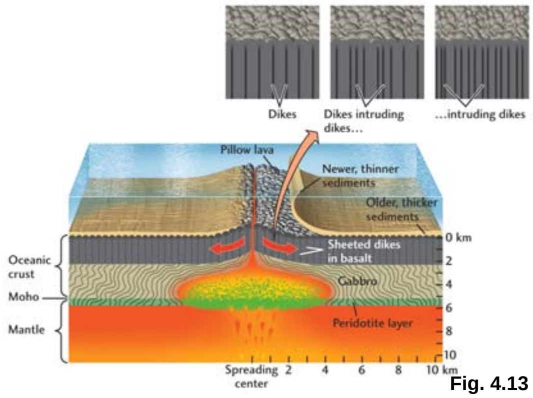


Fig. 4.13

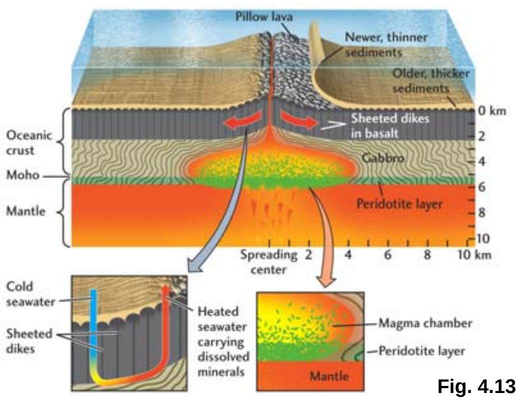


Fig. 4.13

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

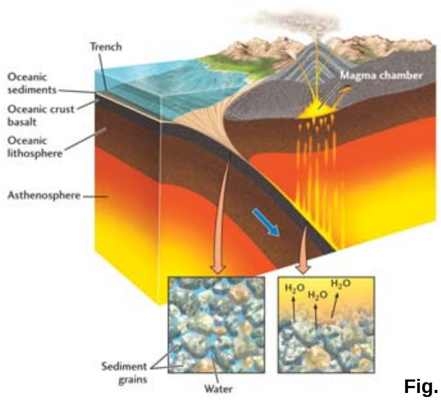


Fig. 4.14

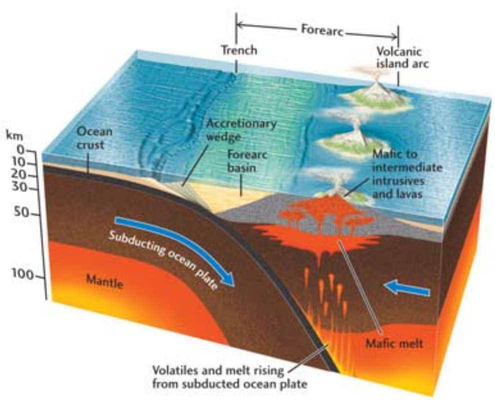


Fig. 4.14