How many impact craters should there be on the earth?

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The moon is the standard by which to estimate the number of craters on the earth. The number of craters greater than 30 km by evolutionary age categories is about 1,900. Scaling to the earth and considering the greater gravitational cross section results in 36,000 craters greater than 30 km. Based on very larger craters on the moon and Mars and the size frequency distribution on the moon extrapolated to the earth, about 100 craters greater than 1,000 km in diameter and a few up to 4,000 to 5,000 km in diameter should have occurred on Earth. This tremendous bombardment must have occurred very early in the Flood, tailing off during the rest of the Flood with a few post-Flood impacts. Such a bombardment would be adequate to initiate the Flood. The evidence for such an impact bombardment very likely can be found in the Precambrian igneous rocks and suggests that the Precambrian is early Flood.

All solid bodies of the solar system, including large asteroids, have been blasted with impacts.[1–5] Also, it seems that the same population of impactors similarly affected the whole inner solar system from Mercury to Mars.[6] Figure 1 shows impacts on part of Mercury, while figure 2 shows the impacts on Mars, including the huge Hellas impact basin. Considering that the inner planets are essentially points when compared to interstellar space, one would expect that the earth (another point) could not have been missed by so many impactors, regardless of the source of the impactors. So if Mercury, Mars, and the moon have a similar impact distribution, the earth must also have been similarly bombarded sometime in its history. We can, therefore, estimate the number of impacts on Earth from the other bodies of the solar system, taking into account the planetary differences.

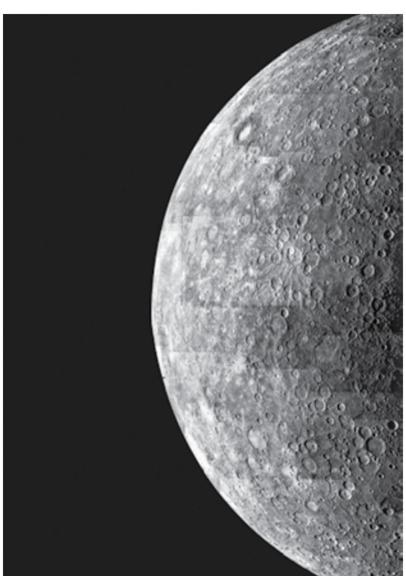

Figure 1. Part of the surface of Mercury showing abundant impacts (NASA).

The moon is the standard

The moon is chosen as the standard by which to “scale” impact parameters to other solid bodies of the solar system, especially the inner solar system, because the moon’s crater populations are best known.[7–9] In scaling from the moon, the differences in gravity and cross sectional area of the other bodies are considered and the statistics from the moon adjusted accordingly. The moon also has preserved most (if not all) of its impact record.[10] Mars and Venus impacts have sometimes been obscured by erosion, impact debris, and volcanism. Few impacts are found on the earth. So, the moon can be used to determine the number of impacts on the other bodies of the inner solar system, whether obscured or not.

Early estimates of the number of craters on some of these bodies have been low. However, more and more large impact basins are being deduced on Mars.[11–12] There likely are many more impacts visible on Venus than previously thought.[13]

The moon is so close to the earth relative to the other planets that it makes sense to use the moon as an analog. So, in order to find out how many impact craters should be found on Earth, one can use the number of craters from the moon and scale them to the earth, taking into account the earth’s different mass, cross sectional area, and gravity.

How many impacts occurred on the moon? Uniformitarian astronomers have developed a history of the moon, starting with its supposed formation about 4.5 Ga ago by a glancing blow to the earth from a giant asteroid, one to two times the diameter of Mars. The debris blown out from the earth supposedly condensed to form the moon. This Giant Impact Hypothesis is still debated by astronomers,[14] although most have come to believe it, mainly because it is believed that the moon is made up of material similar to the earth’s mantle. There is of course no evidence for this hypothesis, but it is the best uniformitarians have now.[15] Computer models have been constructed to study this hypothesis. Although simplified and dependent too much on initial conditions, these models have great trouble forming the moon.[16] It is obvious that the Giant Impact Hypothesis with its multiple *ad hoc* modifications is mainly a reaction to no viable hypothesis at all.

