Name:_____ Points:___/10

SMITH - EARTH SPACE - 2nd PERIOD - OFF-SITE LEARNING PACKET DAY 7

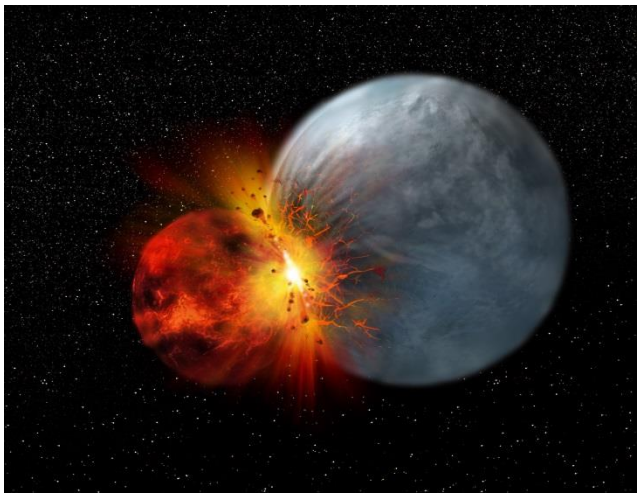
Chapter 9 The Earthlike Planets
Lesson Seven – The Moon Part Two

Lesson Objectives

- **define bellwork vocabulary (regolith, mare, tektites)** with 100% accuracy
- **list the four possible hypotheses for the formation of the moon** with 100% accuracy
- **list the evidence that supports the fourth hypothe**sis with 100% accuracy

Associated Text:

Chapter 9 Lesson 7



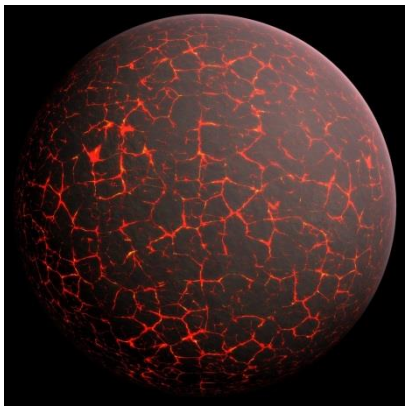
The most favored hypothesis on how our moon formed is the large impact hypothesis. A collision could have also tilted Earth's axis of rotation from the ecliptic.

The Four Stage History of Earth's Moon

The four-stage history of Earth's moon is dominated by a single fact -it is small, only one-fourth the diameter of Earth. The escape velocity is low, so it has been unable to hold any atmosphere, and it cooled rapidly as its internal heat flowed outward into space. As we will see when we study other worlds, a planet's geology is largely driven by energy in the form of heat flowing outward from its interior. Small worlds have less heat and lose it more rapidly, so Earth's moon's small size has been critical in its history.

First Stage – Differentiation

During the first stage of planet formation, Earth's moon formed and differentiated. The Apollo moon rocks show that our moon formed in a molten state, allowing the denser materials it contained to sink to form a small core. Earth's moon has a low density and is poor in iron, so the core is not large and must contain little iron. The lowest-density minerals rose to form a low-density anorthosite crust. Radioactive ages of moon rocks tell us that the surface solidified 4.6 to 4.1 billion years ago.



The moon differentiated, therefore we can assume that it was molten when if formed.

Second Stage – Cratering

The second stage, cratering, began as soon as the crust solidified, and the older highlands show that the cratering was intense during the first 0.5 billion years -during the heavy bombardment at the end of planet building. Earth's moon's anorthosite crust was shattered, and the largest impacts formed giant crater basins hundreds of kilometers in diameter The basin that became Mare Imbrium, for instance, was blasted out by the impact of an object about the size of Rhode Island. This Imbrium event occurred about 4 billion years ago and blanketed 16 percent of our moon with ejecta Between 4.1 and 3.9 billion years ago, the cratering rate fell rapidly to the current rate, roughly 1000 times less than during the early heavy bombardment.

