PRE-APOLLO MARE DATING REVISITED: CAN A PAST PARADIGM PROVIDE CLUES TO CURRENT PLANETARY SURFACE DATING?

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Introduction: Pre-Apollo lunar origin work depended heavily on the observational studies of crater density on the lunar surface, just as studies of Mars and other bodies do today. Ironically, as the isotopic results were being published, setting mare ages in the range of 3.5 billion years, the last of the old guard were publishing papers dating the mare using crater dating.[1] However, once it was agreed that the mare were actually quite ancient features of lunar geology, the line of reasoning that Baldwin and others were following was dropped. This was a watershed in lunar origin history, marking not only a change in the course of scientific thought and inquiry, but also a critical turning point from which selenology has not yet found a new and clear direction.

Prior to the isotopic dating of the lunar samples, the course of thought regarding the Moon's evolution was following a fairly steady path that seemed to be closing in on answers to the mysteries of lunar origin. The hope and expectation was that the Apollo missions would finally resolve key lunar origin questions. However, it is at precisely this point—the new dating of the mare as an ancient geological feature—that the details of lunar origin seem to have become even *more* difficult to ascertain.

This disappointing realization leads one to wonder where the path of these early pioneers in selenology might have taken us had not the return of the Moon rocks set science on its new course? What if we retraced their steps and then followed the direction their ideas were leading—might we gain some new knowledge that would help us today to better view the lunar origin mystery? This presentation will take a fresh, dialectical approach in reexamining the path that lunar science was on prior to the isotopic dating in the hope of discovering new clues to old, still unsolved questions.

Suspending Age Constraints on Mare Dating: The main difficulty with the pre-Apollo hypothesis is the apparent conflict between crater age and isotopic age of the lunar mare. In order to gain any new insight from this line of reasoning, the question of mare age must once again be opened for debate, as it was when pre-Apollo scientists were conducting their studies. With this age constraint released, some interesting questions and intriguing possibilities under various lines of inquiry immediately appear. For example, prior to isotopic dating, crater dating of the lunar mare was typically agreed to be less than 1 billion years old.[2] If this were so, the first question might be: where did the heat source for the formation of the mare come from? Even mare formation 1 billion years after the crustal development of the Moon is not easy to account for, but 3.5 billion years later is even more difficult. A secondary heating event on the Moon some 3.5 billion years after its formation would be required, given the ages from the crater dating hypothesis.

Moon's Retreat from Earth and Tidal Heating: Another phenomenon that is also difficult to constrain is the presumed retreat of the Moon from the Earth. The average presumed time of retreat, when the orbit is calculated backwards, is something in the range of <2 billion years. This time since the Moon would have been in closer gravitational contact with the Earth could presumably provide for a energy source for tidal heating within the Earth-Moon system within the last 2 billion years.[3]

Geologic and Biological Evidence: Coupling these two ideas, the mare being "recent" (<1 billion years old, as the crater dating hypothesis would predict) and tidal heating from a closer Moon as a possible heat source, begs the question: Is there any evidence in the geologic and biological record that would allow for a more accurate dating of a secondary heating event on the Moon?

Flood basalts and the Permian extinction. As many have noted, there are similarities between the lunar mare and the terrestrial flood basalts. One of the more interesting features of Earth's flood basalts is that they seem to have rather suddenly burst onto the geologic map, and have continued with diminishing intensities up to the familiar Columbian flood basalts of the American Northwest. The first and greatest of the Earth's flood basalts is known as the Siberian traps. This flood basalt erupted about 250 million years ago and is often associated with the Permian extinction. The Permian extinction, the greatest extinction of all time, and the Siberian flood basalts are well placed in the Earth's geologic record, occurring at the Permian/Triassic (P/T) boundary. The P/T boundary is a very distinct boundary that divides the geology of the primordial Earth from that of the modern Earth.[4] The changes it represents are unique in both the geological and biological evolution of the Earth.

