The moon's recession and age

Jonathan Henry

The history of modern lunar origins theories traces back to George Darwin in the 1800s. Such naturalistic theories have presumed that the moon is extremely old, but all have been plagued by irresolvable difficulties. In addition, the moon is slowly receding from the earth, a phenomenon which establishes an upper limit for the moon's age of approximately one-third the conventional age of 4.6 Ga. This issue has been a long-standing challenge to conventional chronology. Use of adjustable tidal parameters presumes conventional age rather than proving it, so is no support for a long chronology.

Naturalistic theories put lunar origin close to Earth

According to Genesis 1:14–18, God spoke the moon into existence as a unique celestial body on Day 4 of the Creation Week. Opposing the Genesis account are naturalistic theories of lunar origin: (1) the capture theory ('daughter' theory); (2) the accretion theory ('sister' theory); (3) the fission theory (the 'spouse' theory), popularized first by George Darwin, son of Charles Darwin;[1] and (4) the impact theory. The impact theory is currently in favour as the other theories have been found to 'have serious flaws'.[2]

The capture theory has been discredited because of the improbability of Earth capturing an approaching moon-size object. Rather than explaining the origin of the moon itself, this theory merely displaces the problem of lunar origin to an indeterminate point far from Earth.

The accretion theory claims that the moon coalesced from debris remaining from the solar nebula in close orbit about the earth. The accretion theory, sometimes called the 'double planet theory', says that the earth and the moon formed in tandem from the solar nebula. If this theory were true, the earth and the moon should have similar structure and composition. As might be expected from the creation of the moon as a unique heavenly object, its composition (especially the difference in iron content) does not match the earth's.[3,4] Indeed, the accretion theory has been discredited because of difficulty in explaining how debris can coalesce, and also because of the problem of 'explaining why the abundance of iron in the Earth and the Moon is so different'.[5,6]

The fission theory claims that the moon coalesced from debris spinning off the presumably molten earth eons ago; while the impact theory claims that a Mars-size asteroid once impacted the earth,[7] with the debris eventually coalescing into the moon. The fission and impact theories both require that the debris forming the moon begin coalescing at or near earth's Roche limit.

The Roche limit: site for naturalistic lunar formation

The Roche limit is the distance from a central body, such as a planet, inside of which orbiting debris cannot coalesce.[8,9] The gravitational force of the central body on an orbiting particle is stronger on the particle's near side than on its far side. Within the Roche limit, this differential gravitational force is greater than the particle's own self-gravitation, and particles break apart rather than joining.

A satellite can exist within the Roche limit if non-gravitational cohesive forces hold the object together, but once torn apart into smaller pieces, the pieces cannot rejoin. Saturn's rings are evidently fragments of moons once orbiting Saturn inside the Roche limit. Forces due to collisions, or disruptive forces within the moons, tore the moons apart. Before they fragmented, cohesive forces held the moons together, but once they disintegrated, they could not re-form. Similarly, the earth's moon could never form inside the Roche limit out of debris due to fission.

The impact theory does not resolve lunar origins difficulties

Even the impact theory leaves moon's origin 'still unresolved', and it was adopted 'not so much because of the merits of theory as because of the ... shortcomings of other theories'.[10,11] Lunar origin theories have a history of being accepted with fanfare, then being quietly dropped as unworkable. Indeed, Hartmann quipped,

> 'The moon seems a highly unlikely object. Theoreticians have been led by frustration on more than one occasion to suggest facetiously that it does not exist.'[12,13]

The impact theory was first proposed in 1975 and found widespread acceptance in 1984. Until details of the theory were examined, it was viewed as explaining virtually all observations.[14] Before the impact, the earth's rotation rate was small or non-existent, and 'the projectile must have struck the earth off-center [to] have sped up the earth's rotation to its current value'.[15] However, as mentioned, the moon's iron content is significantly lower than Earth's, and to explain this, 'you need to avoid a grazing collision ... lest too much of the impactor's iron spill into orbit' and become part of the moon.[16] Further, the impactor would need to have been quite large, two or three Mars masses, to propel sufficient debris into orbit to form the moon.[17] But such a large impactor would pose other challenges:

