On the origin of lunar maria

Ronald G. Samec

Classical Newtonian orbital mechanics was used to explore the possibility that near side lunar maria are giant impact basins which originated from a catastrophic impact event that caused the present orbital configuration of the moon. The results show that a collision of an asteroid swarm equivalent to a single ~70-km-diameter rocky asteroid moving at parabolic velocity was sufficient to cause the present radial oscillations orbit of the moon as well as the near-side maria, assuming that the orbit was originally near-circular.[1]

Lunar maria are (Latin 'seas') believed to be basaltic flood plains resulting from lava flows filling giant (140 to ~2500 km) crater-like basins. They are thought to result from asteroids striking the surface of the moon and subsequent volcanism.[2] Some 31% of the near side surface area of the moon is taken up by maria, while only 2.5% of the far side surface is covered by maria.[3] Twenty-three of these objects litter the near side. See the accompanying figure 1.

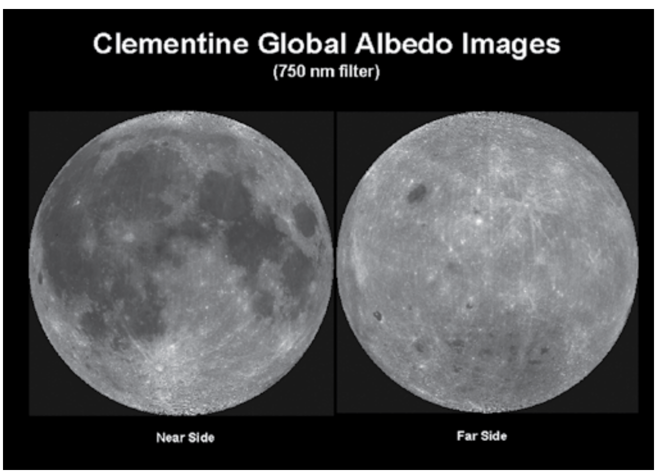


Figure 1. The near and far side of the moon. Clementine Space Craft, JPL.

There are two notable features on the far side of the moon, Mare Orientale and the Aitkin Basin. Orientale has a distinctive bull's eye appearance, which lends strong evidence to its asteroid origin. Its inner ring is 300 km in diameter while its outer ring is 900 km in diameter. The largest maria are Oceanus Procellarum on the near side, and another feature which is mare-like is the Aitken Basin, which is near the South Pole on the far side. Both are larger than 2000 km in diameter. I call the Aitken feature a 'basin' because it is not a mare in the classic sense. It consists of an indentation with some scattered smaller areas of crystallized lava flows. It is believed to be due to an oblique impactor and has a strange ragged shape. I conclude from the distribution of true maria, except for the one and possibly two notable exceptions on the far side, that asteroids hit preferentially on one side of the moon—the side facing Earth. I explore here the idea that this was due to a catastrophic impact by a single asteroid swarm that struck not only the moon, but also Earth. The massive bombardment on the near side of the moon attests to such an event. The far side maria may be due to scattered debris from this event or could have resulted from subsequent and isolated collisions.

Evidence for meteor/asteroid collisions on the moon

In this article, I will assume that craters and maria are products of collisions of meteors and asteroids. What is the evidence for this? Mare Orientale provides strong proof. It shows circular blast shock waves emanating from the point of penetration of the asteroid, producing circular 'rings' frozen forever in time when the viscous molten rock hardened in the middle of its action. See figure 2. This 'rippling' action may be seen when a pebble is dropped into a quiet pool of water (figure 3). Surrounding craters is a crater wall and debris scattered beyond it in all directions, called the ejecta blanket. It has been found that the mass removed from the 'bowl' of the crater is equal to the mass of the ejecta blanket plus the wall. This shows that the mass was blown out by a meteor impact and redeposited nearby. In the centre of the water ripples that result from dropping a pebble in water is a recoil that resembles the central peaks in many craters. Thus, the molten rock recoiled in reaction to the meteor strike and hardened in this state. Recoiling central peaks tell us that the surface became molten *simultaneously* with the meteor or asteroid strike. The terraced walls seen in craters like Copernicus also testify to ripples produced by blast shock waves created by collisions. I also note that craters and maria are circular to elliptical in shape due to meteors

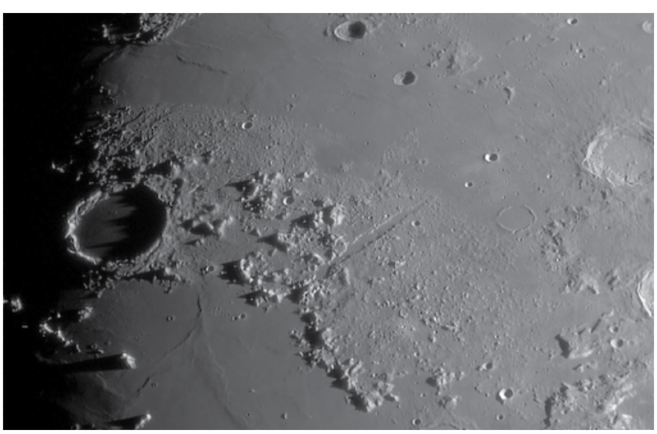
Figure 2. 1967 photograph of the Mare Orientale region made by NASA's Lunar Orbiter 4. Mare Orientale is on the far side of moon and is 1,000 km in its outer diameter.