Secondary Heating. Like the lunar mare basalts, it is unclear why, after a significant geologic time, these large flood basalts would suddenly appear on Earth. The P/T boundary has also been found to coincide with a change in the core/mantle dynamics. These two "heat" features suggest that there was an increase and/or input of energy into the system. The lunar mare, like Earth's flood basalts, also follow a long period of no significant basalt emplacement. If the Moon has been continuing to cool, as current isostatic theory seems to show, it would seem logical that the emplacement of mare basalts would follow this thermal continuum of steady cooling. The "sudden" formation of the mare after some billion years or more of uneventful lunar geology has been a bit of a mystery in itself. However, tidal heating associated with a "closer" Moon in the Earth-Moon system can provide a heat source that could produce both the Moon's mare basalts and the Earth's flood basalts.[5]

Planetary surfaces and plate tectonics. The P/T boundary also represents a shift in the tectonic processes of the Earth. The continent of Pangaea assembled in the pre-boundary plate regime, but its breakup—along with the initiation of modern mid-ocean spreading and the continental subduction regime—is a post-boundary process. Although Wegener [6] was unable to provide a driving mechanism for his theory of plate motion, he did speculate that the gravitational pull of the Moon might be one possible source for the necessary energy. The mantle convection, which is assumed to be the driving force today, is a heat-driven force. If the process is significantly different in the post-boundary era, the driving force of mantle convection must also have changed at the P/T boundary. Tidal heating is the only significant source of heat energy that could be introduced so late in the geologic evolution of the Earth's geologic history.

The Mascons. The Moon rightly has no plate tectonic processes; however there are crustal conditions on the Moon that appear to correspond to a secondary heating. The mascons, which have been something of an anomaly in lunar studies, can be explained if the mare are of "recent" origin. If the mare are 3.5 billion years old, then clearly the crust of the Moon must have held the uncompensated masses of the mare for billions of years. However, a recent age would not be constrained by this time vs. strength problem: instead, the mare are simply "not yet fully compensated."

Orbital Irregularities: The orbital conditions that have been long known to be unique to the Earth-Moon system also begin to make sense if the Moon and Earth have had a closer partnership in the past. The nature of cyclic phenomena in the geologic record has been a topic of debate, specifically in the wake of the impact hypothesis for dinosaur extinction. The nature of cyclic extinction and the closely allied phenomena of flood basalts have produced much literature.[7] It is generally believed that whatever the driving force was, it must have been extraterrestrial, or beyond the control of Earth processes, such as impacts, unseen companion sun, or the solar system passing through the galactic plane. Tidal heating association with the closer and subsequently retreating Moon would be just such an extraterrestrial driving force.

Pole wandering and magnetic reversals also seem to be strongly post-boundary phenomena. The Chandler wobble, the unaccounted for motion of the Earth's axial spin, and other short-term motions may also be accounted for by gravitational interaction with a much closer Moon.

One of the most interesting post-boundary changes is the Earth's increasingly seasonal nature. Prior to the P/T boundary, the Earth's climate is seen as uniquely non-seasonal. Environments are described as generally temperate with strong continental influence. As the Mesozoic era develops, a seasonal tendency begins to be seen. This seasonal tendency is often masked through the Mesozoic by the higher atmospheric pressure that dominates the Jurassic period and the transgression of the oceans during the Cretaceous period. However, as the Mesozoic gives way to our modern Tertiary, seasons become the dominant driving force for the evolution of life on Earth.

Cratering History: The ages of planetary surfaces in the solar system are primarily dated through surface crater counts. The age of the mare and their crater distributions are the gold standard for dating all other surfaces. Yet many of the secondary surfaces in the solar system, particularly those of volcanic origin on Mars, are beginning to show the weakness of the existing paradigm. The problem created by the ancient dating of the mare and their lightly cratered surfaces are manifested in the model of intense bombardment. The MIB has had its fair share of detractors, but as long as the constraint of 3.5 billion-year-old mare is in place, MIB must be maintained. This model then forces older dates onto lightly cratered surfaces throughout the solar system, regardless of what other evidence might suggest.[8]

A recent (~250 million yr ago) date for the mare, produced through tidal heating of a closer Moon, eliminates the need for the MIB. It also allows for the explanation of the greatest number of the Earth-Moon system's phenomena by means of the fewest hypotheses: a single hypothesis is all that is required.

Conclusion: Following the path of pre-Apollo selenologists may bring us to the conclusion that the Moon and Earth were gravitational partners—thus producing tidal heating, which has driven the geology of both bodies since at least the Permian period on Earth. Perhaps the Moon was held in some resonance since the formation of the system, keeping it close to the Earth and providing for this ultimate heating event. Or, more likely, the capture of the Moon actually produced this event.

A return to pre-Apollo mare theories offers the possibility to explore this question and others and opens the door to rich new possibilities for inquiry, debate, and discussion, not only on planetary surface science, but on the nature of the Earth-Moon relationship and its history.

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