1. The combined mass of the earth-moon would be too large unless the earth was only partly formed at the

time of impact; the earth may have been as little as 'half formed'.[18] A current estimate is that the earth was 89 % accreted.[19] However, a collision so intense as to add on the order of 10% to the earth's mass would profoundly disturb the earth in other ways. It is believed that solar He and Ne from the primordial nebula have been detected within the earth, 'but how did this solar gas survive the Giant Impact?'[20] In addition, the elements which would later make up the present 'secondary atmosphere' would have been lost. Replacement of the atmosphere by later cometary impacts seems unlikely because the D/H ratio of Earth is different from that of comets. Thus 'all the D/H data for comets acquired so far preclude this possibility.'[20–22] Another result of a large impactor would have been the formation of a 'terrestrial magma ocean,' but 'there is no direct evidence that a magma ocean ever existed on earth'.[23] On the other hand, an impactor of too small a size requires a 'near grazing [impact orientation] and so too much of the impactor core remains in orbit', leading to a moon too rich in iron.[24]

2. A large impactor would import so much energy into the earth-moon system that the impact debris would vaporize before the moon could form. To counter this problem, a 'hybrid' model was developed in which debris within the Roche limit is allowed to vaporize, but debris outside the Roche limit is allowed to cool by radiation and eventually form the moon.[25] There is no physical basis for such a dichotomy, however; the assumption of such a hybrid scheme is an artificial modelling device.

3. A large impactor 'would produce an Earth-moon system with twice as much angular momentum as they actually have'.[26] Responding to these concerns, claimed to have developed a computer model with a Mars-size impactor 'that [yields] an iron-poor Moon, as well as the current masses and angular momentum of the Earth-Moon system'.[18] This optimism was premature, as we will now see. The degree of vaporization of debris was unknown because of uncertainty in their equation of state (EOS),[24] making the initial mass of the moon's accretion disk also unknown. Generally the mass ratio of earth to moon impactor is an adjustable parameter employed to generate acceptable model results.[27] EOS uncertainties are endemic to all impact models.[20]

Another critical parameter in all impact models is the timing of the impact. In recent years, the hafnium-182/tungsten-182 (^{182}Hf/^{182}W) system has been used in attempts to date the moon, but this and other classical chronometers produce equivocal results. As Podosek notes,

'It is not even clear whether the chronometers are consistent or in conflict with each other. ... all methods rely on models of varying complexity involving assumptions difficult to verify and parameters difficult to measure.'[28]

The uncertainties in ^{182}W lunar dating are ultimately constrained by acceptable dates for the age of the earth.[4] Further, W lunar abundance data are extremely sparse; Kleine and colleagues based their conclusion that the moon was formed 30 Ma after the earth 'on W isotope data from only one [lunar] sample'.[29]

Another unresolved problem is the moon's orbital inclination. Currently the moon's orbit is inclined at about 5 degrees to the earth's orbit.[30] Extrapolation back in time revealed that 4.5 Ga ago, the inclination would have been about 10 degrees.

'The cause of this inclination has been a mystery for 30 years, as most dynamical processes (such as those that act to flatten Saturn's rings) will tend to decrease orbital inclinations.'[9]

In other words, if the moon had originated naturalistically, the inclination should be zero and a lunar eclipse should occur at each full phase.

Biblically, God created the moon with very nearly its present inclination, and the orbital inclination problem is
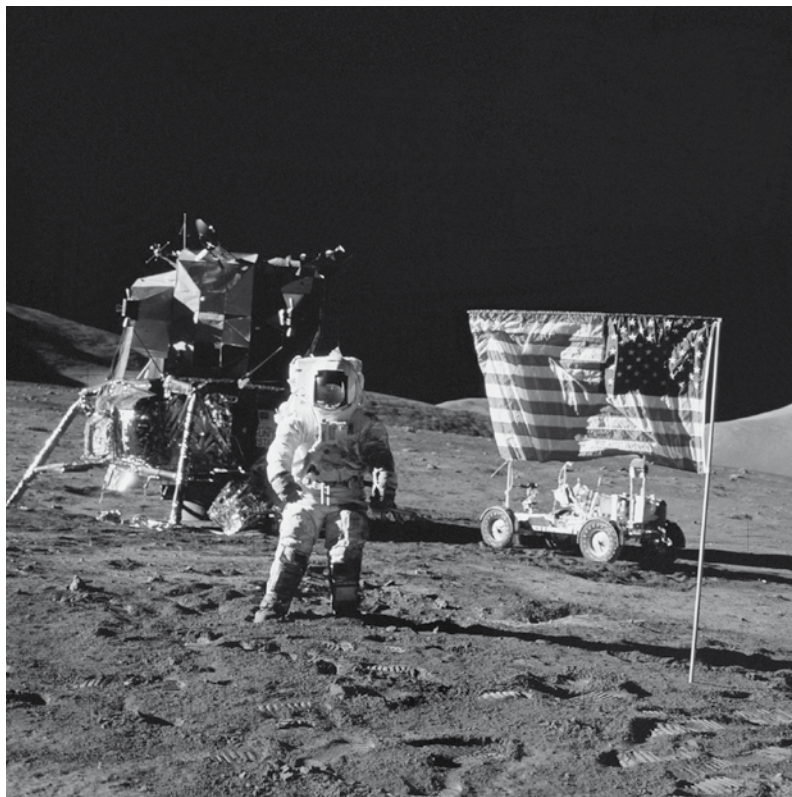