Photograph from <www.sxc.hu>

Figure 3. Ripples in a water tank from a pebble being dropped into the water show the same effects as seen in lunar maria and craters.

Photograph from E. Roach, 31 October 2007.

Figure 4. Multiple impact site near Crater Stöfler, including Maurolycus and Heraclitus.



Photograph from Tom Bash.

Figure 5. Small secondary craters in the area of Plato.

coming in at various altitudes. In addition, craters such as Stofler reveal areas of multiple impacts as meteors broke up and created craters upon craters upon craters. See figure 4. In some cases, strings of small craters associated with larger ones reveal that secondary craters were created when the material rebounded after the strike. Many craterlets are seen about the area of Plato in figure 5. All of these attest to the fact that the bulk craters on the moon arise from meteor collisions. I note that although this brief section does address larger craters on the lunar surface and their origin, the main thrust of this paper is the origin of the maria on the lunar surface. These are described in detail in this paper and are believed to be due to large asteroids striking the surface of the moon followed by a period of volcanism.

Uniformitarian formation of the moon

The usual uniformitarian history of the moon is recounted in any modern day astronomy text.[4] The moon's formation is believed to be caused by a one to two Mars-mass planet striking Earth with a glancing collision. The scattered crustal debris from this event collected following the collision to produce the present moon about 4.6 billion years (Ga) ago. This was followed by a period intense bombardment creating the lunar highlands. Large asteroids supposedly struck the moon between 4.0 and 4.4 Ga, gouging out the mare basins. Within the next Ga or so, magma surfaced through cracks and fissures from hundreds of km deep, filling the basins and thus hardening to form maria. Isotopic results give dates of about 3.5 Ga (3.1–3.8 Ga) for the crystallization of the maria. This period was followed by a period of very light bombardment which includes the present.

Ghost craters

So called 'ghost craters' are circular ridges that occur in lunar maria. They are evidently the tops of the walls of craters that have been buried in the molten flows that filled the maria. Some are indicated in the image in the region of crater Mare Nubium in figure 6. Also present in these regions are sharply defined craters formed from meteors which struck the maria after the lava was sufficiently hardened. All this happened—the major asteroid bombardment creating the mare basins, the mare flows, their crystallization, followed by smaller asteroid hits—in the course of supposedly ~1.5 Ga. To the creationist, the *time factor* is the first question I address here. (Later, I will question the uniformitarian formation model).[5] When an

Photograph from Peter van de Haar.

Figure 6. Ghost craters near mare Nubium in the region of the Straight Wall.

asteroid strikes, large enough to blast the surface by gouging out huge basins many hundreds of km across, how long would it take for the pulverized rock to liquefy? How long would it take for the underlying compressed crust to release lava flows? Hours, days, maybe at the outside, a few years, certainly not upwards to a billion years! The heat released would initially liquefy much of the rock and then magma would swiftly leach its way to the surface through the weakened crust and the fissures (cracks) that were created. Ghost craters tell us that many meteors struck the moon shortly after the asteroids struck. And the craters soon were inundated by lava flows. During the subsequent centuries or millennia, rather than billions of years, other asteroids struck the mare surfaces making the fresh appearing craters seen in the mare surfaces presently. Smaller renditions of maria are seen in large normal craters such as Clavius. These craters are partially filled with crystallized magma and all the other features mentioned indicate the same mechanism on a smaller scale. From space craft orbiting the moon, it has been found the center of mass of the moon is shifted toward the Earth.

Uniformitarian explanations of mare distribution

From space craft orbiting the moon, it has been found that the centre of mass of the moon is displaced toward Earth. A uniformitarian explanation of mare distribution states that lunar core, aesthenosphere and the mantle is off-centre whereas the crust is not—so the crust is thicker on the far side. See figure 7. Thus the basalt would reach the surface more easily on the near side due to thinner crust (to 60 km near side, 100 km far) than on the far side. So there would be fewer maria on the far side, as we observe. However, Maria Zuber of MIT[6] states, 'That doesn't explain the whole story, because some of the *thinnest* crust on the moon is on the *far side*'. Dr Zuber used Clementine data to map lunar crust thickness. She finds that near the South Pole, the Aitken Basin on the far side has regions of *extremely thin crust*, just the opposite of the preceding notion. With thinner crust you would expect it to have more mare flows than the near side. But, again, we observe the opposite—it actually *lacks vast basaltic mare flows* as areas of thicker crust on the near side. Thus, the thin crust idea fails to solve the problem of the asymmetric distribution of maria for the uniformitarian. Also, how long did it take for the moon's rotation and orbit to become gravitationally locked and how many billions of years would it take for the subsequent shifting of the moon's centre of mass? Gravitational locking, alone, is believed to take billions of years! In the uniformitarian model, the lunar crust would not be expected to be thin on one side and thick on the other in the early heavy bombardment years of the moon's history. So this mechanism does not solve the uniformitarian's problem. Yet another theory is that there are more radioactive materials in the interior on the near side. This explanation would be strange indeed. The supposed collision that formed the moon would have most likely resulted in a homogeneous mixing of all materials.