Following the formation of the moon, impacts by planetesimals were so intense that they caused a “magma ocean”. Planetesimals are the hypothetical large chunks of rock that earlier coalesced from dust in evolutionary

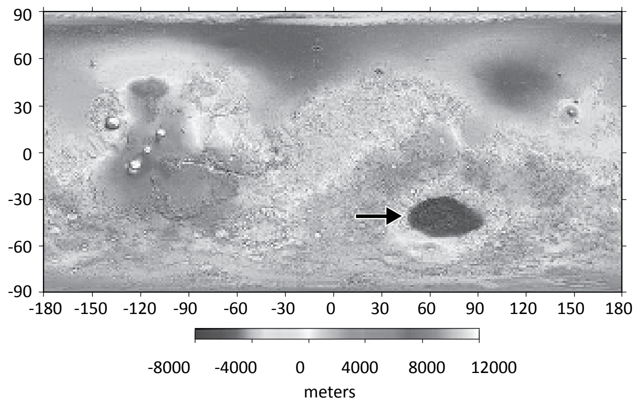

Figure 2. Thetopography of Mars by the Mars Orbiter Laser Altimeter (MOLA) showing abundant impacts, especially in the Southern Hemisphere (NASA). Craters are often buried by sediments and volcanic debris in the Northern Hemisphere. The huge Hellas impact crater, 2,000 km in diameter, is shown by arrow.

models for the origin of the solar system. This very early bombardment has been called the Early Heavy Bombardment (EHB). Planetesimal bombardment decreased with time, causing the surface to cool. However, many astronomers believe that impacts briefly increased about 3.9 Ga ago, called the Late Heavy Bombardment (LHB). The LHB is a controversial concept among astronomers,[17] because they have trouble finding a source of impactors 700 Ma *after* the formation of the solar system. This was a time when all the planetesimals should have already impacted growing planets with very few left in the inner solar system. Warren Hamilton stated:

> "The postulate of a late heavy bombardment suffers from the implausibility of parking numerous large bolides somewhere in the inner solar system for hundreds of millions of years until they were released at ca. 3.9 Ga, or otherwise suddenly deriving them …"[18]

Continuing within the evolutionary story, impacts rapidly decreased after the LHB to a general steady state for the past 3 Ga. Thus, the moon is broken up into various periods to account for this impact history (Table 1). There is some controversy over the ages of the oldest periods.[19]

Table 1. The periods, ages, and basis for evolutionary time division on the moon.[20,21]

"Historical" period	Age (Ga)	Basis for age
Pre-Nectarian period	4.6–3.92	Before the Nectaris basin
Nectarian period	3.92–3.85	After Nectaris basin, before Imbrium basin
Early Imbrium period	3.85–3.80	After Imbrium basin, before Orientale basin
Late Imbrium period	3.80–3.15	After Oriental basin
Eratosthenian period	3.15–~1.0	Lack of rayed craters
Copernican period	~1.0–present	Rayed craters

Crater dynamics

Before we estimate the number of craters on the moon and Earth, we need to review crater dynamics. The energy for an asteroid or comet impact is the kinetic energy of the impactor, which is proportional to its mass and the square of its velocity. Asteroid velocity generally is in the neighborhood of 20 km/sec, but it can vary considerably. Comets move significantly faster than asteroids. Since most astronomers believe the impacts were caused mainly from asteroids, comets will not be considered further. Substituting comets for asteroids would not change the results of the number of impactors that hit the earth. If the asteroid is assumed to have come from the asteroid belt between Mars and Jupiter (a common assumption by astronomers), then the velocity is less on Mars and increases for bodies close to the Sun because of the gravitational acceleration of the Sun.[22] The velocities of asteroids may be different than assumed if the impactors of the inner solar system did not originate from the asteroid belt.

When an asteroid or comet hits a solid body, a transient crater is quickly excavated in a matter of seconds. The size of the transient crater is approximately based on the size, mass, velocity, and impact angle of the impactor, as well as the gravity and density of the planet or moon:

$$D_t = 1.16\ (\delta/\rho)^{1/3}\ D_p^{0.78}(\upsilon \sin \alpha)^{0.43}\ g^{-0.22} \qquad (1)$$

where D_t is the transient crater diameter, D_p is the projectile diameter, ρ and δ are densities of target and projectile materials, υ is the impact velocity, α is the impact angle, and g is the gravity acceleration.[23] Generally the depth of the transient crater is about 1/3 to 1/4 its diameter.[24] Craters will be circular unless the impact angle is less than 15° from the horizontal.[25,26] The most probable impact angle is 45°. Hardly any craters will be made by vertical impacts. Equation (1) is an estimate and does not necessary hold to reality, especially since there are other variables, such as the properties of the impacting body.

