Volcanic eruptions release magma, which consists of melted rocks and dissolved gases. Magmas are hot (800-1200°C) and are derived from deep (50 to 150 km) below the earth’s surface in the mantle or lower part of the crust.

There is no permanent reservoir of liquid magma inside the earth. Magmas are generated by perturbations of the earth’s mantle and lower crust due to plate tectonics. The outer core of the earth is liquid iron, but magmas are rock, not iron, and the outer core is too deep to be tapped by volcanism.

Magmas are generated in 3 different tectonic environments. The main two (figure 1) are:

1) at extensional or rifting/spreading plate boundaries, such as the mid-oceanic spreading ridge and rift system, below which convectively upwelling hot mantle moving melts due to decompression as it approaches closer to the earths surface. As it melts, the lower density liquid magma escapes from the mantle and erupts through the normal fault systems that are associated with extension at this type of plate boundary.

2) above subduction zones, in collision or compressional plate boundaries, such as in the northwest USA and many other localities around the Pacific Ocean “rim of fire” due to the fact that subducting lithosphere tectonically carries water and crust into the mantle which lowers the melting temperature of the mantle. As water is released from the subducting lithosphere, it rises into the overlying mantle and causes it to melt.
The third environment is at “hot-spots” which occur both along plate boundaries and in inter-plates areas such as below Hawaii and Yellowstone Park. Hot-spots represent a disturbance of the deep mantle, originating perhaps as deep as the core mantle boundary (figure 2) which generates magmas that rise through the lithosphere generating chains of volcanoes as the lithosphere plate on which the hot-spot volcanoes are located moves above the hot spot (figure 3).

No volcanoes occur in association with strike-slip plate boundaries, such as along the San Andreas fault, or above crustal thrust faults, such as in Los Angeles, since these faults do not disturb the deep crust or mantle.

Magmas may erupt passively to form lava flows as have been forming in the still active eruption of Kilahua volcano, Hawaii (see figure at the end) that began in 1983, or explosively such as at Mt St Helens on May 18th, 1980 (see lecture #9). This different behavior causes very different risks and hazards.

Whether or not a magma erupts passively as a lava flow or explosively depends on a number of different factors including 1) the magma composition; 2) its viscosity as determined by its composition and temperature; and 3) its volatile (water) content since it is the expansion of water dissolved in a magma that causes volcanic explosions.
These different factors are in turn controlled by the tectonic environment of magma formation: lava flows result from very hot, low viscosity, volatile-poor magmas formed at mid-oceanic spreading centers or hot-spots in oceanic regions as a result of the decompression of upwelling mantle, while explosive magmas form by cooler, lower viscosity, volatile-rich magmas formed above subduction zones, or where mantle derived magmas formed by rifting or above hot-spots must pass through the continental crust, where they cool and increase both their viscosity and volatile content (figure 4 below)

Three different types of magmas -- and rocks formed from magmas -- with different composition, environments of formation, temperature, viscosity, volatile content and eruptive behavior are basalt, andesite and rhyolite:

<table>
<thead>
<tr>
<th>Table 6.5</th>
<th>Comparison of Three Types of Magma</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volcanic Rock Types</strong></td>
<td><strong>Rock Description</strong></td>
</tr>
<tr>
<td>Basalt</td>
<td>Black to dark gray; contains Ca-plagioclase, pyroxene, olivine</td>
</tr>
<tr>
<td>Andesite</td>
<td>Medium to dark gray; contains amphibole, pyroxene, intermediate Ca-Na-plagioclase</td>
</tr>
<tr>
<td>Rhyolite</td>
<td>Light-colored; contains quartz, K-feldspar, biotite, Na-plagioclase</td>
</tr>
</tbody>
</table>
In summary:

**BASALTS and BASALTIC MAGMAS:**

Form by decompression melting of convectively uprising mantle at extensional plate boundaries, continental rifts and hot spots. They are dark in color because of their relatively low silica and high iron content. They have low viscosity because they are hot (>1000°C) and have low silica content and have low volatile (H2O) contents. Therefore they erupt passively as lava flows, forming spatter cones and flows, shield volcanoes (like in Hawaii -- see figure below) and large lava plateaus (like the Colombia plateau basalts)

**RHYOLITES and RHYOLITIC MAGMAS:**

Form by either 1) melting of mantle fluxed by water and sediments carried into the mantle in subduction zones; and/or interaction of mantle derived basaltic magmas with the continental crust (figure 4 above). They are light in color because of their relatively high silica and low iron contents. They have high viscosity because they are cool (600-800°C) and have high silica content. They have high volatile (H2O) contents and therefore they erupt explosively, forming pyroclastic flows associated with stratovolcanoes (like Mt St Helens) and calderas (like Crater Lake or Yellowstone park)

**ANDESITES and ANDESITIC MAGMAS**

Form by either 1) melting of mantle fluxed by water and sediment carried into the mantle in subduction zones; and/or interaction of mantle derived basaltic magmas with the continental crust They are intermediate between basalts and rhyolites in color, silica content, iron content, volatile content, temperature (800-1000°C) and viscosity. Therefore they may erupt either passively forming domes and stratovolcanoes (like all the Cascade volcanoes), or explosively forming pyroclastic flow associated with stratovolcanoes and calderas (like at Mt St Helens in 1980 and Vesuvius in 79 AD)