



# Moon Anomalies

## Purpose

To investigate and try to explain various lunar anomalies.

## Background [also see “Teacher’s Guide” Pages 4, 10]

In this activity teams of students present hypotheses that attempt to resolve four anomalies of the Moon. They will be expected to prepare written and oral presentations for the entire class. Using a forum format, students will debate the merits of each hypothesis, with no right or wrong answers.

The four anomalies are:

“Quakes or No Quakes, that is the Question”

“Where Have All the Volcanoes Gone?”

“Maria, Maria, Where For Art Thou?”

“Magnetic Field Forever?”

Some of these anomalies are more complicated than others. The class need not discuss all the anomalies; the most straightforward are Quakes and Missing Volcanoes.

## Preparation

Review and prepare materials listed on the student sheets.

Schedule library time, if needed.

## Some possible solutions to the anomalies

### Quakes or No Quakes, that is the Question

The number and strength (magnitude) of **moonquakes** is much less than the number and magnitude of **earthquakes**. The probable cause of this difference is the Moon's smaller size and cooler interior. Earth is hot and active, manifested most dramatically in **plate tectonics**. Tectonic plate motions in Earth are driven by convection in the **mantle**—the solid mantle actually moves at rates of a few centimeters a year. The Moon’s mantle, too cool to move easily, has no convection and no active tectonic plate motions. Fewer movements inside the Moon mean fewer quakes. The few moonquakes that do occur are driven primarily by gravitational tugs by Earth and Sun (tides in the solid Moon).

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## Where Have All the Volcanoes Gone?

The Moon has lots of **lava** flows, but no (or at least few) **volcanoes**. The clue to solving this dilemma lies in understanding why volcanoes form on Earth, Mars, and Venus. In fact, those bodies also have large expanses of lava flows that are not associated with volcanoes. For example, vast deposits of lavas occur in Oregon, Washington, and Idaho. These are called the Columbia River Basalts. They **erupted** from long cracks called **fissures** and flowed across the surface. The path the magma took was far different from that in other places. The magma never concentrated to narrow conduits that were fed periodically over a long time to form a high mountain over the site.

The transport of magma for the Columbia River basalts was controlled by the stress environment of the region. Long fissures developed which provided the magma with pathways to the surface. On the Moon, plenty of fractures occur around the rings of the multi-ringed basins. These fractures undoubtedly extend far into the Moon, and may have provided easy access to the surface for magma, and at the same time did not allow the magma paths to concentrate in one small area. Result: no large volcanoes formed. The idea that some did form but were destroyed by impacts is always a possibility on the Moon, but lots of volcano-sized mountains on basin rings survived, so one would expect volcanoes to do so, too.

## Maria, Maria, Where For Art Thou?

Almost all of the lunar maria decorate the Earth-facing side of the Moon. Only a few add contrast to the **farside**. See the first two photographs in the “Teacher’s Guide” on Page 1. The most likely cause of this asymmetry is the variation in thickness of the Moon’s **crust**. The crust is lower in density than the mare-basalt magmas that must pass through it to erupt onto the surface. This, in turn, requires that the magmas have a sufficient driving pressure to migrate through the crust. Scientists think that magmas on the Moon tend to stall and collect at the base of the crust. They stay there until the pressure is enough to begin to form fissures for the magmas to travel through. On the nearside, the crust is about 70 kilometers thick. Many of the mare-basalt magmas were able to reach the surface once the pressure was large enough to form cracks. However, on the farside, the crust is twice as thick, so very few magmas could reach the surface. Most stalled on their way through it.

## Magnetic Field Forever?

The lunar **magnetic field** is one of the least understood properties about the Moon. It is about 10,000 times weaker than Earth’s magnetic field. The Moon had a weak field in the past, but none is being generated at the present time.

# Moon Anomalies

The most likely reason for the decline in field strength is that the Moon's tiny metallic **core** (no larger than 400 kilometers in radius) did generate a field the way Earth's core does, but the field-generating engine kept losing power. Earth's field is generated by convective motions inside the liquid portion of the core: hotter iron rises, cooler iron sinks, and the differential motions create a magnetic field. On the Moon, the whole body cooled much faster than Earth (because the Moon is smaller), so the core also cooled, and probably solidified. Motions fast enough to generate a magnetic field do not occur today inside the Moon's core.

## In Class

Divide the class into cooperative teams of 4-5 students. Encourage each team to generate a team name and logo. Give each team a "Task Sheet" describing their duties. Each team then develops a hypothesis that reconciles the dilemma given them. They must work together to produce a written report describing their anomaly, hypothesis, and supporting evidence. You may want to copy and distribute all the final reports so each team has a complete set.