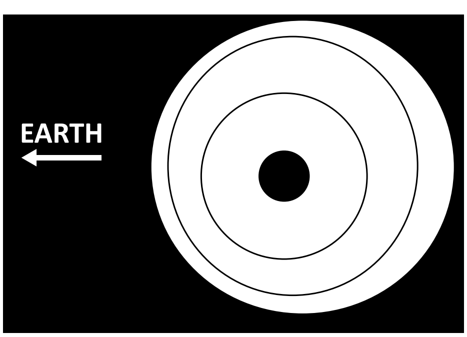


Figure 7. The moon's centre of mass is not its geometric centre.

Moon rocks

Highland rocks are largely anothosite of isotopic 'ages' from 4 to 4.3 Ga. They are not quite as old as oldest rocks known. In a creationary context and assuming the RATE hypothesis,[7] if accelerated decay began on Day 3 (at the formation of the dry land), the moon was not created till Day 4, the isotopic 'ages' would show that its 'oldest' rocks underwent less decay than Earth rocks. As far as lunar maria basalts, whose isotopic ages are 3.1–3.8 Ga, I suggest in this article that they may arise from collateral materials from asteroids that also blasted Earth. Accelerated decay is indicated by their isotopic ages. Mixing of young materials from the asteroids with old lunar materials is also possible. Mixing can produce an apparent isochron (radioisotopic age) that has a lower average aggregate age of the original material.

The time frame of the collision event

However, the problem still stands. Why is the near side of the moon populated with scars of an asteroid bombardment while the far side is not? *Why would asteroids preferentially strike one side of the moon over the course of a half a billion years?* Rather, it is more likely that we are observing the aftermath of a single event, a single swarm or a single large asteroid or planetoid that broke up (possibly due to tidal forces as it approached Earth) and pieces of it stuck the moon in one episode. Since the period of the moon's sidereal rotation is 27.3 days and the maria cover only about a 45% spread across the lunar surface (see figure 8), the maximum time interval for this event would be about 12 days. I prefer a much shorter time frame. Thus, the entire formation of the mare basins could have occurred over a span of a few days.

An interesting image of the moon was obtained from the Clementine mission (figure 9). It shows that the heaviest mineral iron concentrations match the *maria on the near side*. Since meteorites are known to be largely iron (the average is 22%),[8] and since I assume that the asteroid was similar to a stony meteor in composition which would have somewhat less iron content (14% is the maximum concentration in the maria), is it possible that the object or swarm of objects struck the moon, liquefied and partially filled the newly made mare basins, all in one event? Paint

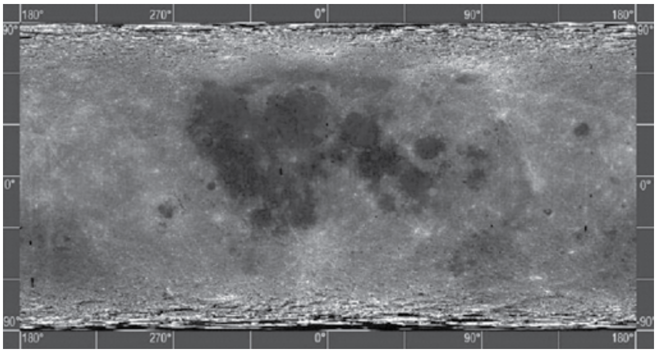


Figure 8. Full surface map of moon. Clementine Space Craft, JPL.

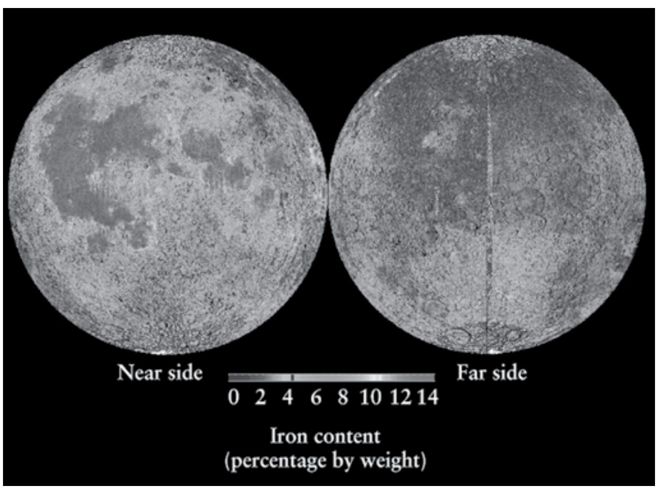


Figure 9. The position of the maximum iron concentrations match the maria on the near side. Since meteorites are known to be largely iron, this supports the idea that the maria were caused by asteroid collisions. Clementine Space Craft, JPL.

ball marks would be a good analogy—the moon's maria are marked by molten iron from asteroid hits as a paint ball player is marked by the hits of the paint balls.

