

## Lunar Features - Why Is The Moon Blotchy?

When you look up at a full Moon, at first glance you are met with a bright, white shining globe. But upon closer inspection, the lunar surface is not as uniform as it might at first seem. As the Moon waxes and wanes during its cycle, various features become more, or less, apparent. With the naked eye the most noticeable are the dark patches which litter the surface; some people see the “Man in the Moon”, some see a snowman, some even see a basketball player

(<http://www.universetoday.com/26683/the-basketball-player-in-the-moon-catch-it-tonight/>). With binoculars or a small telescope it is possible to see these darker patches even when the illuminated portion of the Moon is only a slim crescent, due to the phenomenon called Earthshine. (Earthshine is when the lunar surface which would usually be in shadow becomes illuminated by light reflected back from the surface of the Earth.) So what are these features and why are they darker than the rest of the lunar landscape?

*Dark patches on the lunar surface, visible by Earthshine. Photo by Mary Spicer*



First of all let's summarize how the Moon was formed. Using radiometric dating techniques it has been determined that the Moon formed approximately 3.5 billion years ago. There were several theories about how exactly it formed, but the most widely accepted theory today is that an object, roughly the size of Mars, collided with Earth. This jettisoned out a large quantity of material which coalesced to form a new rocky body; our very own satellite, the Moon. The Moon is approximately 3,500km in diameter, i.e., approximately a quarter of the size of Earth. As satellites go, it is the largest in our solar system, compared to its parent body. Because it is locked in a synchronous or captured rotation (which means its orbital period is identical to its rotational period) the Moon

always shows us the same face. This is referred to as the near-side. The side that we never see is commonly referred to as the “dark-side”, but this is incorrect; the correct name for it is the far-side. We had no idea what the lunar far-side looked like until the Soviet Lunar 3 Probe photographed it in 1959. Then in 1968, Apollo 8 beamed back live images as it orbited around the far-side. More recently the Lunar Reconnaissance Orbiter (LRO) has taken much more detailed pictures of the entire lunar surface.

## Comparison between the lunar near-side and far-side



“Supermoon” 24/06/13. Lunar near-side, showing numerous maria. Photo by Mary Spicer

Lunar far-side, showing numerous impact features and few maria. Photo by the Lunar Reconnaissance Orbiter (LRO). Source: Wikipedia

The far side looks very different than the nearside. This is primarily because the far side is lacking the many darker patches that we see on the nearside. These are called maria, singular mare; the Latin name for seas, and they cover approximately 16% of the lunar surface. Early astronomers erroneously took these dark patches to be oceans of water on the lunar surface. They are in fact solidified lava plains which are comprised of iron-rich basalt. The iron content makes this material far less reflective than the rocks which make up the surrounding lunar highlands, therefore they appear as the smooth, dark, patches we see. The other big difference between the maria and the rest of the lunar surface is the number of impact craters present. This gives us a clue about how the lunar surface evolved.

Soon after the Moon was formed, the solar system went through a period called the Late Heavy Bombardment Period. This was a torturous time for the inner planets. Mercury, Venus, Earth and Mars, and their corresponding moons, were subjected to repeated impacts by large numbers of asteroids, which resulted in hundreds of thousands of impact craters being formed. Today on the Moon alone there are in excess of 30,000 craters visible telescopically, and a good number more visible from probes or satellites in orbit around it. The heavily scarred far-side is how the near-side would have looked following the period of heavy bombardment. So what happened to change it? Some 500 million years after the late heavy bombardment period, the Moon went through a period of heavy volcanic activity. Lava was forced to the surface and the low lying areas became flooded,

filling in many of the impact features beneath, before solidifying into the basalt basins we see today. Evidence that the Maria formed much later than the rest of the lunar surface, comes from the relatively small number of craters found within the lava plains. If the maria had been present at the time the Moon first formed, they too would be littered with numerous craters just like the rest of the surface. Because the lava flooded a lot of the lower lying regions, most of the heavily cratered parts of the surface we see now are found in higher regions.