When the teams make their oral presentations to the class they must use visual aid materials, such as maps, posters, charts, slides, laserdiscs, etc. After each presentation, other teams may challenge the presenters with questions or arguments.

## Wrap-up

After all teams have presented, lead a discussion to summarize what has been learned.

## Extension

You may wish to discuss another mysterious aspect of the Moon's magnetic field: the presence of several small areas (30-60 kilometers across) that have exceptionally large surface magnetism, about 10 times the normal Moon magnetic field. These are associated with bright swirly deposits. Possible origins include impact of a comet that is highly magnetized or magnetization of a comet during impact. In either case, the magnetism is transferred to the ejecta deposits at the site of impact. Another suggestion is that the field results from giant, basin-forming impacts. It turns out that most, but not all, magnetic swirl deposits are on the exact opposite side of the Moon from a large basin (i.e., antipodal to the site of impact). The idea is that seismic waves generated by the large impact interact vigorously when they meet half way around the Moon. Somehow these interactions reinforce existing magnetic fields to create the anomaly. The whitish swirls, by the way, may form because the solar wind (mostly hydrogen nuclei) is deflected by the strong magnetic field. Thus, no hydrogen gets implanted into the regolith, and subsequent micrometeorite bombardment does not cause formation of dark agglutinates. Instead of being dark glass, the agglutinates are colorless or nearly so.

Names: \_\_\_\_\_

Date: \_\_\_\_\_

## Moon Anomalies

### Task Sheet

Everyone on your team should be assigned one or more of the following tasks:

*Chief Strategist* : oversees the entire project, works closely with all members, makes critical decisions.

*Material Person* : collects, cares for, and returns all materials needed for the activity.

*Media Consultant* : oversees development of all the visual aid materials that your team will use during the presentation, such as maps, posters, models, etc. Also coordinates the use of slides, photographs, laserdisc, computer, etc.

*Administrator* : keeps notes, assists media consultant, and prepares final written report.

The oral presentation may be made by any one or all team members.



## Quakes or No Quakes, that is the Question

### Purpose

To investigate and try to explain why the Moon has fewer moonquakes than Earth has earthquakes.

### Key Words

earthquake

moonquake

### Materials

maps of the Moon

background information on  
the Moon

“Moon ABCs Fact Sheet”

“Task Sheet”

art supplies

### Background

The Moon is safer than San Francisco—at least from earthquake damage. Each year Earth has more than 10,000 earthquakes of magnitude 4 or greater. In contrast, the Moon has less than 500, and most of these are smaller than magnitude 2.5. The largest moonquake recorded during the eight years that the Apollo seismic instrument operated on the Moon was slightly less than magnitude 5. On Earth, the largest quakes reach magnitude 8, or even 9. Finally, the total amount of energy released by moonquakes is the same as released by three 100-watt light bulbs. Earthquakes release the equivalent of 300,000,000 100-watt light bulbs.

### Dilemma

Why does the Moon have fewer quakes than Earth? Is it because people live on Earth? Because the Moon is smaller? Because Earth has moving tectonic plates? Because the Moon has craters?

### Task

Develop an hypothesis that explains why the Moon has fewer quakes than Earth.



## Where Have All the Volcanoes Gone?

### Purpose

To investigate and try to explain the absence of volcanoes on the Moon.

### Key Words

volcano  
lava flows  
maria

### Materials

maps of the Moon  
background information  
on the Moon  
“Moon ABCs Fact Sheet”  
“Task Sheet”  
art supplies

### Background

The dark areas of the Moon’s surface, called the lunar maria, are composed of solidified lava flows. Scientists know this from photographs that show the margins of individual lava flows and from examination of rocks returned from the maria. The lava plains cover 16% of the lunar surface and are up to about 2 kilometers thick. This is a substantial amount of lava. Scientists estimate that a total of 10 million cubic kilometers of lava erupted during a period of about a billion years to fill the mare basins. This is a lot of lava! -- enough to fill 10 billion football stadiums! Most of the maria occur inside the huge circular impact craters called multi-ringed basins. The formation of these immense craters did not cause the formation of the lava that made the maria, but the basins did provide low areas into which the liquid lava flowed.

### Dilemma

Ten million cubic kilometers of lava flowed across the Moon’s surface, yet there are no obvious source volcanoes. There are no mountains that rise dramatically as they do in Hawai'i or the Cascades of the Pacific Northwest. If there are no volcanoes on the Moon, then what is the source of the lava? Were the volcanoes destroyed? Did the lava erupt in some other way? What other ways could lava erupt?

### Task

Develop an hypothesis that resolves the missing volcanoes dilemma, without rejecting the idea that the maria are composed of solidified lava flows.



## Maria, Maria, Where For Art Thou?

### Purpose

To investigate and try to explain why the farside has fewer maria than the nearside of the Moon.

