Clues to Lunar History

Geologic History of the Moon

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Introduction

A large object that struck Earth about 4.0–4.5 billion years ago is credited with creating conditions that resulted in the formation of our Moon. It is sometimes referred to as "The Big Whack" Theory. It explains evidence collected from Earth and Moon rocks that were collected by the Apollo astronauts in the 1970s. The Moon probably looks today much like it did within the first months to years of its formation. Impact events occurred immediately and repeatedly, changing the newly formed lunar surface to the image of the Moon we see in our night sky.

Background

The Big Whack: Theory of Lunar Formation

Approximately 4.0 billion years ago, a planet-sized object smashed into our still forming Earth. The impact was so great that it nearly split our planet apart—instead vast amounts of molten material were splashed out into space and quickly solidified in the cold temperatures there. The debris orbited Earth but formed quickly, forming our only natural satellite, the Moon. Estimates made by computer modeling of this process estimate the time required for the Moon to begin to form as one solid body was only about 24 hours. As the accreting material increased in mass, the increasing pressures at the core were high enough to melt the inner portions of the Moon. In the early 1970s Apollo astronauts observed small lunar quakes taking place with special seismographs. These weak lunar quakes indicate that the Moon is not entirely solidified, but remains partially molten at great depths.

Impacts occurred during and immediately following the formation of the Moon. These large (and some small) impact basins remain preserved on the lunar surface. Since large numbers of meteors in orbit remained around Earth after the Moon formed, Earth too, was bombarded by numerous meteorites from this event. Unlike Earth however, the Moon has no atmosphere to weather away this evidence of ancient bombardment. No atmosphere means no weather (clouds, precipitation, ice, wind, etc.). Without an atmosphere, impacts (and Apollo astronauts' footprints) remain on the lunar surface indefinitely.

The Highlands and Maria

There are two basic types of surface materials on the Moon. There are the Highlands and the Maria. The Highlands are composed of a light-colored rock called anorthosite. Because anorthosite reflects light better than the darker basalt of the Maria regions, the Highlands appear brighter. The Highlands are older than the Maria.

The "mare" or maria is Latin for "sea." These areas are made of dark igneous basalt. Basalt is also formed naturally on Earth—where lava solidifies near or on Earth's surface, it solidifies to form this dark, fine-grained igneous rock. Geologists use a principle called Uniformitarianism to figure out how events worked in the past by studying what occurs around us today. The concept is that processes that occurred in the distant past probably don't occur too differently than those same processes do today. By studying the processes of basalt formation on Earth, planetary geologists who studied the moon rocks were able to determine a probable means of its formation on the Moon.

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Shortly after its formation, large asteroid-sized objects bombarded the freshly formed surface of the Moon. Some of these impacts were so large, that they essentially cracked the Moon's surface open, allowing some of the molten material to seep out. This "lava" flowed out under pressure and filled in the lower elevations (maria) of the lunar surface.

Using basic principles of Relative Age dating, the sequence of impact basins can be put in order. Couple this with evidence from radiometric dating and a much more complete picture of lunar history can be pieced together.

Activity Overview

In this activity, features of the lunar surface will be located and labeled on an enlarged lunar photograph.

Materials

Photographs of lunar surface visible to Earth, 6

Labeled drawings of the lunar surface visible to Earth, 2

Scissors

Bright colored pencil (red, green, etc.)

Transparent tape

"Radiometric Dates of Prominent Lunar Surface Features" data table

Procedure

1. Carefully cut out the six detailed photographs of the lunar surface. Carefully situate them on your desk to match up the gray areas. Tape them together to form a mosaic picture of the lunar surface.
2. Locate and label the following features on the mosaic of the lunar surface.
   a. Rheita Valley
   b. Lunar highlands near the South Pole
   c. Mare Crisium lava flows
   d. Archimedes impact crater
   e. Copernicus impact crater
   f. Aristillus impact crater
   g. Eratosthenes impact crater
   h. Mare Imbrium impact crater
   i. Mount Pico
   j. Tycho impact crater
   k. Kepler impact crater
   l. Mare Tranquillitatis

3. Determine the relative ages of these features on the basis of the three principles listed below and assign numbers to each of the features (1–10). 1 is the oldest, while 10 is the youngest.

Principle of Superposition

Younger formations sit atop older formations. Examples: Small craters inside larger ones are always younger than the larger craters. Craters sitting atop lava flows are always younger than the lava flows. Likewise, impact basins or craters filled with lava flows are older than the lava flows that filled them.

Principle of Cross-Cutting Relationships

Younger features always cut across older features. Examples: Bright ejecta rays are thrown on top of existing features. The ejecta rays are younger because they cut across events that have already occurred.