The first moon landing—astronauts placed mirrors on the moon, making possible lunar laser ranging experiments leading to precise determination of the lunar recession rate.

really a 'pseudo-problem'. However, Ward and Canup claimed to have solved the problem by invoking inter-gravitational attractions or 'resonances', and possibly only one resonance, among the particles of debris forming the moon.[9] Such resonances have been invoked to explain the structuring of the Saturnian and Uranian rings, for example. For this resonance model to work for lunar origins, the time of lunar formation and the mass of the accretion disk are 'input parameters' and the 'resulting [present] inclination depends mainly on [these] two parameters'.[31] As mentioned above, these two parameters are unknown. A model depending on them cannot be said to have yielded dependable results, and the orbital inclination problem remains unresolved for the investigator ruling out special creation.

The moon's maximum age is less than 4.6 Ga

The moon was never at the Roche limit, but was positioned or 'set' in the firmament (Genesis 1:17) at approximately its present distance from the earth. Highly accurate lunar laser ranging measurements have shown that the moon is very slowly receding from the earth. Based on these measurements we can compute the time, which would hypothetically be required, for the moon to recede from the Roche limit to its present position.

The recession rate dr/dt of the moon is

$$\frac{dr}{dt} = \frac{k}{r^6} \, , \tag{1}$$

where r is the semimajor axis of the moon's orbit about the earth, t is time, and k is a proportionality constant.[32–34] When t = 0, r = r_0.

To compute the moon's recession time to its present orbit, we first integrate equation (1). Over the time interval 0 to t, the moon's distance from the earth increases from the Roche limit r_0 to its present orbit at distance r:

$$t = \frac{1}{7k}(r^7 - r_0^7), \tag{2}$$

in which t is the maximum age of the earth-moon system. The present value of r is 3.844 x 10^8 m. For an object orbiting a planet, the Roche limit r_0 is

$$r_0 = 2.4554R\left(\frac{\rho_p}{\rho_m}\right)^{1/3}, \tag{3}$$

where R is the radius of the central body (the earth in this case); ρ_p is the density of the central body; and ρ_m is the density of the orbiting body, in this case the moon.[35] With R = 6.3781 x 10^6 m for the earth; ρ_p = 5515 kg/m³; and ρ_m = 3340 kg/m³, we find that r_0 = 1.84 x 10^7 m. This is less than 5% of the moon's current orbital radius.

From equation (1), the proportionality constant k is the product of the sixth power of the distance r, and the current recession rate. The present value of the recession rate is 4.4 ± 0.6 cm/yr, or (4.4 ± 0.6) x 10^{-2} m/yr.[36–38] Therefore, k = 1.42 x 10^{50} m⁷/yr. With this value for k, the right hand side of equation 1 equals the present recession rate dr/dt, when r = the moon's current orbital radius.

From equation (2), the time for the moon to recede from r_0 to r is 1.3 Ga. Without introducing tidal parameters, to be discussed below, this is the moon's *highest allowable* evolutionary age, similar to DeYoung's estimate.[39] This is a serious challenge to the belief that the moon is 4.6 Ga old.[40] As Baldwin noted:

> 'Jeffreys' early studies of the effects of tidal friction [the cause of lunar recession] yielded a rough age of the Moon of 4 billion years. ... Recently, however, Munk and MacDonald have interpreted the observations to indicate that tidal friction is a more important force than had been realized and that it would have taken not more than 1.78 billion years for tidal friction to drive the Moon outward to its present distance from any possible minimum distance. This period of time is so short, compared with the age of the earth, that serious doubts have been cast upon most proposed origins and histories of the moon.'[41]