Simple bowl-shaped craters are formed by small impacts. Meteor Crater, Arizona (figure 3), is a simple crater, assumed to have been formed by an iron meteorite 30 m in diameter traveling at 20 km/sec.[27] Simple craters undergo minimal change after impact, so the final crater is similar to the transient crater.

Large impacts are more complicated. After the transient crater is formed, the crater undergoes rapid modification. The loss of mass in the crater causes an isostatic upward bulge. Central peaks and multiple rings

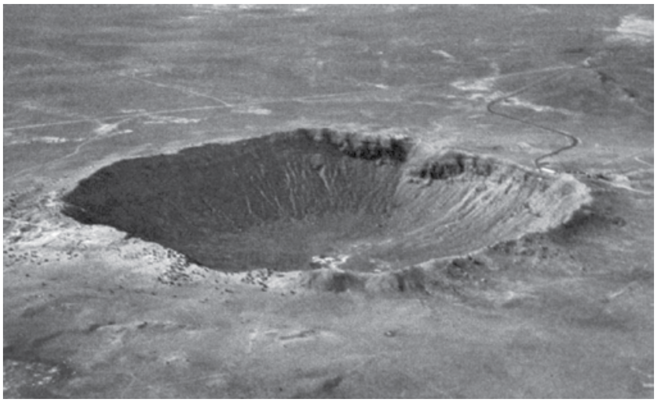

Figure 3. Meteor Crater, Arizona (USGS). The crater is 1.3 km in diameter and 170 m deep.

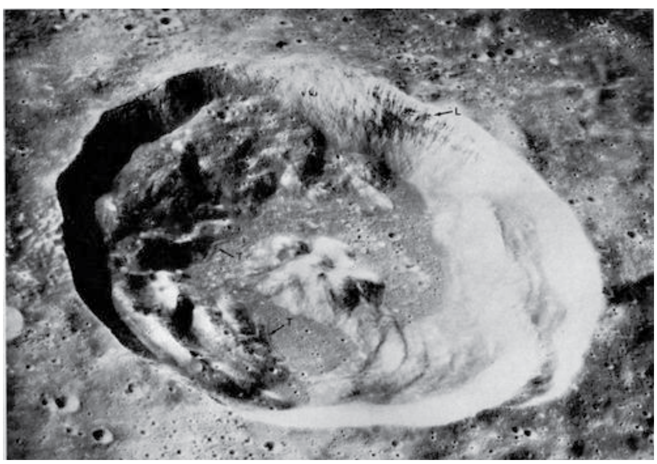

Figure 4. Euler Crater, 28 km in diameter and 2.2 km deep, on the moon (NASA). Note the peak ring and the material that has slumped into the crater from its edge.

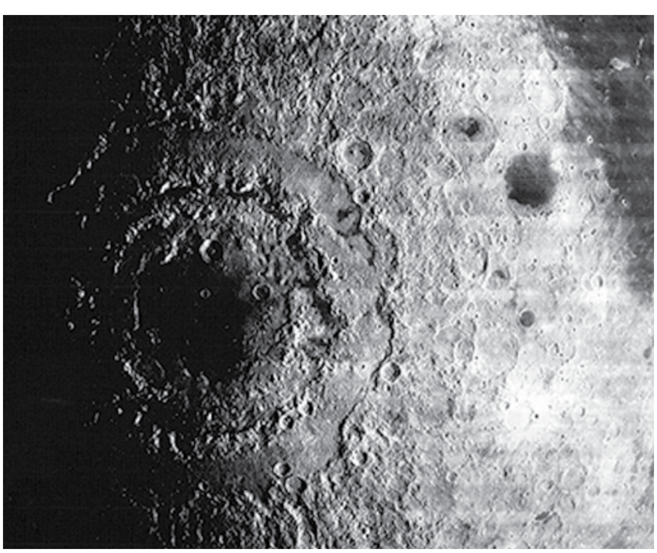

Figure 5. Orientale Impact crater on the moon with three concentric rings (NASA). The diameter of the outer ring is 900 km.

form. Figure 4 shows Euler Crater on the moon with a central peak and slumped material into the crater from its edge. Figure 5 shows the multi-ringed Orientale Crater on the moon with three concentric rings up to 900 km in diameter. The central peak is material raised from below the crater. Large craters have a large central uplift.[28] Also, the edges of the crater slump and slide into the crater, enlarging the transient crater according to the following equation, which is an approximation:

$$D_t = D_*^{0.15} \times D^{0.85} \quad (2)$$

for $D > D_*$, where D is the final crater diameter and D_* is a critical diameter that defines the boundary crater diameter when edge collapse begins and depends upon the target material strength and gravity.[29] On Earth, D_* is 4 km for crystalline rocks. Generally, the final crater diameter of a complex crater is 1.5 to 2 times the diameter of the transient crater with a depth much less than the depth of the transient crater.[24]

The transition from simple to complex craters is inversely proportional to the gravity of the body. For larger planets, the transition from simple craters to large complex craters occurs at a larger diameter than from a small body like the moon. For the earth, craters become complex at diameters greater than 10 to 20 km.

