# Evolution Of Our Moon

**Early Stages: A Magma Ocean** — As the rocky materials orbiting Earth accreted, the Moon grew larger and hotter. Heat from accretion caused the outer surface, and perhaps more, of the Moon to melt, forming an ocean of magma.

The evidence for a magma ocean comes from the layering of the Moon's interior. The uppermost part of the Moon's crust is mainly the rock anorthosite, which is primarily made of a single mineral: low-density, aluminum-rich, plagioclase feldspar. This rock forms the "lunar highlands," the brighter, light-colored, heavily cratered regions we see on the Moon. Deeper parts of the Moon's crust and mantle include larger amounts of other minerals, such as pyroxene and olivine. As the magma ocean cooled and crystallized over a period of 50–100 million years, low-density minerals such as plagioclase floated to the top, while denser minerals such as pyroxene and olivine sank. The oldest rocks collected by Apollo astronauts are 4.5 billion years old, which is thought to indicate when the Moon's crust solidified.

As the outer layers solidified, the interior of the Moon also differentiated. The heavier iron separated from the less-dense rock in the mantle and sank, forming a small core surrounded by the rocky mantle and crust.

**Big Impacts, Big Basins** — Our early solar system was a messy place! An abundance of material remained in space and debris of all sizes constantly pummeled the Moon and all other planetary bodies. The impactors left their mark; huge impact basins such as Imbrium, Crisium, and Serenitatis, hundreds of miles across, occur where they struck the Moon. The upturned rims of these basins form mountain chains on the lunar landscape. The impacts broke apart the rocks at the surface of the Moon and fused them into impact melt breccias — rocks made of angular, broken fragments, finer matrix between the fragments, and melted rock. These rocks, collected by Apollo astronauts, provide scientists with the timing of basin formation, ranging from 3.8 to 4.0 billion years ago. By 3.8 billion years ago, the period of intense bombardment came to a close; impact events became less frequent and were generally smaller. Impacts still occur today.

**Basin Filling** — Although cooling, the Moon was still hot, heated by radioactive decay of unstable isotopes of elements, such as uranium and thorium, and the processes of accretion and differentiation. Isolated pockets of hot mantle material slowly rose to the surface, melting at lower pressures. This magma poured out through cracks in the lunar surface — fissures — many of which were created by the earlier impacts. The magma flooded across the lowest regions on the lunar surface to fill the impact basins. It crystallized quickly, forming basalt, a dark, fine-grained, volcanic rock. The composition of the basalt varies because the magma formed in different places in the lunar interior. Some basalts have more titanium, others are more enriched in other elements such as potassium and aluminum. The large, smooth, dark regions we see on the Moon are the basaltic "lunar maria." "Maria" is Latin for "seas," as these areas looked like seas to early astronomers. They are smooth because they are less cratered than the lunar highlands. The smaller number of craters in the maria suggests that these regions have not been impacted as much and therefore are younger. Mare basalts have been radiometrically dated to be between 3.0 and 3.8 billion years old.

Imagine standing on the Moon at this time. Hot basalt lava flowed from long fissures, filling regions of low elevation. Fountains of lava sporadically erupted along the fissures, spewing molten rock high above the lunar surface. Chilled magma droplets fell back as beads of colored volcanic glass, later sampled by Apollo astronauts. Flowing lava cut channels into the landscape. In a few locations, small volcanic domes built up on the surface of the maria. Gradually, as the Moon's interior cooled, volcanism ceased.

**Recent History** — For the last one billion years, our Moon has been geologically inactive except for small meteoroids pummeling its surface, breaking the rocks and gradually adding to the layer of fine lunar dust — regolith — that covers the surface. In some places the regolith may be thicker than 50 feet (15 meters). The Moon has no atmosphere, flowing water, or life to erode or disturb its surface features. Other than impactors, only a few spacecraft, and the footsteps of 12 humans, have reshaped its landscape.

The data returned by orbiting spacecraft and the Apollo program reveal much about the formation and evolution of our Moon and, in turn, of our own Earth. Resurfacing processes active on Earth have obscured our planet's early history of formation, differentiation, and asteroid bombardment. New missions will help scientists piece together details of the history and evolution of the Moon (and Earth) and will help us better understand lunar processes and the distribution of resources in preparation for humans to live and work on the Moon.