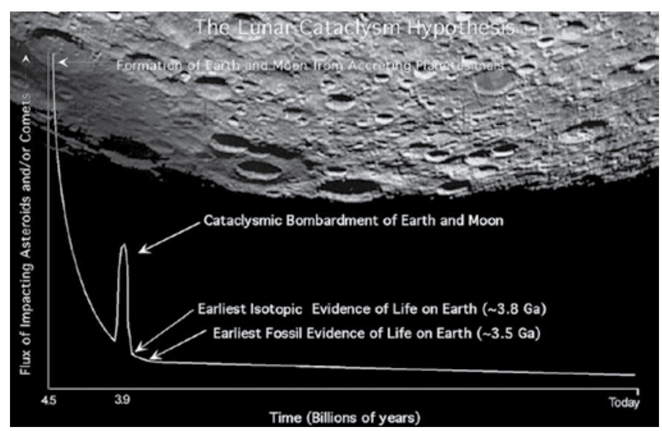
On the other hand, if I assume this iron came from subsequent volcanism, as many believe, the question is 'Where does this iron come from?' The iron should have differentiated following the creation of the moon and sunk to tiny, deep core of the moon. The distance to the core is prohibitive for its delivery via volcanism to the surface.

The lunar cataclysm hypothesis

A similar, albeit old-age, hypothesis, comparable to mine is the *cataclysm hypothesis*:[9]

> 'Analyses of lunar samples collected by Apollo astronauts revealed a surprising feature: the crust of the Moon seems to have been severely heated ~3.9 billion years ago, metamorphosing the rocks in it. Scientists (Tera *et al*., 1974) [[10]] suggested this metamorphic event may have been created by a large number of asteroid and/or cometary collisions in a brief pulse of time, <200 million years, in what was called the lunar cataclysm.
>
> 'If a lunar cataclysm really occurred, then lots of impact melted rocks with that same age should also exist. And, indeed, additional analyses of impact melts collected by Apollo astronauts revealed a range of impact ages, but, significantly, none older than 3.85 Ga (Dalrymple and Ryder, 1993; 1996). This also seemed to imply a lunar cataclysm ~3.9 Ga, which completely destroyed or metamorphosed impact melts produced by older impact.'

This cataclysm was believed to have produced a massive bombardment of Earth's surface. Recent samples, beginning 1981, have been found on Earth, which are very similar to the Apollo rocks. These are believed to be debris from meteorites that were delivered to Earth from impact events on the moon. The ages revealed that none were older than 3.85 Ga.[11,12] This also seemed to imply a lunar cataclysm occuring at ~3.9 Ga, which completely destroyed or metamorphosed impact melts produced by older impact events. While I do not accept these absolute ages, I do believe that these rocks are associated with their lunar counterparts and may arise from the same event. This seems to lend credibility to the claims of this article. See figure 10.



Photograph from Jake Bailey and David A. Kring, Space Imagery Center.

Figure 10. Lunar Cataclysm Theory. Large crater features up to 1000 km in diameter apparently result from the cataclysm that covered a brief interval of Geologic time.

The moon's orbit

The moon is characterized as having a low eccentricity, $e = 0.05490$, elliptical orbit. Its orbit can well be represented as a circular orbit undergoing radial oscillations. Such a configuration can result from what is known as a small oscillation Newtonian orbit that is caused by a circular orbit that underwent a sudden perturbation such as an asteroid strike. This type of orbit is of interest here since the period of radial oscillation, the 'ringing' component possibly caused by the collision, has the same angular frequency as the periodic revolution of the angular component. The two motions, radial and angular combined, result in an orbit that appears to be an off-centre, circular orbit. Such an orbit is essentially identical to the present low eccentricity orbit. Is the perturbation that caused this 'ringing' in the moon's orbit an asteroid collision? Is the moon's orbit a major clue from our creator that such an event actually took place? Could a swarm of asteroids have struck Earth in the past with the moon suffering impacts as 'collateral damage' (see figure 11)?

Figure 11. The moon was collateral damage.

Existence of swarms of asteroids in elliptical orbits

It is clear that the existence of such orbital streams of asteroids have *no present day counterpart*. Belts of such debris do exist following the orbits of present and former comets but they contain only micron-sized dust and ice particles which result in meteor showers when Earth passes through them. Asteroids and Kuiper Belt Objects (except for isolated scattered KBOs) usually follow fairly low eccentricity, low inclination orbits. But, the multitudes of crater features on the solid surfaces of rocky and icy 'worlds' in the solar system (planets, moons, dwarf planets, asteroids and comet cores)[13,14] attests to the possible former existence of asteroids in highly elliptical orbits.