It is typical of impact craters to not only excavate a deep hole, but also to push up its rim. For instance, the rim of Meteor Crater has been uplifted and overturned. The 102 km diameter Theophilus crater on the moon has a depression 2.8 km below the surrounding plain with a rim pushed up 1.3 km.[30] Sometimes the rim's material is thrusted upward and outward.[31]

Rocks blasted upward by the impact usually come back down on the planet or moon creating "secondary craters", which are small, generally less than 2 km in diameter, and tend to form in chains or clusters.[24] Comets and asteroids less than 100 m typically explode in Earth's atmosphere, so asteroids greater than 100 m will mostly pass through the atmosphere with little affect.[24,32]

How are impacts dated in the inner solar system?

Uniformitarian astronomers estimate the number of impacts greater than a certain diameter (D) for each period in supposed moon history, based on dating craters. Dating impact craters on the moon and other solar system bodies is based mainly on the law of superposition, in other words younger impacts overlie, cut, or overlap older ones.[10] More impacts on a certain area of a solid body means that the impacts are older, assuming a decrease in impacts with time.[33–35] For the moon, this relative dating scheme is calibrated to the dates of moon rocks,[36] which cluster around 3.9 Ga ago.[37] These dates provide the main evidence for the concept of the LHB.[3] Astronomers also use these moon dates to date the time of heavy impact cratering on other bodies of the inner solar system.[8]

An example of relative dating is the difference between highland cratering and mare basalt cratering on the moon. Highland lunar crater density is 32 times higher than on the average mare that fills up the large craters, predominantly on the near side.[36] Since the mare basins and highlands are assumed to have been bombarded during the LHB, this relative dating by the number of craters means that the mare basalts are hundreds of millions of years younger and the basalt is not a direct cause of the bombardment, according to uniformitarian reckoning. The LHB supposedly occurred at 3.9 Ga, while lunar mare basalt are relative dated to about 3.2 to 3.5 Ga.[38] The oldest mare is about 3.8 Ga old.[39]

However, it makes sense that the mare basalt filling of basin craters occurred very soon after the impact basins formed.[40] This is because impacts crack the rock below the impact and should cause magma to form by decreasing the pressure of the underlying rock (by blasting away a large amount of the crust). Furthermore, isostatic uplift of the crater rock results in decompression melting. Hence, the difference between the 3.9 Ga for the LHB and the 3.2 to 3.8 Ga ages of the mare basalts is greatly exaggerated and indicates problems with their radiometric dating methods.

The number of impacts on the moon

Several estimates for the number of craters greater than a certain diameter have been made on the moon. These craters are "dated" and the total number is broken down into subsets during each period of moon history. However, because of the problem of saturation in some areas, in which so many impactors hit that earlier craters are either obliterated or obscured, the crater estimates are *minimums*. Wilhelms *et al*.[41] have counted all the impact craters on the moon with a diameter greater than 30 km in each period of moon history. These impact craters usually have a maximum size limit of about 300 km, and so do not include the small number of large basins, discussed below. Table 2 gives these statistics for each period of presumed moon history.

Table 2 does not include the large basins, the number and age of which is controversial. Wilhelms *et al*. stated that there are 30 pre-Nectarian large basins and 10 to 12 Nectarian and Early Imbrium basins.[41] This estimate is close to that of Ryder,[39] who states that there are 45 large basins that formed during pre-Nectarian to early Imbrium period. Adding these to the above statistics does not change the numbers much. Most of the lunar impacts occurred in the LHB (Nectarian Period) and tailed off dramatically afterwards. Cratering rate supposedly was 500 times higher at 4 Ga than the past 3 Ga.[43] Such a bombardment suggests that 80% of the lunar surface was resurfaced by craters and ejecta.[44] Such statistics are of course minimum estimates because some areas are saturated.[5] In fact, on Mars, surfaces older than 3.5 Ga are saturated.[45] So if we include the large impact basins in the statistics of table 2, and considering saturation, then a conservative estimate (still a minimum) for lunar impacts greater than 30 km would be 1,900 impacts.