Crater Counts

Old areas of the lunar surface are blanketed with craters while younger areas are not. The oldest regions of the lunar surface house the largest impact basins, while younger areas have smaller craters.

4. Assign these chronological numbers (#1–10) to the appropriate locations on the Moon mosaic. Color code the mosaic, if desired.

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Radiometric Dates of Prominent Lunar Surface Features

Features with no radiometric date provided are listed in relative age chronology.

Type of Surface Feature		Surface Feature Name	Absolute Age (b.y.o.)	Relative Age (b.y.o.)
Impact Event	Maria (lava flow)			
*		Tycho		.1
*		Copernicus		.9
*		Eratosthenes		2.0 (?)
	*	Oceanus Procellarum	3.29–3.08	
	*	Eratosthenes Basalts	3.2	
	*	Mare Crisium	3.3	
	*	Mare Imbrium	3.3–3.7	
	*	Mare Fecunditatis	3.41	
	*	Mare Tranquillatiatis	3.57–3.88	
*		Archimedes		3.8 (?)
	*	Mare Serenitatis	3.65–3.85	
*		Mare Imbrium (including Apennine Mts.)	3.85	
*		Mare Serenatatis	3.87	
*		Mare Crisium		
*		Mare Nectaris	3.92	
*		Mare Fecunditatis		
*		Marae Tranquillatatis		
		Oldest Mare Basalt within a Highland Breccia	4.2	
		Oldest Highland rock within a Breccia	4.356	

Questions to Master

1. For each of the major Maria (Mare) on the lunar surface listed in the table above, which came first, the lava flow or the impact (note the second listing in the table)?
2. Describe the scale of the impact to have formed the lunar Maria.
3. When did most of the prominent, large features occur during the Moon's history?
4. Why would the lunar Maria be named after "seas"?

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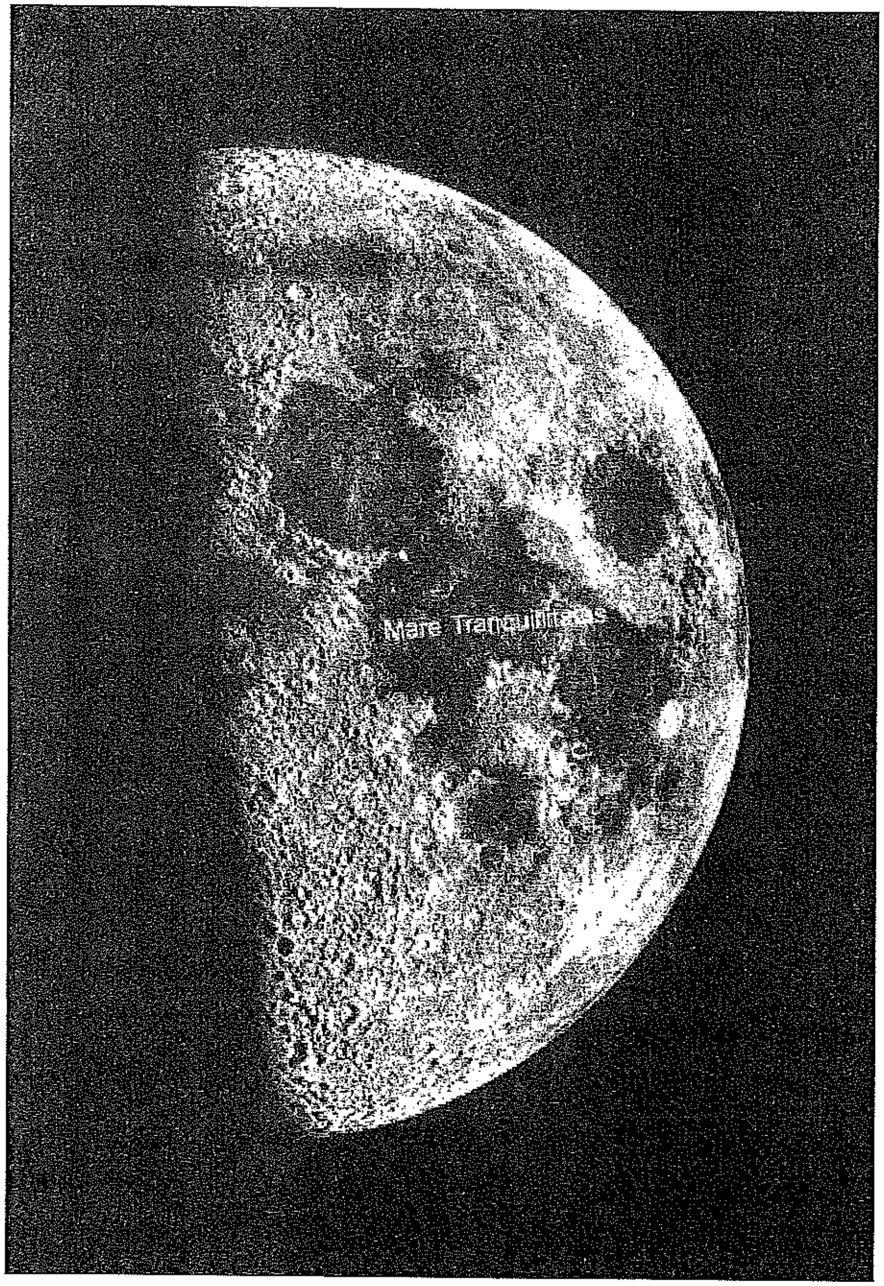