The theory of small oscillations orbits

Let us review the Newtonian mechanics theory of small oscillation orbits.[15] The force due to gravity is a conservative one and a central force which we represent by *F(r)*, so we may write,

$$\vec{F}(r) = -\vec{\nabla} V$$
$$\vec{\nabla} \times \vec{F} = 0$$
$$V = -\int \vec{F}(r) \bullet d\vec{r}$$

where V is the gravitational potential. Since, the torque, N, is zero,

$$\vec{N} = \vec{r} \times F(r)\hat{r} = \frac{d\vec{L}}{dt} = 0$$

where L is the orbital angular momentum, the orbit of a two body system is confined to a plane, where r and θ are the plane polar coordinates:

$$L = mr^2\dot{\theta} = \text{constant} \tag{1}$$

The radial acceleration in the plane is,

$$\vec{a} = (\ddot{r} - r\dot{\theta}^2)\hat{r} \tag{2}$$

From (1) and (2) we write:

$$F(r) = m\ddot{r} - \frac{L^2}{mr^3}$$

The effective potential,

$$V_{eff} = -\int (F(r) - \frac{L^2}{mr^3})dr$$
$$V_{eff} = V(r) + \frac{L^2}{2mr^2}.$$

For gravitation,

$$V = -\frac{K}{r},\ K = GMm$$
$$V_{eff} = \frac{-K}{r} + \frac{L^2}{2mr^2},$$

where m is the mass of the moon, 7.353×10^{22} kg and M is Earth's mass, 81.301 m.

Minimizing this potential, and solving for r_0, the radius of minimum energy, a circular orbit results (for this, at $r = r_0$, $d^2V_{eff} / dr^2 > 0$). The frequency of radial oscillations is

$$\omega_r = \sqrt{\frac{\frac{d^2V_{eff}}{dr^2}\Big|_{r=r_0}}{m}} = \sqrt{\frac{K}{mr_0^3}}.$$

From the angular momentum for a circular orbit we obtain the period angular motion,

$$\omega_\theta = \sqrt{\frac{K}{mr_0^3}}.$$

Since $\omega_\theta = \omega_r$, the period of radial oscillations is the same as the period of the angular motion. Thus, the motion is that of an off-centre circle. Figures 12 and 13 show the orbit and the two potentials, that of a small radial oscillation and that of a gravitational, $-K/r$ potential. Note that the first is a parabola, while the standard potential is more complicated. However, for small energies, they both match.

A well known and easily derived relation between energy and eccentricity is:

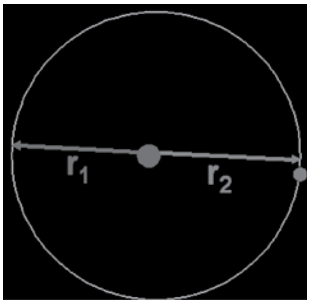


Figure 12. The lunar orbit is an off-centre circle with a maximum and a minimum radius.

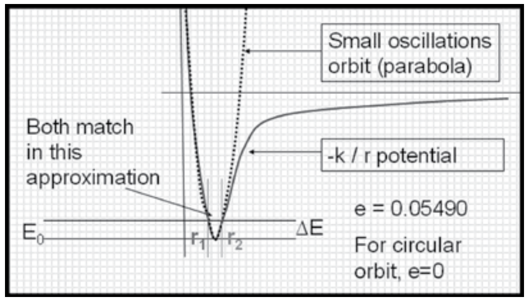


Figure 13. The potentials of a small radial oscillation and that of a gravitational, $-K/r$ potential. The first is a parabola, while the standard potential is very different. For small energies, however, they both match.

$$E = \frac{mK^2}{2L^2}(e^2 - 1) = \frac{GMm}{2r_0}(e^2 - 1),$$

where r_0 = 384,401,000 m. Calculating E for e = 0.05490 and for e = 0 and subtracting the two, we obtain the energy above the ground state for the present lunar orbit, ΔE = 1.14943 × 10^{26} J.