Efforts to save conventional lunar chronology have failed

One response to the chronological challenge of recession has been the impact theory, in which lunar material originates within the Roche limit but is quickly
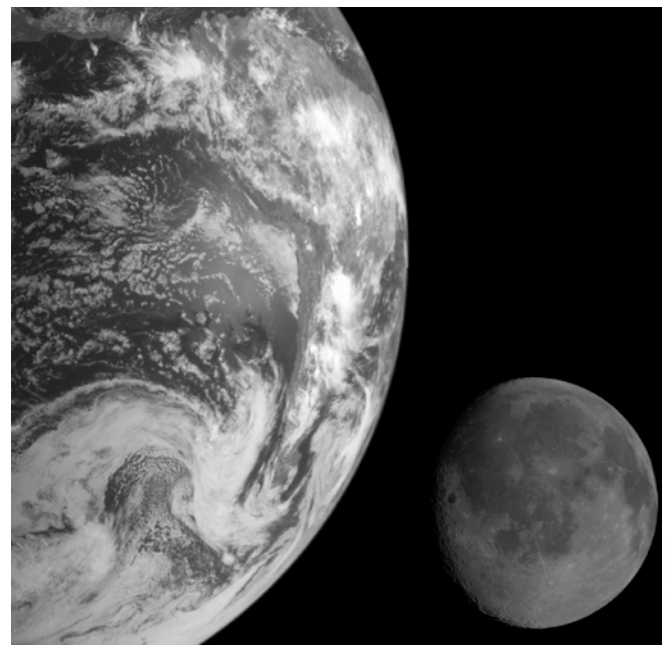

Image by NASA

Recession rates for the earth-moon system challenge conventional lunar chronology

ejected beyond it. The impact theory in turn is grounded in an older concept, the 'orbital resonance theory', which claims that the moon was never actually at the Roche limit. According to this theory, the moon is currently receding, but was once approaching the earth as part of a series of alternating recession/approach events as old as the moon's conventional age.[42,43] The resonance theory, however, presumes conventional age rather than proving it, so is no support for evolutionary chronology.

Another response has been to minimize the lunar recession rate. NASA put the current recession rate at 3.8 cm/yr,[44,45] which is at the *lower* end of the range of lunar recession rates discussed above. Fix goes further and cites a value of only 3 cm/yr.[46]

However, if the moon's distance r had ever been much smaller than its current value, equation (1) shows that the recession rate dr/dt 'must have been much larger in earlier times'.[47] George Darwin stated, 'Thus, although the action [rate of lunar recession] may be insensibly slow now, it must have gone on with much greater rapidity when the moon was nearer to us',[32] a view echoed much more recently by Verhoogen.[47]

Using equations 2 and 3 above, together with the conventional age of 4.6 Ga for the earth-moon system, we can compute how far the moon should have receded from the Roche limit over that time. Using $r_0 = 1.84 \times 10^7$ m, k $= 1.42 \times 10^{50}$ m^7/yr, and $t = 4.6 \times 10^9$ yr, we find that $r = 4.7 \times 10^8$ m. This is 20% higher than the actual distance of the moon from the earth.

Using Fix's estimate of recession rate gives a value 14% greater than the current distance, or a time frame of 1.8 Ga, still far short of the 4.6 Ga date.

A third response is to employ adjustable tidal parameters to stretch recession chronology into harmony with the conventional solar system lifetime.[47,48]

Tidal parameter adjustments fail to save a long lunar chronology

The primary cause of lunar recession is the tides of the earth's oceans.[49,50] Friction between ocean water and the earth causes the earth to lose rotation energy and therefore angular momentum. Momentum conservation requires that the moon gain angular momentum in an equal degree, so the moon accelerates in its orbit, with a resulting recession from the earth.[51] Analysis of astronomical and historical evidence dating back 2,700 years to Babylonian civilization shows that the day has lengthened by an average of 1.7 milliseconds per century, consistent with the earth's slowing rotation rate.[50,52]

As Mignard has observed, unless the moon had a slower recession rate in the past than it does now, the moon's age is only 1.3 Ga, the maximum age computed above. He continues,

'Such a time scale has now been proved to be unrealistic. ... what is wrong in the computation of the time scale and how can it be corrected? The solution to this problem is thought to be a reduced

The full moon.