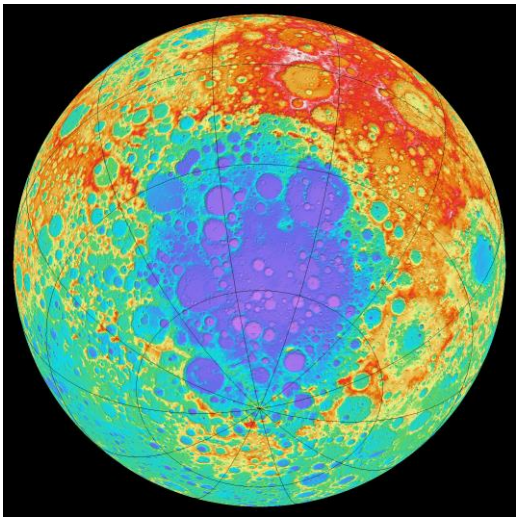
Mare Imbrium was formed by an impact of a planetesimal the size of Roade Island around 4 billion years ago.

Third Stage - Flooding

The tremendous impacts that formed the lunar basins cracked the anorthosite crust as deep as a few kilometers and led to the

third stage-flooding. Though Earth's moon cooled rapidly after its formation, some process, perhaps radioactive decay, heated the subsurface material; and part of it melted, producing lava that followed the cracks up into the giant basins. The basins were flooded by successive lava flows of dark basalts from 3.8 to 3.2 billion years ago, thus forming the maria.

Studies of our moon show that its crust is thinner on the side toward Earth, perhaps due to tidal effects. Consequently, while lava flooded the basins on the earthward side, it was unable rise through the thicker crust to flood the lowlands on the far side. The largest impact basin in the solar system is the South Pole- Basin. It is about 2500 kilometers (1500 miles) in diameter and as deep at 13 kilometers (8 miles) in places, but flooding has never filled it with smooth lava flows.



Luna South Pole Basin. The largest impact basin in the solar system. 1500 miles in diameter, 8 miles deep.

Fourth Stage – Slow Surface Evolution

The fourth stage, slow surface evolution, is limited because our moon lacks water and has cooled rapidly. Flooding on Earth included water, but our moon has never had an atmosphere and thus has never had liquid water. With no air and no water, erosion is limited to the constant bombardment of micrometeorites and rare larger impacts. Indeed, a few meteorites found on Earth have been identified as moon rocks ejected from our moon by major impacts within the last few million years. As our moon lost its internal heat, volcanism died down; and Earth's moon became geologically dead. Its crust never divided into moving plates - we find no folded mountain chains and it is now a one-plate planet, frozen between stages 3 and 4.

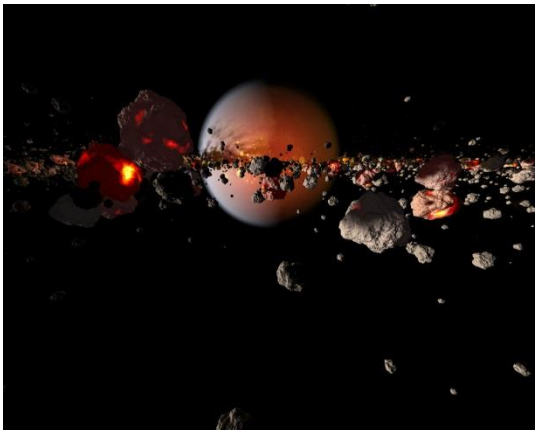
Although we can tell the story of the lunar surface, we have neglected one important point. We have not said how Earth's moon formed. We will explore that idea in the next section.

The Origin of Earth's Moon

Over the last two centuries, astronomers have developed three different hypotheses for the origin of Earth's moon, but these traditional ideas have failed to survive comparison with the evidence. A theory proposed in the 1980s may hold the answer. We begin by testing the three unsuccessful theories against the evidence.

The **fission hypothesis** proposed that our moon broke from a rapidly spinning proto-Earth. If this happened after the proto-Earth differentiated, our moon would have formed from iron-poor material. However, moon rocks differ chemically from those of Earth. Also, if the proto-Earth had spun fast enough to break up, the Earth-moon system should now contain much more angular momentum than it does.

Artist conception of the fission hypothesis of lunar formation.