Table 2. The number of impact craters per historical period greater than 30 km for each period and the total.[41] The figure for the Pre-Nectarian period is an extrapolation before the Nectarian assuming that there were many more impacts before the Nectarian. This number is not included in the total, since there are very few or no impacts (except for a small number of large impacts) deduced before the Late Heavy Bombardment during the pre-Nectarian Period.[14,39,42]

"Historical" period	Number of impacts
Pre-Nectarian period	(3,400)
Nectarian period	1,330
Early Imbrium period	174
Late Imbrium period	195
Eratosthenian period	88
Copernican period	44
Total moon history	1831

The number of impacts on the earth

In view of all the craters on the solid bodies of the solar system, the earth could not have been missed. Furthermore, craters on Mercury and moon are similar, implying the same cratering history.[7,46] If objects as far away as Mercury and the moon have a similar cratering history, it means the earth must also have a similar cratering history as the remainder of the inner solar system. The timing of all these impacts will be discussed in a later section.

How can we estimate the number of impacts that hit the earth? Since the moon is the standard for the inner solar system and the earth is so close to the moon, it is obvious that the number of Earth impacts can be estimated directly from the moon. First, we must consider the effects of gravity on the different size of the craters on the moon versus those on Earth. The acceleration of gravity on the moon is 1.62 m/sec and the earth is 9.81 m/sec. The stronger gravity on the earth will cause less material to be blasted upward by the impact, resulting in a smaller transient crater. So, the transient crater size difference between the earth and the moon is related by the gravity term in equation (1) above with all other variables the same.[47] The effect of gravity on the transient crater will be rather small; the effect is closely related by the power of 0.22 for g for the earth divided by the moon:[7,48]

$$D_E/D_M = (g_E/g_M)^{-0.22} \tag{3}$$

Where the subscript "E" refers to the earth and the subscript "M" refers to the moon. Hence, for a 5 km impactor, gravity scaling for lunar and terrestrial craters would be about 62 km and 44 km, respectively.[49] This is a 3:2 ratio for the transient cavity.[50]

However, the greater gravity on Earth will cause a greater slumping of the sides on Earth, resulting in a greater enlargement of the crater on Earth. So with a 5 km diameter object, the final crater on Earth would have a similar size as on the moon; 77 km on the moon and 70 km on Earth.[51] When one considers that an asteroid approaching the earth will be accelerated more than for the moon (see below), larger craters will result from the same size impactor. This increase in velocity will more than make up for the 7 km difference in the final crater diameters. Therefore, we can simply assume that the same object will produce the same size final crater on both the earth and the moon.

In scaling from the moon to the earth, the differences in gravity and cross sectional area of each body must be considered. Since the cross-section area of the earth is 13.5 times the moon, the number of moon impacts must be multiplied by this number.[52] This gives 25,650 Earth impacts greater than 30 km in diameter.

However, because of the stronger gravity of the earth, the earth will attract many more incoming bodies.[53] This is called the "gravitational cross section", and is related to the escape velocity of the earth:

$$R_g = R\,[1 + (V_{esc}/V_{inf})^2]^{1/2} \qquad (4)$$

where R_g is the gravitational radius, R is the physical radius, V_{esc} is the escape velocity of the earth, which is 11.2 km/sec, and V_{inf} is the velocity of the asteroid outside the gravitational influence of the earth.[48,54] R_g will vary by the approach velocity and so for approach velocities of asteroids, the gravitational cross section will range from 1.3 to 1.5 times the number of impacts per unit area of all sizes as on the moon.[55] Therefore, we need to multiply the number of craters that would impact the earth's physical cross sectional area by 1.4, which results in 35,910 Earth impacts, which we can round off to 36,000 impacts in Earth history that produce craters greater than 30 km. Note that the problem of saturation on the earth will be even more significant since there will be 1.4 times the area hit by impacts on the earth as on the moon.

Size of the craters

The above calculation was just for final crater sizes greater than 30 km in diameter. The relationship between any given crater size and the number of such craters is given by a size-frequency distribution (SFD), which when plotted on a log-log scale is a straight line with a slope of about –2. In other words the number of craters greater than a given size is proportional to the inverse square root of crater diameter.[56] This means that there will be many more small craters than large craters; there will be tens of thousands of craters less than 30 km in diameter on the earth. Also, since the earth has a significantly larger gravitational cross section, an extrapolation of the moon SFD should result in a few craters significantly larger than the largest on the moon, but just exactly how much larger is speculation. We will obtain a few crude estimates of the larger sized impacts from the literature.

