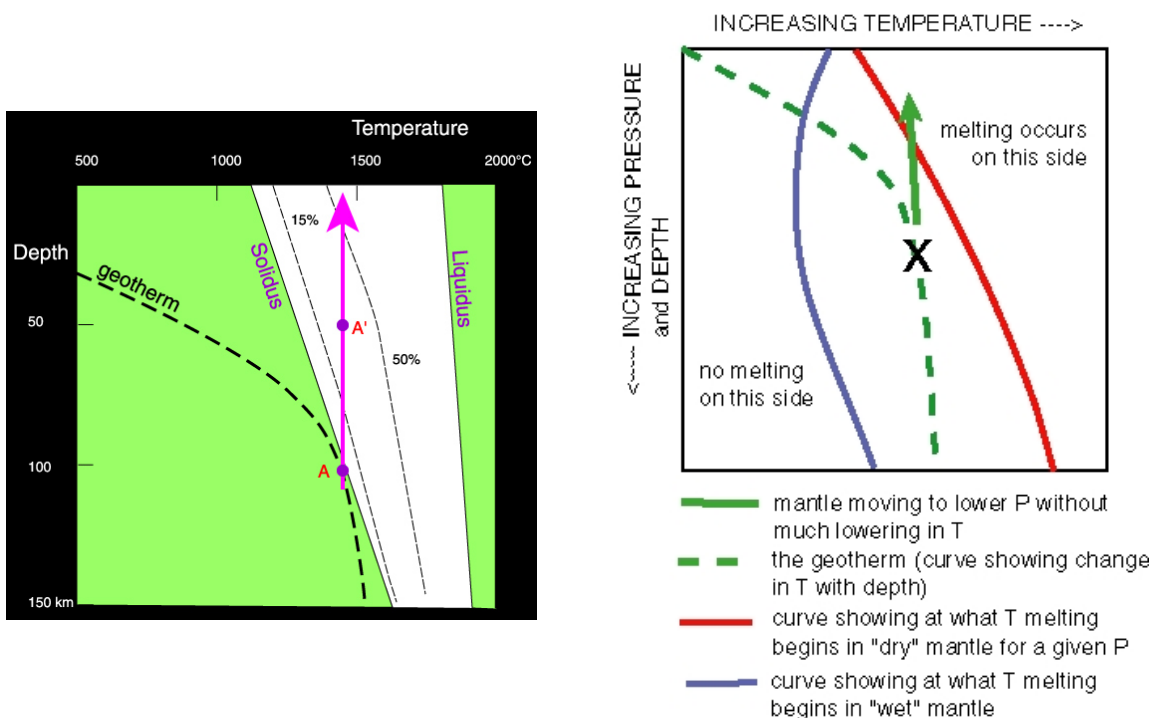


## Volcanoes

**Mantle melting** The magma that feeds volcanoes is generated by melting of the mantle. Whether the mantle melts or not depends on its temperature, pressure and composition; melt can be generated by altering each one of these properties whilst keeping the others constant:

1. Increase the *temperature*;
2. Decrease the *pressure*;
3. Alter the *composition*, so as to decrease the melting temperature.

The mantle is a polycrystalline aggregate of *peridotite* composition (i.e. pyroxene and olivine); it undergoes *partial melting* at the crystal edges. It is unlikely that more than 50% melting of any lump of mantle rock ever occurs at present.