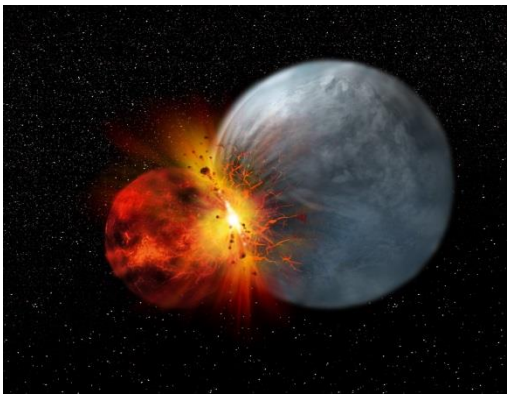


Artist conception of the condensation hypothesis of lunar formation.

The **condensation hypothesis** suggested that Earth and its moon condensed from the same cloud of matter in the solar nebula. This idea doesn't work, however, because Earth and its moon have different densities and compositions. The moon, for example, is very poor in volatiles-materials such as water, sodium, and calcium, which are easily vaporized.

The **capture hypothesis** suggested that our moon formed elsewhere in the solar nebula and was later captured by Earth. However, if our moon passed near enough to Earth to be captured, Earth's gravity would have ripped it to fragments.

Until the mid-1980s, astronomers had no acceptable hypothesis for the origin of Earth's moon, but at that point a hybrid theory offered hope. The large **impact hypothesis** supposes that our moon formed when a planetesimal at least as large as Mars smashed into the proto-Earth and ejected debris into an orbit, where it formed our moon.



Artist conception of the large impact hypothesis of lunar formation.

This would explain a number of phenomena. If the collision occurred off center, it would have spun the Earth-moon system rapidly and would thus explain the present angular momentum. If the proto-earth and impactor had already differentiated, the ejected material would have been mostly iron-poor mantle and crust. Models show the iron core of the impactor would have fallen into Earth within 4 hours, leaving our moon to form from iron-poor rock. Also, the material would have remained in a disk around Earth long enough to have lost the volatile materials that our moon lacks.

The large-impact hypothesis survives comparison with the known evidence and is now a widely considered hypothesis.

The evolution of Earth's moon has been restricted by its small size. Another world in our solar system has also suffered from its diminutive size. Mercury, like Earth's moon, is a small, rocky world, cratered by impacts and flooded by ancient lava flows that are driven by its internal heat.

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Guided Reading Questions: (10 pts.)

Use the above text and class notes to answer the following questions

The History of Earth's Moon

1. Why does the moon have no atmosphere?

2. What caused the moon to cool so rapidly (compared to the Earth)?

3. Why do we think the moon formed in a molten state?

4. How long ago did the moon's surface solidify?

5. Has the intensity of meteor impacts always been the same? When was it most intense?

6. Why are there more maria on the side of the moon that faces the Earth?

The Origin of Earth's Moon

7. List the three incorrect hypotheses on the origin of the moon.

8. What is the current hypothesis called?

Lesson Notes:

Humans on the Moon

- Starting in 1969 and ending in 1972
- 12 American Apollo astronauts have walked on the moon
- Neil Armstrong was the first
- Eugene Cernan was the last

The Moon's History

- dominated by the small size (1/4 diameter of Earth)
  - cooled quickly
  - no internal heat
    - no tectonics
  - can't gravitationally hold atmosphere

First Stage

- moon is differentiated
  - must have formed molten
  - 4.6 to 4.1 bya
  - low-density anorthosite crust
  - small, iron poor core

Second Stage

- bombardment heavy on first 500 my
- crust shattered by impacts
- current impact rate 1000 times less

Third Stage

- flooding occurred when large impacts caused basins to flood with lava
- formed maria
- stopped forming 3.2 bya
- crust thicker on side away from Earth
- far side has no maria
- crust too thick there for magma to come to surface and fill in basins

Fourth Stage

- limited due to lack of water and no tectonics
- erosion due to impacting meteorites and micro-meteorites

The Moon's Origin
4 Hypotheses

- fission
  - moon spun off of still molten Earth
  - problem: not enough angular momentum
- condensation
  - moon formed along side Earth
  - problem: wrong composition
- capture
  - moon came from other place
  - problem: physics
- large impact
  - moon resulted from collision of Earth and another protoplanet
  - best hypothesis so far

Vocabulary:
regolith - the layer of loose material covering the bedrock of the earth and moon, etc., comprising soil, sand, rock fragments, volcanic ash
mare – name given to plains composed of basalt on the moon
tektites – objects made from natural glass that are created from the impact of meteorites