Koeberl states that the earth would have undergone impact events an order of magnitude larger than the moon and experienced many more such events.[3] There would be hundreds of objects with sizes similar to those that created the Imbrium and Orientale craters that must have struck Earth during the basin-forming era. Ryder also says that the earth would have undergone events an order of magnitude larger than the moon with many more impacts.[57] Melosh suggests that there should be 100 impact structures with diameters greater than 1,000 km on Earth, based on the moon.[58]

Samec calculates that the moon was hit by an asteroid swarm equivalent to a 70 km diameter solid asteroid.[59,60] He divides this asteroid up into 23 equal chunks with sizes averaging 24.5 km in diameter, equal to the number of large impact basins, and calculates a crater average diameter of 850 km, which is close to the average of those large impact basins on the moon. Samec uses an average distribution, but in reality the sizes of the impactors would vary significantly around the mean diameter of 24.5 km resulting in a variety of crater diameters as observed on the moon. Using the moon as an analog and the average crater size, he obtains 310 collisions for the earth, each causing 740 km diameter craters. However, he used the physical cross sectional area and not the gravitational cross section area. So, these 310 collisions would have to be multiplied by 1.4 to obtain 434 huge impacts greater than 740 km. The upshot of Samec's and other's research is that the earth should have been bombarded with several hundred impacts producing craters larger than 740 km in diameter.

Kring and Cohen believe that the LHB was by asteroids from a single dynamic reservoir.[4] They estimate the earth was hit by 13 to 500 times more mass than the moon, depending upon size distribution among impactors. Just using the lower number of mass, they conclude that the earth had 22,000 impact craters during the LHB greater than or equal to 20 km, including about 40 impact basins about 1,000 km in diameter, and several with diameters of about 5,000 km! But scaling to Mars would predict 6,400 craters greater than or equal to 20 km, but there are 9,278 craters of those dimensions. So, Kring and Cohen's numbers are probably low for the earth.

There is the question of how Kring and Cohen came up with the result that the earth should have a few impact basins 5,000 km in diameter. They obviously extrapolated the SFD for the moon to the earth. The largest impact on the moon is South Pole-Aitken with a diameter of about 2,500 km (figure 6). Using more sophisticated analysis, Mars may have 20 craters larger than 1,000 km with five 2,639 to 3380 km in diameter.[11] Since Mars has a smaller gravitational cross section than the earth, the earth should

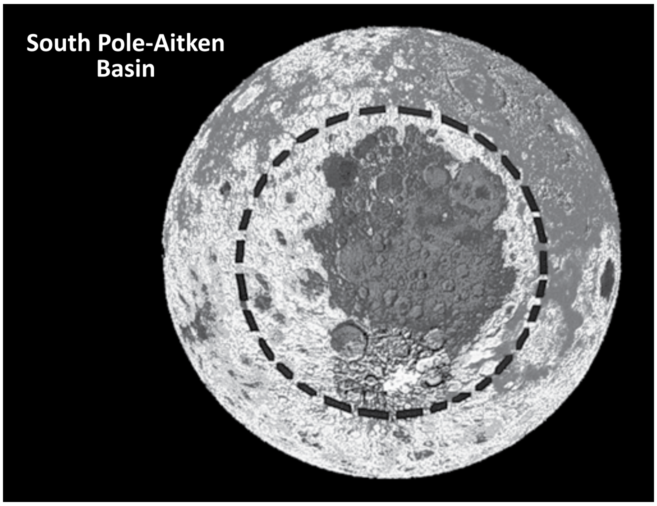

Figure 6. The South Pole-Aitken Impact crater on the moon (NASA). The basin is elliptical shaped with a diameter about 2,500 km and a depth of about 7 km.

Figure 7. The near side of the moon showing abundant large impact craters filled with basalt (NASA). There are only a few medium sized impact basins on the far side.

have significantly larger diameter craters than Mars. So there is justification for an extrapolation to the earth from Mars and the moon for a few large craters around 4,000 km in diameter or more, so a 5,000-km diameter crater is not too outlandish.

So, it is safe to conclude that the earth should have 36,000 impact craters with about 100 over 1,000 km, and a few with diameters of 4,000 to 5,000 km. Such a great bombardment would pulverize a larger portion of the earth surface.

When did Earth impacts occur?

When could such a bombardment occur in biblical Earth history? It is likely that very few impacts occurred after the Flood (assuming the Flood/post-Flood boundary is in the very late Cenozoic), since there are only a few pristine impact craters, such as Meteor Crater (figure 3) that are clearly post-Flood.[61] If even a small fraction of the 36,000 impacts occurred after the Flood (as well as before the Flood), all biology would have been wiped out.