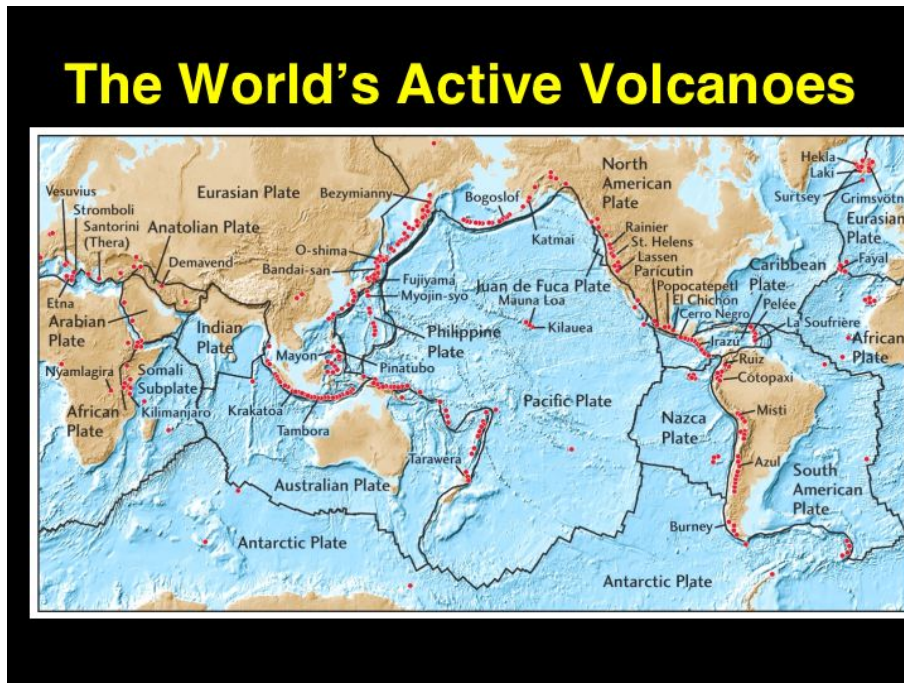


### Where does melting occur?

1. *Mid-ocean ridges* (decompression melting);
2. *Subduction zones* (addition of water);
3. *Hotspots* (high temperatures coupled with decompression melting).

**Melting and plate tectonics** The first two items in the list above show that melting, and consequently volcanic activity, is concentrated along constructive and destructive plate boundaries. Only transform plate boundaries are not associated with active volcanoes. Melting at mid-ocean ridges occurs because mantle is drawn upward to fill the gap left by diverging oceanic plates. Importantly, the rate of plate spreading is usually sufficiently high that the mantle beneath does not have time to cool by conduction as it rises. The resulting decrease in pressure at roughly constant temperature then causes melting. At subduction zones, water-logged sedimentary and upper crustal rocks are recycled back into the mantle along with the oceanic plates. The water becomes incorporated in the

mantle minerals within the wedge of mantle that lies above the subducting plate and beneath the over-riding plate. In this way, water reduces the melting temperature of the mantle rocks so that they start melting.



## Volcanism Associated with Plate Tectonics

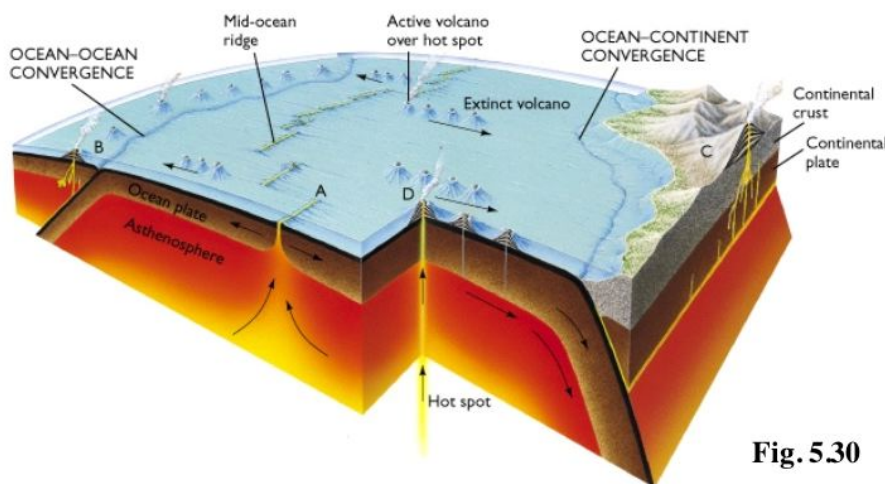


Fig. 5.30

**Hotspots** Hotspots are the surface expression of the hot, upwelling regions in the convecting mantle. The classic examples are Hawaii and Iceland (the fact that latter happens to lie at a constructive plate boundary is thought a coincidence). Two processes contribute to melting at hotspots. First, the mantle is hotter than normal. Second, the

hot mantle has a relatively low density, which is what drives the convective upwelling, so decompression melting is also important.

**Controls on eruption style: Viscosity** Magmas rich in Fe and Mg and poor in silica ( $\text{SiO}_2$ ) are termed *mafic*. These magmas produce basalts or gabbros when they solidify. Mafic magmas have relatively low viscosity, so basaltic lavas often flow for long distances over land. Magmas poor in Mg and Fe and rich in silica are termed *felsic* and have a relatively high viscosity. These magmas solidify to form granites, rhyolites and andesites. Felsic magmas have relatively high viscosity, so andesite and rhyolite lavas cannot flow far from their vents before they cool.

**Controls on eruption style: Volatile content** The main volatile is water, but  $\text{CO}_2$  is also important. Volatiles have two important effects.

1. Melting of a volatile-rich mantle generates relatively felsic magmas, which have a relatively high viscosity.
2. When the volatiles are dissolved in a magma, its viscosity is reduced.