The parabolic velocity, v_e, for our asteroid in the vicinity of Earth's orbit is 42,000 m/s. From ½ $m_a v_e^2 = \Delta E$, we obtain a combined asteroid mass, m_a = 1.3 × 10^{17} kg. We assumed an asteroid density of 3.0 g/cm^3 (rocky asteroids). The lunar density is 3.341 g/cm^3. From this we obtain an asteroid diameter of ~44 km if *all* the impactor kinetic energy goes into orbital energy. Further, if we divide the asteroid it up into 23 fragments (the number of nearside maria: see the next section for a thorough discussion), the average size would be ~15 km. This is a major asteroid in its own right. Such an asteroid would produce a 550 km diameter mare, which is well within the normal range of average sizes of maria (140 to ~2500 km). It is of interest that this result immediately fits into the realm of possibility. A better agreement arises when we consider that much of the expended work goes into 'internal energy' to create a crater and possibly induce a lava flow or melt. The remaining energy would become orbital energy. Here we introduce a coefficient of restitution, η,[16] to evoke an inefficient energy transfer. Using η = 0.5 (~75% of the energy loss as compared to that of a totally inelastic case), we obtain an asteroid radius of ~70 km. Coefficients of restitution of ~0.5 are regularly and arbitrarily used for asteroid collisions, so we chose that value.[17]

The hypothesized asteroids

If we break up the 70 km object into 23 equally sized fragments, we find that the diameter of each asteroid would be about 24.5 km. Such fragments striking the moon at parabolic velocity would each produce 23 basins of about 850 km in diameter and 9.8 km deep (to partially fill with lava). This nearly duplicates the average mare size. The r.m.s. (root mean square) mare radii on the near side is ~810 km.[18] Actually, the 70 km asteroid would be broken up into chunks of particular sizes to explain the actual distribution of near moon maria. However, I choose to work with the r.m.s. average in this article instead of a distribution. In addition, I have chosen η to produce a near match to the actual mean of the radii of lunar maria. But I feel that an asteroid collision is a very inefficient means of transferring orbital energy. I believe our calculation is quite reasonable. A coefficient of restitution would allow for 'rebound' and therefore the production of mare 'walls'. These walls are termed 'mountain ranges' on the moon that encircle maria to several km in height. The rest of the internal energy would go into producing ejecta and secondary craters as well as heat and mechanical vibrations. Figure 14 shows the action of a large asteroid striking the moon.

Why would the moon be created with a circular orbit?

In our calculation, we assume that the moon started with a circular orbit. One may ask, 'Why would the moon be created with a circular orbit?' There are design aspects for this. Such an orbit would stabilize Earth against planetary perturbations. It is also the lowest energy, most energy efficient orbit and the orbit of highest stability. Also, it makes the moon's orbit similar to other satellites close to their parent body in solar system with gravitationally locked orbits, like the four Galilean moons of Jupiter. (Of course I do not believe the moons orbit just results naturalistically from proximity effects (body tides) combined with long age, since I believe that the solar system is young and little tidal evolution has taken place.) Scripturally, the process of 'setting' (Genesis 1:17) the sun and moon in place could refer to a created constant radius orbit (e = 0) for Earth and the moon. Both still have low, but nonzero eccentricity orbits. (The placement of the moon gyrostabilizes the Earth, thus preventing it from undergoing major changes in its spin axis. This aids in maintaining Earth's seasons.)

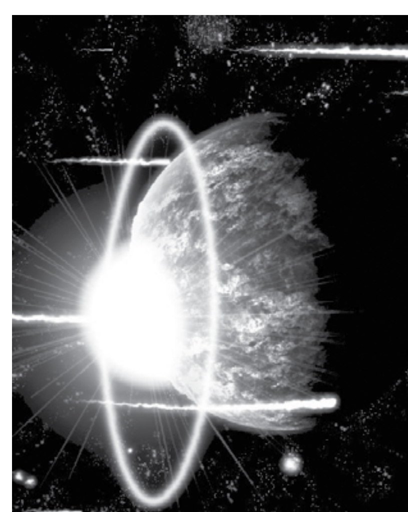


Figure 14. Blast wave created by asteroid collision.

Earth

It is also of interest here that Earth has a small eccentricity orbit, $e = 0.016710219$, actually less than that of the moon. However, things are not as clear as for the moon. The moon has no atmosphere or oceans to erode away craters. And the moon is close enough to Earth to maintain an orbit that is gravitationally locked. The situation for Earth's orbit about the sun is quite different. There is a relatively large distance between the sun and Earth and no gravitational locking or resonance effects are expected. We find no reasons for assuming that the original orbit of Earth was exactly circular except for the present very small eccentricity.

Another concern has to do with the existence of terrestrial craters and their asymmetrical distribution. Astrons and astroblemes are roughly circular blemishes on Earth's surface. These are believed to be due to major asteroid collisions. Astrons are larger (>150 km) and are analogous to maria on the moon's surface. Astroblemes are smaller and usually more established as true terrestrial asteroid craters. About 150 astroblemes[19] have been identified on Earth's surface and a dozen or more astrons are apparent. Notable craters[20] include those in the North Sea (Silverpit crater, 600 × 400 km),[21] Sudbury, Ontario (200 km diameter), Chicxulub, Mexico (170 km), Acraman, Australia (160 km), Vredefort, South Africa (140 km) and Chesapeake Bay (90 km). Major astrons[22] include the West African circular bulge, China coast, Himalayas, Gulf of Mexico, Aleutian Archipelago and the Great Australian Bight. The origin of such 'scars' on Earth's surface are a subject of conjecture. This study is clouded by erosional effects of the Flood and subsequent weathering.