In regard to possible impacts before the Flood, I accept Spencer's analysis[56] that the solar system was created stable with no impact structures. This seems logical to me, since everything was created very good, and meteorite bombardments do not seem to be very good phenomenon, especially if there were organisms living on the earth at the time. So, it does not seem likely that there were two bombardments, one at the Creation or the Fall and a second during the Flood as advocated by Danny Faulkner.[62] The moon was created on Day 4, so that any moon bombardment afterwards could hardly have missed the earth, in which case all or practically all newly-created organisms would have been wiped out. A bombardment at the Fall would also be devastating.

So, all these 36,000 impacts very likely occurred during the Flood, which I have maintained for a long time:

> "Impact craters are common on the inner planets and our moon, which implies that the earth probably was bombarded at some time in the past. We find very few impact craters on the surface of the earth, indicating that catastrophic meteorite bombardment would have occurred either before the Flood or during the Flood. If the pre-Flood earth was a time of climatic and geographic stability, it is doubtful that the meteorite bombardment was before the Flood. The only possibility left is that the event occurred during the Genesis Flood."[63]

All the solar system bodies were likely struck by the same event, as indicated by similar crater SFD statistics on the inner solar system, except for Venus. However, Venus likely has many more visible impacts than astronomers believe.[13]

Based on the relative dating of the moon, it looks like most of the very large impacts struck right away on the near side of the moon (figure 7) with a rapid tailing off of impacts. The far side has only a few medium sized basins. Because of the 27.3-day rotation of the moon and the maria being spread horizontally over 45% of the lunar surface, mainly on the near side, Samec concludes that the large impacts on the moon occurred over a period within 12 days.[60] He prefers a much shorter time frame, probably over a span of a few days. These large impacts could be associated with the late LHB. (The LHB is controversial among astronomers, but this dispute does not concern creationists since the LHB depends upon whether there was an Early Heavy Bombardment that formed the moon and caused the magma ocean, both of which there is no evidence for and depend upon evolutionary speculation.)

Since the mare basalts likely flowed soon after the impacts and have much fewer impacts than the lunar highlands, the number of impacts must have decreased rapidly after the initial large barrage. Also, the radiometric dates between the LHB and the mare basalt show that the radiometric dates are highly exaggerated. Remember that relative dating, which seems reasonable, only gives the sequence of events and not the absolute time or the real time between events. So, it looks like the larger impacts struck at the very beginning of the Flood in a matter of a few days, or even less, and decreased rapidly afterwards with only a few small impacts after the Flood.[56,64,65] We can also conclude from the near side moon impacts that the largest impactors came from one direction.

Impacts likely caused the Flood

So many impacts, some huge, would have provided a prodigious amount of energy to the earth. Such an amount of energy, especially delivered quickly and not over millions and billions of years, would have many effects on the earth. It is beyond the scope of this paper to estimate the effects of this energy, but regardless the amount would have been devastating. Since the Flood requires energy, meteorite impacts could easily provide the necessary energy to start and maintain the Flood. A number of creationists have suggested impacts as the source of this energy, regardless of whether catastrophic plate tectonics occurred later or not.[56,59,60,62,64–70]

Where are the impact craters on Earth?

If the earth had 36,000 impact craters greater than 30 km with more than 100 greater than 1,000 km in diameter and a few up to 4,000 to 5,000 km, then where is the evidence for all these craters? Only about 170 impact craters and structures, some buried, are claimed for the earth,[3] mostly in the Paleozoic.[71] The answer is that the tremendous tectonics, erosion, and deposition during the Flood would have altered or destroyed the vast majority of these craters.

The Paleozoic and Mesozoic sediments are mostly large sheets of strata that cover large areas, while the Cenozoic and Precambrian is more restricted, assuming the uniformitarian geological column. Since geologists have studied much of the sedimentary rocks either by direct observation or by seismic methods, very little evidence for impact structures has emerged. So, it is not likely that a significant proportion of the 36,000 impacts will be found within sedimentary rocks. Therefore, it seems apparent that such a large amount of impacts will mainly have affected the Precambrian igneous rocks, which likely was the pre-Flood upper crust. There are only 3 or 4 examples of Precambrian impact craters or structures.[71] Because of all the Flood devastation, the evidence for a huge amount of impacts in the Precambrian likely would be found if we look for more subtle indicators. Regardless, it seems evident that most of the impacts will be associated with the Precambrian.