When volatile-rich magma rises to the surface within a volcano, the pressure decreases so the volatiles exsolve (think of opening the top of a bottle of fizzy drink). The pressure in the magma rises significantly, since the volatiles are now in gaseous form. Simultaneously, the magma viscosity increases, so the magma cannot flow fast enough to let the gas bubbles out and relieve the pressure. The result is an *explosive eruption* in which the high gas pressure blows the viscous magma apart.

### Volcanic products

*Magma* results from melting of the mantle.

*Lava* is magma that is extruded at Earth's surface and cools to form volcanic rock.

*Pyroclastic rocks* result when magma is fragmented in an explosive eruption, and the fragments are deposited by sedimentary processes.

*Pumice* is a pyroclastic rock formed from a pyroclastic flow

### Eruptive styles

#### Fissure Eruptions Form Lava Plateaus

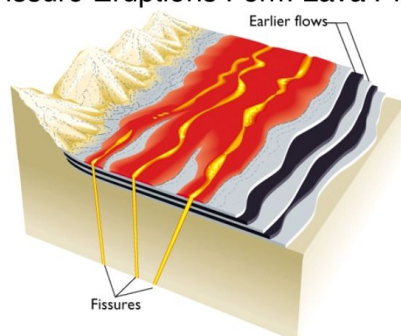


Fig. 5.20

#### Shield Volcano

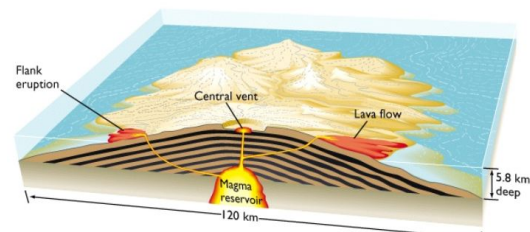
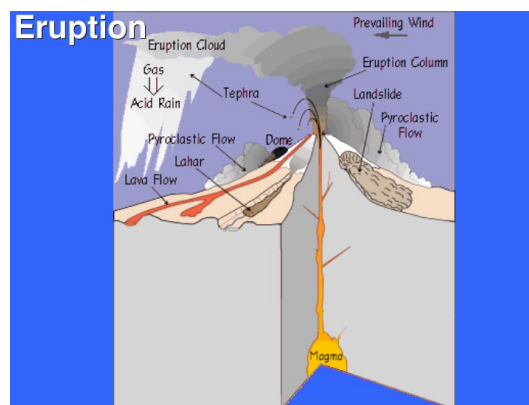
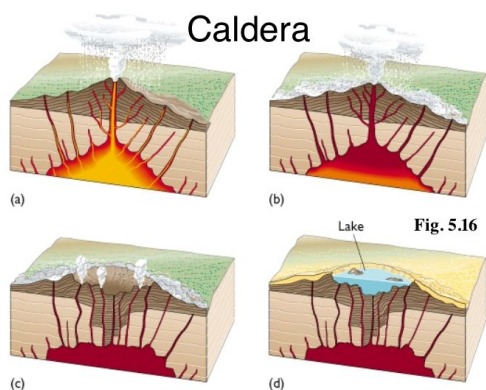
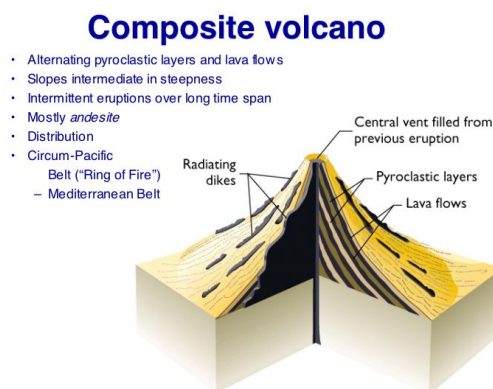
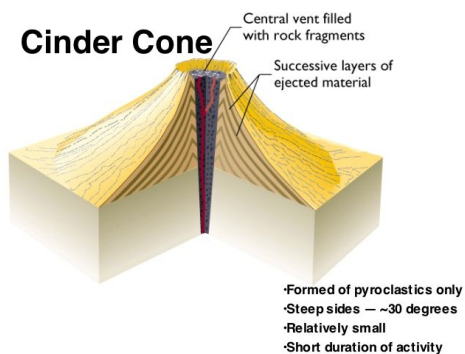


Fig. 5.10



**Eruptive style related to plate tectonics** Water is the key here. Destructive plate boundaries introduce water into the mantle, and the resulting magmas are both relatively felsic and volatile-rich. Hence the eruptive style above subduction zones is explosive, producing domes, cones and strato- (or composite) volcanoes. The mantle beneath constructive plate boundaries and at hotspots has a much lower water content, so the resulting magmas are mafic, volatile-poor and have a low viscosity. Shield volcanoes and fissure eruptions are the characteristic subaerial eruptive styles, and pillow basalts result when the eruption is under water.