The distribution of astroblemes and astrons appear to be somewhat random with widely separated apparent concentrations in Northern Europe, Middle North America and Central Australia. I suspect the oceans also received many impacts. So there is no definite 'strike zone' as the near face of the Moon. If a CPT (catastrophic plate tectonic) event took place, we would expect that some of the scars from an asteroid barrage would have been effectively erased and altered. Using the same size and cross sectional number density of meteors as those that struck the moon's near side and Earth's cross sectional area, we obtain about 310 collisions, each creating 740-km-diameter craters. Each would produce an explosive energy of 5.4×10^9 megatons of explosive power, or a total of 7.7×10^{11} megatons. (These effects could have been weaker if the centre of the stream targeted a region well displaced from Earth as suggested by the centre of the large maria on the near side of the moon (see figure 15).) I reiterate: the situation surrounding apparent crater remnants on Earth is less clear than for the moon with many complicating factors such as catastrophic plate tectonics (CPT), volcanism, earthquakes, weathering and erosion acting.

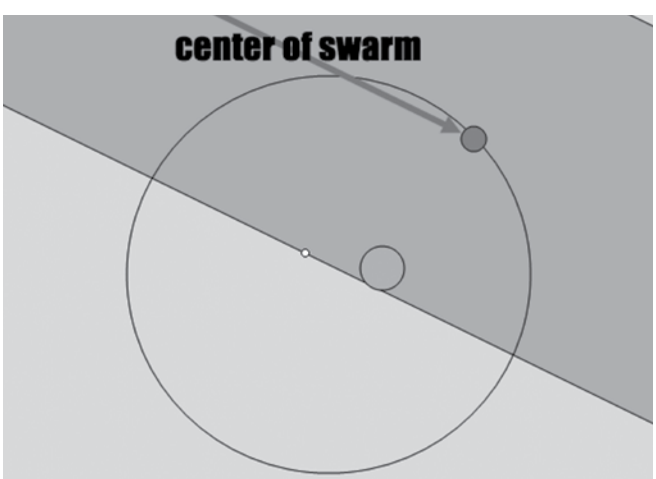


Figure 15. A collision by an asteroid stream targeted near the centre of the main large mare strike zone (near Aristarchus, located at 23.7° N, 47.4° W) would mean an oblique strike with the moon in a waning gibbous position. Thus the moon would have taken a greater density of the destruction than Earth.

Discussion and conclusion

In this exploratory paper, I applied ordinary Newtonian orbital mechanics to test the possibility that near side lunar maria are left over scars from a catastrophic impact by a swarm of asteroids. I note the impact energies that caused the asymmetric distribution of maria as well as the orbital perturbation of the moon point to the conclusion that they resulted from same event. This cataclysmic event could have resulted from a swarm that struck both the moon and Earth. Since the moon is airless, the lack of erosion has allowed the scars to remain while catastrophic plate tectonics and erosional effects acting on Earth have erased many of the terrestrial effects. But scars from these events may still remain as astroblemes and astrons, attesting to this event.

Such an asteroid bombardment of Earth could very well be the trigger that cracked the ocean floor adjacent to the super continent setting the CPT event in motion.[23,24] So the asteroid bombardment provides a 'trigger', so to speak, needed to begin the Noahic Flood. It also provides a justification, a reason for the bombardment—it is a precursor to the Flood judgment. I reiterate: *we may well be discussing the mechanism that God used to initiate the Noahic Flood*. God created the object or swarm of objects that would strike Earth (the Moon shows collateral damage) to judge mankind for his gross sin and willful disobedience. In this scenario, there was a definite, supernatural cause to the hypothesized event, if indeed, the event took place. And, *the permanent disfigurement of the moon may represent a clue from the Creator that we can not readily dismiss*.

Regardless of whether the reader accepts this interpretation or not, the results of our analysis are quite reasonable. I conclude that there is evidence from the moon's orbital perturbation and its corresponding bombardment was a result of a cataclysmic asteroid strike, and I believe that this analysis should be taken as a serious possibility. I believe a detailed hydrodynamic computational simulation is warranted. Indeed, an asteroid bombardment could be the cause of the observed mare distribution on near side of the moon and may well be the trigger that initiated the Flood event!