### Key Words

maria

crust

lava flows

### Materials

maps of the Moon

background information on the Moon

“Moon ABCs Fact Sheet”

“Task Sheet”

art supplies

### Background

About 16% of the Earth-facing side of the Moon is covered with dark maria. But less than 1% of the farside is covered with maria. Scientists think that the magmas were formed inside the Moon by melting of the Moon’s mantle, and that these magmas then moved to the surface. They probably moved in long cracks. Good evidence suggests that the crust on the farside is about two times thicker than on the nearside.

### Dilemma

Assuming magma was generated throughout the Moon’s mantle, why are almost all the maria on the nearside of the Moon? Did they get covered up by other rocks on the farside? Did Earth’s gravity help them get out onto the nearside? Was it too hard to travel through the thick, farside crust?

### Task

Develop an hypothesis that resolves the maria-are-more-abundant-on-the-nearside dilemma.



## Magnetic Field Forever?

### Purpose

To investigate and try to explain why the Moon has a weaker magnetic field than does Earth.

### Key Words

magnetic field  
core

### Materials

background information  
on the Moon  
“Moon ABCs Fact Sheet”  
“Task Sheet”  
art supplies

### Background

The Moon has a much weaker magnetic field than does Earth. However, the field was stronger in the past, as shown by study of the magnetic properties of lunar rocks. Earth's magnetic field is formed by motions inside its iron core. The Moon also has a core, but it is much smaller than Earth's core. The Moon's core is no larger than 400 kilometers in radius, and may be as small as 100 kilometers. In contrast, Earth's core is 2900 kilometers in radius.

### Dilemma

The Moon had a stronger magnetic field in the past (billions of years ago), but it is weak now, much weaker than Earth's magnetic field. Why is it so much weaker than Earth's? Why was it stronger in the past?

### Task

Develop an hypothesis that explains why the Moon has a weaker magnetic field than does Earth, and why the Moon's field was stronger in the past.

# Moon ABCs Fact Sheet

Property	Earth	Moon	Brain Busters
Equatorial diameter	12,756 km	3,476 km	How long would it take to drive around the Moon's equator at 80 km per hour?
Surface area	510 million square km	37.8 million square km	The Moon's surface area is similar to that of one of Earth's continents. Which one?
Mass	$5.98 \times 10^{24}$ kg	$7.35 \times 10^{22}$ kg	What percentage of Earth's mass is the Moon's mass?
Volume	---	---	Can you calculate the volumes of Earth and the Moon?
Density	5.52 grams per cubic cm	3.34 grams per cubic cm	Check this by calculating the density from the mass and volume.
Surface gravity	9.8 m/sec/sec	1.63 m/sec/sec	What fraction of Earth's gravity is the Moon's gravity?
Crust	Silicate rocks. Continents dominated by granites. Ocean crust dominated by basalt.	Silicate rocks. Highlands dominated by feldspar-rich rocks and maria by basalt.	What portion of each body is crust?
Mantle	Silicate rocks dominated by minerals containing iron and magnesium.	Similar to Earth.	Collect some silicate rocks and determine the density. Is the density greater or lesser than the Earth/Moon's density? Why?

# Moon ABCs Fact Sheet

Property	Earth	Moon	Brain Busters
Core	Iron, nickel metal	Same, but core is much smaller	What portion of each body is core?
Sediment or Regolith	Silicon and oxygen bound in minerals that contain water, plus organic materials.	Silicon and oxygen bound in minerals, glass produced by meteorite impacts, small amounts of gases (e.g., hydrogen) implanted by the solar wind. No water or organic materials.	Do you think life ever existed on the Moon? Why or why not?
Atmosphere (main constituents)	78 % nitrogen, 21 % oxygen	Basically none. Some carbon gases (CO <sub>2</sub> , CO, and methane), but very little of them. Pressure is about one-trillionth of Earth's atmospheric pressure.	Could you breathe the lunar atmosphere?
Length of day (sidereal rotation period)	23.93 hours	27.3 Earth days	How long does daylight last on the Moon?
Surface temperature	Air temperature ranges from -88°C (winter in polar regions) to 58°C (summer in tropical regions).	Surface temperature ranges from -193°C (night in polar regions) to 111°C (day in equatorial regions).	Why are the temperatures of Earth and the Moon so different?
Surface features	25 % land (seven continents) with varied terrain of mountains, plains, river valleys. Ocean floor characterized by mountains, plains.	84 % heavily-cratered highlands. 16 % basalt-covered maria. Impact craters-- some with bright rays, crater chains, and rilles.	Compare maps of Earth and the Moon. Is there any evidence that plate tectonics operated on the Moon?