Image by NASA

rate of dissipation of [tidal] energy in the past ... .'[53]

In this view, it is therefore 'necessary to make an empirical adjustment for the tidal acceleration'.[54] This is tantamount to saying that the proportionality constant k in equations (1) and (2) is actually variable,[55] and must be adjusted to bring lunar chronology in line with that of the earth.[56] The extremely speculative nature of such an adjustment was emphasized by Mignard who said, 'even if we have sound reasons to accept a substantial reduction of the dissipation in the past, we are still lacking evidence of what the Moon's orbit looked like 3 or 4 billion years ago'.[57]

Slichter, one of the earliest investigators to suggest a slower rate of terrestrial energy dissipation in the distant past, remarked that if 'for unknown reasons' this occurred, the dilemma of lunar chronology would be resolved,[58] and Goldreich searched for possible causes.[59] Lambeck concluded,

'... unless the present estimates for the accelerations are vastly in error, only a variable energy sink can solve the time-scale problem and the only energy sink that can vary significantly with time is the ocean.'[60]

A globally open ocean would experience the least friction with land and would therefore dissipate energy at the lowest rate. Accordingly, investigators searched for continental configurations which would provide minimum resistance to the tides. Hansen proposed two models, one with a single polar continent and another with a single equatorial land mass.[42] Piper[61] and Webb[62] proposed that

the present continental arrangement on earth is abnormal and that one continent is normal. Bowden pointed out that 'particularly the Americas which are strung from north to south across the path' of the tides are responsible for a high energy dissipation rate.[63]

Reconstructing ancient continental configurations is 'exceedingly difficult',[64,65] yet attempts have continued to link plate tectonics with past oceanic energy dissipation.[66,67] From a creationist perspective, doubts exist about whether plate tectonics has occurred in the conventional sense.[68]

The layering in stromatolites and other banded geological deposits is supposed to confirm the enlarged chronologies obtained by manipulating continental configurations.[69] The tidal layering of such deposits, called rhythmites, required billions of years according to conventional assumptions. Tidally laminated sediments are taken to imply a lunar recession rate of 1.27 cm/yr between 2.5 Ga and 650 Ma ago,[70] and 2.16 cm/yr on average since then.[71]

Though claimed to be reliable, rhythmite data sets are often short, and periodicities must be interpreted from selected data sets.[72] Varves themselves are dated with respect to the presumed age of the earth.[73,74] Thus lunar recession rates derived from such varve chronologies constitute circular reasoning as 'evidence' that the moon is old. Indeed, the varves now taken to reflect lunar behaviour were not too long ago claimed as evidence of *solar* behaviour patterns and constituting 'potential solar observatories' shedding light on the sun's processes and history.[75,76] However, there is no known mechanism linking varve characteristics and solar behavior.[77] After reinterpretation, varves were viewed as luni-solar[78] or as a lunar phenomenon.[79,80] Confidence is now placed in the reinterpretation of varves as a window on lunar history. Nevertheless, a recent assessment concluded that analysis of tideal rhythmites has not eliminated 'paleorotational parameters in the distant geologic past [that] are highly speculative'.[81]

Conclusions

Over the approximately 6,000 years since the creation of the universe, the lunar recession rate has been essentially constant at the present value. However, assuming a multi-billion year age, lunar recession rates would have been much higher in the distant past than now. The currently accepted parameters indicate that the moon would have required 1.3 Ga to move from its origin at the Roche limit to its present position. This is the moon's upper-limit age and shows that the conventional chronology is incorrect. If the solar system were actually 4.6 Ga old, the moon would have receded to a distance from earth approximately 20% beyond its present position. There is a widespread belief that the impact theory of lunar origin has neutralized these dilemmas for conventional chronology. However, this is not true. Lunar scientist Irwin Shapiro used to joke that 'the best explanation [of lunar formation conundrums] was observational error—the moon does not exist'. The situation has not fundamentally changed, for lunar scientist

Jack Lissauer recalled this anecdote as continuing to apply in a post-impact theory paper.[11]

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Jonathan Henry earned his doctorate from the University of Kentucky in Chemical Engineering. He is now Chairman of the Science Division and Professor of Natural Science at Clearwater Christian College in Florida. In 1987 he began speaking and writing in defence of 'recent creation' when his teaching schedule permitted. He has authored *The Astronomy Book* published by Master Books.