Figure A. First-quarter Moon (7 days old).

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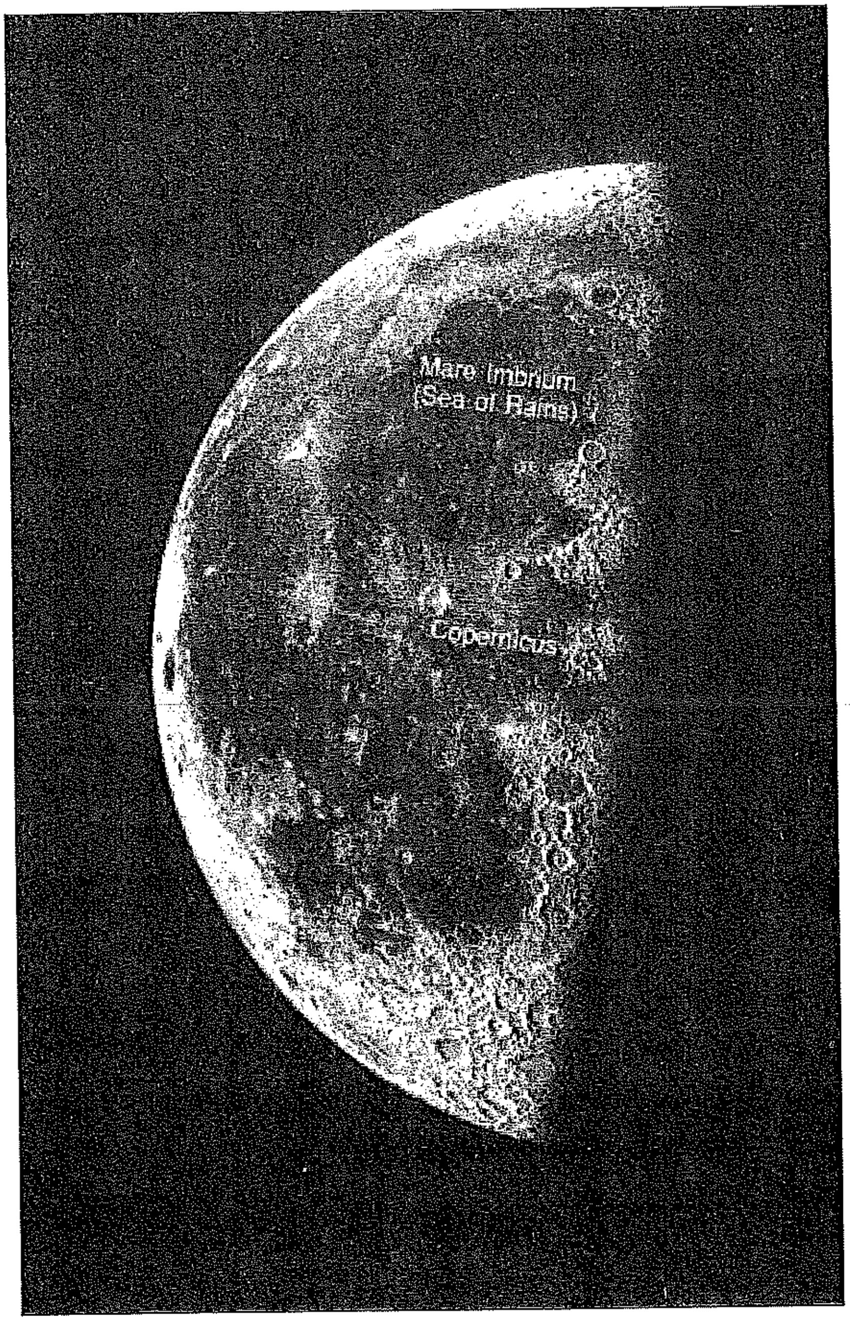

Figure B. Third-quarter Moon