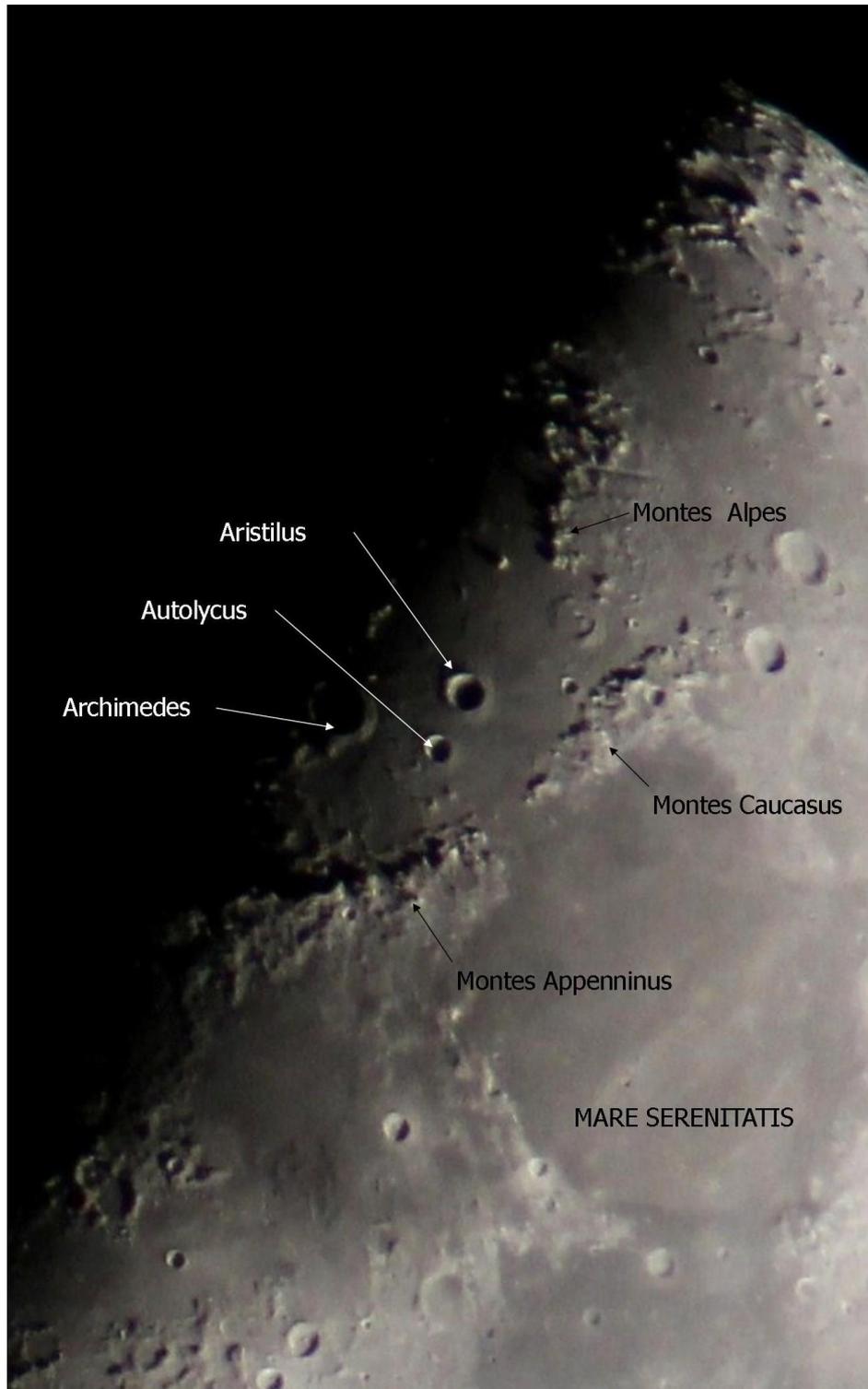
Differences between the Northern maria regions with relatively few impact features, and the heavily cratered higher regions in the South.  
Photos by Mary Spicer



As the Moon moves through its phases each month, different features become more easily visible. For example, the best time to view craters is when the Moon is around its first quarter or last quarter phase. At this time the numerous craters can be seen along the terminator (the line between the illuminated and non-illuminated portions of the Moon). Maria become more easily visible the more illuminated the surface of the Moon becomes, therefore are best viewed when the Moon is almost full. One thing which is apparent at any phase though, is that the higher a feature is geographically, the more brightly illuminated it is. By far the brightest features are the peaks of the many mountain ranges found on the Moon. Most of the mountain ranges are named after those found on Earth. The highest peaks reach a whopping 5km in height, which when measured as a proportion of the overall size of the Moon makes them comparatively higher than the highest mountains found on Earth. The peaks on the Moon are also numerous, for example, there are over 3,000 peaks found in the Appenine Mountains alone. The mountains are best viewed when they are close to the terminator so the best phase to view each mountain range will vary depending on their location. If you time it right, you not only see the brilliantly illuminated mountain peaks, but also the shadows they cast on the lower lying areas. For example, around the first quarter phase is a great

time to observe the peaks of The Alps, The Appenines and The Caucasus Mountains. The photo below shows the peaks and shadows seen during this phase.

*The Northern mountain ranges seen during the first quarter phase. Photo by Mary Spicer*



So why are the maria so numerous on the near-side and yet so few on the far side? This has been the subject of debate for many years. For a long time it was assumed that the crust on the near-side was thinner, therefore the lava chose those regions to break through and flood rather than the thicker crust on the far-side. However, it is now known that the crust beneath the very low lying South pole Aitken basin on the far side is much thinner than the crust beneath the largest maria region on the near-side, Oceanus Procellarum (The Sea of Storms). So the size of the crust is not the only factor responsible for the uneven distribution of the maria. It is now thought that KREEP is responsible for the differences in volcanic activity on the two sides. KREEP is an acronym, "K" for potassium, "REE" for rare Earth elements, "P" for phosphorous. It describes the geochemical component of a type of rock called breccia (a type of rock which is made up from broken mineral fragments) and basaltic rock. KREEP has a higher than normal concentration of elements which produce heat, namely radioactive uranium, thorium and potassium, and this heat would almost certainly affect volcanic activity. So where did KREEP come from? To understand this, we need to go back to the beginning, and the giant impact which initially formed the Moon.

The collision was a huge one, and due to the energy involved, a large proportion of the material which was jettisoned out would have been liquefied. This formed a lunar magma ocean. As this magma began to crystallize, some minerals, such as olivine and pyroxene would have sunk to the bottom to form the lunar mantle. As the solidification was approximately three quarters complete, the relatively low density material called anorthositic plagioclase (a mineral which is abundant in the Earth's crust) would have floated to the top and formed a solid crust. This left liquid magma sandwiched in between the 2 layers. Because of the process involved in its formation, this liquid layer was rich in elements which would under normal circumstances be incompatible together, hence the formation of KREEP-rich magma. The Lunar Prospector Satellite showed that KREEP-rich rocks were concentrated beneath the vast area of Oceanus Procellarum and the Imbrium basin. This area is collectively called the Procellarum KREEP Terraine. The concentration of KREEP beneath this area is almost certainly responsible for the longevity of the volcanic activity within the near-side regions. The exact mechanisms behind why KREEP would be concentrated in those regions and not others are still unknown.

So next time you hear stories about the Man in the Moon, think of the excitement of the real story behind those lunar maria!