References

1. This is an extended and corrected update of Samec, R.G., Is the moon's orbit 'ringing' from an asteroid collision event which triggered the Flood; in: Snelling, A.A. (Ed.), *Proceedings of the Sixth International Conference on Creationism*, Creation Science Fellowship, Pittsburgh, PA, pp. 255–261, 2008.
2. Melosh, H.J., *Impact Cratering. A Geologic Process*, Oxford Monographs on Geology and Geophysics no. 11 New York, Oxford, Oxford University Press, 254 pp., 1996. First paperback edition; first published 1989.
3. Gillis, J.J. and Spudis, P.D., The composition and geologic setting of lunar far side maria, *Lunar and Planetary Science* **27**:413–404, 1996.
4. For example, Freedman, R.A. and Kaufmann III, W.J., *Universe*, 8th ed., W.H. Freeman, New York, NY, 2007.
5. Henry, J.F., The Moon's recession and age, *Journal of Creation* **20**(2):65–70, 2006.
6. Monastersky, R., Science News, 18 Nov. 1995.
7. Vardiman, L., Snelling, A. and Chaffin, E. (Eds.), *Radioisotopes and the Age of the Earth*, Vol. II, ICR, El Cajon, CA and CRS, Chino Valley, AZ, 2005.
8. Abundance in meteorites of the elements, <periodictable.com/Properties/A/MeteoriteAbundance.html>, accessed 18 September 2008.
9. Kring, D., The lunar cataclysm hypothesis, Space Imagery Center, <www.lpl.arizona.edu/SIC/impact_cratering/lunar_cataclysm/Lunar_Cataclysm_Page>, accessed 19 September 2008.
10. Tera, F., Papanastassiou, D.A. and Wasserburg, G.J., Isotopic evidence for a terminal lunar cataclysm, *Earth and Planetary Science Letters* **22**:1, 1974.
11. Dalrymple, G.B. and Ryder, G., The U–Th–Pb, Sm–Nd, and Ar–Ar isotopic systematics of lunar meteorite Yamato-793169, *Journal of Geophysical Research* **98**(E7):13085–13095, 1993.
12. Dalrymple, G.B. and Ryder, G., ^{40}Ar/^{39}Ar laser step heating ages of some Apollo 17 melt rocks and the age of the Serenitatis impact, *Lunar and Planetary Science* **27**:285–286, 1996.
13. Faulkner, D., A biblically-based cratering theory, *Journal of Creation* (*TJ*) **13**(1):100–104, 1999.
14. Spencer, W.R., The origin and history of the solar system; in: Walsh, R.E. (Ed.), *Proceedings of the Third International Conference on Creationism*, Creation Science Fellowship, Pittsburgh, PA, pp. 513–523, 1994.
15. Symon, K.R., *Mechanics*, 3rd ed., Addison-Wesley, Reading, MA, pp. 111–136, 1971.
16. For those not familiar with the coefficient of restitution, η, I define it here. In a collision, the relation between initial and final velocities of the two bodies is given by 'Newtons' equation', $(v_{2f} - v_{1f}) = -\eta\ (v_{2i} - v_{1i})$, where $\eta = 1$, for an elastic collision (conservation of energy), $\eta = 0$ for a totally inelastic collision and $0<\eta<1$ for an inelastic collision.
17. Michel, P., Modelling collisions between asteroids: from laboratory experiments to numerical simulations, *Lect. Notes Phys.* **682**:117–143, 2006.
18. All data about lunar maria is from the USGS Lunar Nomenclature Database, <arizona.usgs.gov/Flagstaff/>. I used the ES2506 Impact Calculator at <www.classzone.com/books/earth_science/terc/content/investigations/es2506/es2506page08.cfm> to calculate the impacts.
19. Pilkington, M. and Grieve, R.A.F., The geophysical signature of terrestrial impact craters, *Reviews of Geophysics* **30**:161–181, 1992.
20. Kring, D.A. and Bailey, J., Web Page of the Department of Planetary Science Lunar and Planetary Laboratory, The University of Arizona; Impact Craters, and their environmental effects, <www.lpl.arizona.edu/SIC/impact_cratering/World_Craters_Web/intromap.html>, accessed 18 September 2008.
21. Chatterjee, S., Guven, N., Yoshinobu, A. and Donofrio, R., *The Shiva Crater: Implications For Deccan Volcanism, India-Seychelles Rifting, Dinosaur Extinction, and Petroleum Entrapment at the KT boundary*, Seattle annual meeting (November 2–5, 2003), GSA, 2003.
22. Norman, J., Price, N. and Muo, C.-I., Astrons—the Earth's oldest scars, *New Scientist* **73**:689–692, 1977.
23. Snelling, A., A catastrophic breakup, *Answers* **2**(2):45–47, April–June 2007.
24. Spencer, W.R., Geophysical effects of impacts during the Genesis Flood; in: Walsh, R.E. (Ed.), *Proceedings of the Fourth International Conference on Creationism*, Creation Science Fellowship, Pittsburgh, PA, pp. 567–579, 1998.

Ronald G. Samec is a professional astronomer and physics/astronomy educator. He has the following degrees: Ph.D. Physics (1987), Clemson University with research in Observational Astronomy, an MA in Science education from the University of South Florida (1976) and a BA in Astronomy, also from the University of South Florida (1969). He is a presently a professor of Physics and Astronomy at Bob Jones University and a former professor and department Chair in Physics at Millikin University, Decatur, IL and a professor and observatory director at Butler University Department of Physics and Astronomy, Indianapolis, IN. He presently has 144 professional publications abstracted on the SAO/NASA Astrophysical Data System (ADS).