4,100,000,000 years ago

4,200,000,000 years ago

4,300,000,000 years ago

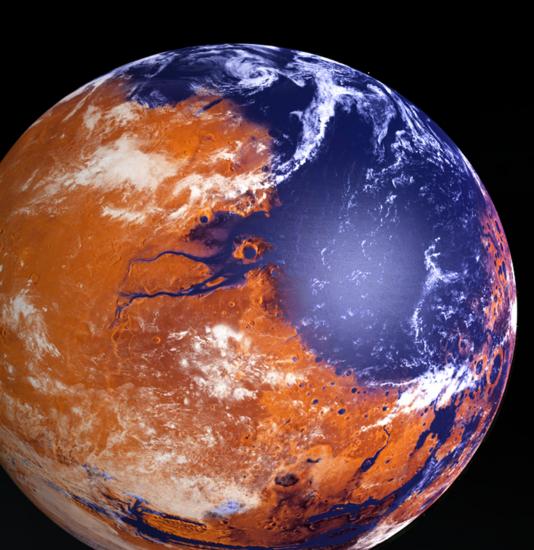
4,400,000,000 years ago

4,500,000,000 years ago

4,600,000,000 years ago

Oceans on Mars?

Exploration of Mars suggests that the planet has abundant water ice and may have had oceans in the northern lowlands early in its history. As Mars cooled, the water collected as ice beneath the surface and in the polar ice caps.



Lunar Crust

Earth's Early

Atmosphere and Oceans

Volcanic eruptions spewed gases from Earth's interior to the

Earth Adds

Land

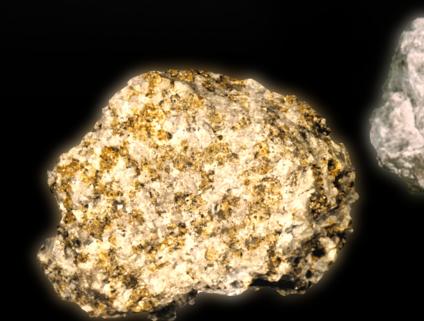
atmosphere, a process called outgassing, that continues today. Most

of the gas was carbon dioxide and water vapor. The water vapor condensed

to form part of Earth's oceans as the surface cooled. Comets may also have

contributed water and complex organic molecules to Earth's environments.

The lunar magma ocean cooled and crystallized, forming a crust about 40 kilometers thick. Asteroids continued to bombard the Moon, leaving impact craters.



Oldest Moon Rocks

The Apollo missions returned samples of ancient lunar crustal rocks. These rocks are about 4.5 billion years old, indicating that parts of the Moon's crust solidified soon after the Moon formed.

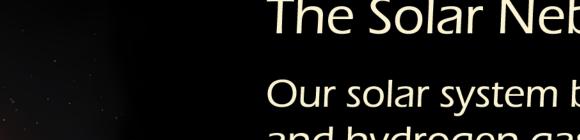


A Mars-sized object collided with Earth, vaporizing, melting, and throwing debris from the impactor and Earth's outer layer into orbit around Earth, creating an encircling debris ring.

Material in the debris ring accreted to form our Moon,

possibly within a few hundred years. The young

Moon was much closer to Earth, and orbited



The Solar Nebula

Our solar system began forming in a concentration of interstellar dust and hydrogen gas. The cloud contracted under its own gravity and our proto-Sun formed in the center, surrounded by the swirling disk of the solar nebula.

Circumstellar Disks



Most stars forming in our galaxy, like those in the Orion Nebula, are surrounded by disks of dust and hydrogen gas called circumstellar disks. Scientists study these disks to learn about processes that occurred billions of years ago in our solar nebula.

Planetesimals

In the solar nebula, dust and ice particles occasionally collided and merged. Through this accretion, these tiny particles formed larger bodies that eventually became planetesimals up to a few kilometers across. In the inner, hotter part of the nebula, planetesimals were composed of silicates and metals. In the outer, cooler portion, water ice was the dominant component.

Terrestrial Planets (Inner Solar System)

Planetesimals were massive enough that their gravity influenced other planetesimals. This increased the frequency of collisions, causing the largest bodies to grow more rapidly, eventually becoming planetary embryos. Accretion continued until only four large bodies remained — Mercury, Venus, Earth, and Mars.

Gas Giants (Outer Solar System)

In the cold outer solar nebula, where our Sun's gravity was weaker, much larger planetary embryos formed. The largest ones swept up other embryos, planetesimals, and nebular gas, leading to the formation of Jupiter, Saturn, Uranus, and Neptune.

Solar Nebula Disperses

The growing proto-Sun accumulated much of the nebula's material long before planets formed. A small portion was later incorporated into the

planets, but the remainder was swept away when nuclear reactions were initiated in our Sun's core. These reactions created a strong solar wind, which expelled the Sun's outer layers far beyond our solar system. A much weaker solar wind continues to flow today.

Asteroids are rocky remnants from our early solar system; most orbit between the inner and outer planets. Occasionally, asteroids reach Earth's surface as meteorites, providing scientists with information about

**Asteroids** 

the inner solar system.

Planetesimals that have not had enough time to accrete into planets populate the Kuiper belt, which extends beyond Neptune. Pluto, considered a dwarf planet, is a large our solar system and contains icy planetesimals.

Comets

Comets formed in the outer reaches of our solar system early in its development. They are made of ice and dust, materials left from the original nebula. Comets periodically pass close enough to the Sun to heat up and release a long tail of dust and gas.



Earth's Initial Crust

The surface of the early Earth was molten, heated mostly by asteroid impacts such as the one that formed our Moon. As Earth cooled, its outer surface soldified into a crust. Until it thickened, continued asteroid bombardment broke up the crust.

Volcanism on Earth The interior of the early Earth was heated primarily from decay of radioactive elements. While this heat-generating process is still important today, it was much more significant volcanically active than it is now.

in the early Earth, causing the planet to be more

Earliest Remnants of the Earth's Crust

Tiny zircon grains within the sedimentary rocks of the Jack Hills of Western Australia formed about 4.4 billion years ago. These zircon grains are the remnants of some of the Earth's oldest crust and have survived multiple cycles of erosion, redeposition and tectonic deformation.

Planetary Layers

formed from the lightest materials.

As the inner planets formed, they heated up. Their interiors melted and reorganized into layers of different densities. Melting was caused by heat from impactors striking and accreting, the sinking of heavy materials to the center, and the decay of radioactive elements. This reorganization caused the rocky planets to have dense, metal-rich inner cores, less-dense mantles, and outer crusts

The Moon Forms

Lunar Magma Ocean

The heat from accreting particles

caused the Moon to at least partially

melt, creating a lunar magma ocean.

the planet once every few days.

Kuiper Belt

member of the Kuiper belt. The Oort cloud envelops Comets originate in the Oort cloud and the Kuiper belt.

4100 million years ago

4200 million years ago

Undersea volcanos erupted lava that eventually reached the ocean

on the Hawai'ian islands and other volcanic island chains today.

surface, forming active volcanic islands. Similar processes are observed

4300 million years ago

4400 million years ago

4500 million years ago

4600 million years ago