So, it looks like the beginning of the Flood would correspond to the Precambrian of the uniformitarian geological column.[72] Much of the Precambrian and Phanerozoic sedimentary rocks likely are the deposits churned up by all the impacts and laid down after the initial chaos of the Flood mechanism.

Such a scenario goes along with two general diastrophic cycles recognized by Thom over the western United States.[73] He recognized an Early Precambrian diastrophic time of basin subsidence and sedimentation, orogenic compression and folding with volcanism, regional vertical uplift, and planation of mountain system. Such energetic effects could be the result of the initial Flood impacts, since impacts would cause basins with mountains formed along the rims of the basins. The basin would then fill with sediments, and of course much volcanism would be expected with the impacts. The impact uplifted rims and isostatically uplifted basins would supply vertical tectonics. Very strong currents in water caused by the impacts could easily plane rocks.

The second diastrophic cycle is continuing today, according to Thom, but started with the deposition of thick Precambrian sediments and continued with the Paleozoic and Mesozoic sedimentation. Then uplift has ensued with orogenic compression and folding with volcanism and planation, mainly in the late Mesozoic and Cenozoic.

Such a general sequence would correspond to the stages and phases of the Flood.[74,75] in which the first diastrophism was caused by impacts, the mechanism of the Flood, followed by the deposition of all the debris churned up by that devastation in the later part of the Flooding Stage. The second diastrophism would correspond to the Retreating Stage with uplift and volcanism as the Floodwater retreated off the continents.

Knowing that the Flood would greatly modify the craters, we need to look for more indirect, subtle evidence for these impacts in Precambrian igneous and metamorphic rocks. One example of such subtle evidence could be ophiolite belts where mantle rocks were overthrust onto other rocks, especially if the ophiolite belt has a semicircular shape. The Oman ophiolite would fit an impact scenario.[76] Another subtle piece of evidence probably is the ultrahigh-pressure minerals and microdiamonds now found in mountains areas all over the world.[77] Ultrahigh-pressure minerals and microdiamonds can be formed by impacts. Otherwise the alternative is to rapidly push continental rocks well below 100 km and then rapidly exhume them, presenting a tectonic conundrum, especially for uniformitarians.

Summary and discussion

Mercury, Mars, and the moon have similar cratering histories.[56] The moon is used as the standard by which to estimate the number of craters that bombarded the earth. The number of craters greater than 30 km calculated for the moon is about 1,900, which is a minimum because of the problem of saturation. In scaling from the moon to the earth, the difference in crater sizes must be taken into account. The earth's stronger gravity will result in a transient crater only 2/3rds the size of one on the moon with the same velocity and size of impactor. However, the greater gravity of the earth will result in the crater becoming larger because of gravitational mass movement and slumping. So, the final crater size on the earth will be close to that on the moon.

Scaling the number of impacts from the moon to the earth is based mainly on the greater gravitational cross section of the earth. As a result, there should have been 36,000 craters greater than 30 km on the earth. Of these, by an extrapolation of the size-frequency distribution, about 100 craters greater than 1,000 km in diameter and a few up to 4,000 to 5,000 km in diameter should have occurred on Earth.

Since such a bombardment did not occur after the Flood because there are very few pristine craters, the bombardment must have been pre-Flood or during the Flood. But if pre-Flood, the devastation would have wiped out all biology on Earth. So, the only logical conclusion is that all these impacts occurred during the Flood. Based on the moon, it seems that the largest impacts must have occurred very early in the Flood, tailing off during the rest of the Flood with only a few post-Flood impacts. Such a bombardment would have enough energy to initiate the Flood, although many details need to be worked out. The evidence for such an impact bombardment very likely first affected the pre-Flood crystalline rocks and suggests that the Precambrian is early Flood.

The number of impacts that occurred during the Flood seems sound. However, there are many questions and additional areas of research beyond the scope of this article. Although impacts into the pre-Flood oceans would blast up plenty of water into the atmosphere and beyond for subsequent heavy rain,[78] one issue is how such a bombardment caused the Flood. Another issue is whether the amount of energy is too devastating. Of course, much subtle geological evidence should point to impacts, but this evidence, almost always interpreted within a non-impact uniformitarian framework, needs to be worked out within an impact model. It is to be expected that God protected the ark from asteroid impacts, but why does the Bible not directly mention impacts? Regardless, the number of impacts to bombard the earth, the objective of this paper, is the first step in developing a new model of the Flood, based on impacts.

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