Lunar Cataclysm? Depends On What "Cataclysm" Means

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FUSION TECHNOLOGY INSTITUTE

UNIVERSITY OF WISCONSIN

MADISON WISCONSIN

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Harrison H. Schmitt

Fusion Technology Institute
University of Wisconsin
1500 Engineering Drive
Madison, WI 53706

http://fti.neep.wisc.edu

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LUNAR CATACLYSM? DEPENDS ON WHAT "CATACLYSM" MEANS H. H. Schmitt, Dept. of Engineering Physics, University of Wisconsin-Madison, 1500 Engineering Drive, Madison, WI 53706 schmitt@engr.wisc.edu #1133

Introduction: The hypothesis of a lunar cataclysm at about 3.9 b.y. (1) has enjoyed a recent revival (2) in part based on the dating of the solidification ages of glass in lunar meteorites (3). The Apollo sample suite has a predominance of apparent impact ages near 3.9 b.y.; however, this could be explained by a sampling bias related to the concentration of landing sites within the obvious reach of Imbrium and other young large basin ejecta (4,5). New data from four anorthositic lunar meteorites cited above either support the cataclysm hypothesis, indicate a continued sample bias, or indicate that the influence of young large basin ejecta and secondary impacts has a global reach.

Cataclysm Definition: The lunar cataclysm might be defined as the ~700 b.y. period from the solidification of all but a few percent of the magma ocean at about 4.5 b.y. ago (6,7) to the formation of Orientale, the last of the young large basins, at about 3.80 b.y. (8). Most would agree that this definition contains all events in question. Such a period would include (a) the post-accretion saturation cratering of the lunar crust to form the Cratered Highlands (7), (b) the formation of the extremely large basins South Pole-Aitken, Procellarum, and possibly one earlier such basin (9), and (c) the formation of ~50 large basins of which Orientale was the last (10). If the definition is narrowed to the apparent 400 m.y. period that includes just the formation of the ~50 large lunar basins greater than 300 km in diameter, then broad agreement would also be possible. If the definition is further narrowed to the <200 m.y. period that encompasses the formation of only the 12 young large basins, i.e., the mascon basins, some agreement continues to be possible. The current lunar cataclysm hypothesis begins to have problems if most or all the impact and related activity prior to 3.8 b.y. are stuffed into a very short period defined by the analytical error in dating impact events that occurred about 3.9 b.y. ago.

The Stuffing: In its extreme form, the lunar cataclysm hypothesis would require an unlikely cessation of the impact of accretionary debris and other objects immediately after the solidification of the lunar anorthositic crust. Thus, the following events and periods of lunar activity must take place <u>in sequence</u> at or near 3.9 b.y.:

a) saturation of the crust with impacts capable of producing craters 60-70 km in diameter and a megaregolith 20-25 km deep.

b) During the post-accretion saturation cratering of (a), above, impact of as many as three very energetic objects, possibly planetesimals, to form extremely large basins of distinct ages relative to each other. These are the Prospector anomaly centered on the Tranquillitatis region and shown by an arcuate iron concentration (9), the Procellarum basin, and the South Pole-Aitken basin. Taken in this sequence, the original features of these extremely large basins have been obscured to lesser and lesser degrees by the effects of post-accretion saturation cratering.

c) Following the post-accretion saturation cratering, about 30 old large basins, >300 km in diameter, formed. These basins are distinct from those that followed because of the relative degradation of characteristic basin features and shape and the absence of any associated positive or negative mass concentrations (10).

d) Eruption of large regions of cryptomaria (11) either contemporaneous with or soon after the formation of the old large basins of (c), above, possibly due to pressure release melting of the mantle and mobilization of residual urKREEP liquid at the base of the crust. Cryptomaria and associated intrusions thus may be represented in the Apollo sample suite by relatively young Mg-suite rocks (4.3-4.2 b.y.) or by relatively old KREEP-rich rocks (4.4-4.2 b.y.). These ages in turn may roughly date the period of formation of the old large basins as well as Procellarum (7).

e) Migration and solidification of the final residual liquid (urKREEP) of the magma ocean either contemporaneous with or soon after the formation of the old large basins of (c), above, with significant strengthening of the lunar crust as a consequence (12).

f) Formation of 14 young large basins, >300 km in diameter, that are sharply circular, have many characteristic basin features clearly delineated, and have both positive and negative mass concentrations (mascons) associated with them. Measured and inferred ages for these events range from 3.92 (Nectaris) to 3.80 b.y. (Orientale). Ejecta from the young large basins covered areas of cryptomaria (thus the name) across much of the Moon, confirming the global reach of their effects. It should be noted that the estimate of 3.80 b.y. is roughly supported by studies of the Apollo 17 landing sites where no Orientale-related effects were noted and the oldest, near-surface basalts are dated as 3.82 ± 0.25 b.y. (13), respectively.

Conclusion: From the above discussion, the most likely explanation for the predominance of impact related ages being 3.9 b.y. or less is the global effect of the ejecta and secondary impacts related to the formation of the young large basins and the youngest old large basins. This, combined with the geographical bias of the Apollo landings, would appear to be the best explanation for an apparent "lunar cataclysm." A final conclusion, however, awaits gathering a more general suite of samples from the Moon through additional exploration targeted at specific localities where the effects of the events listed above can be observed directly. In the meantime, the existing sample suite, particularly samples from the mountain stratigraphy of the Apollo 15 and 17 sites should be re-examined for samples that may represent the effects of pre-3.9 b.y. events. Studies like that of Apollo 17's Boulder 2 at Station 2 (14) come to mind.

References: [1] Tera, F., and co-workers (1974) *Earth Planetary Science Letters,* 22, 1-21. [2] Ryder, G. (1990) *EOS,* 71, 313, 322-323. [3] Cohen, B.A., and co-workers (2000) *Science,* 290, 1754-1756. [4] Wilhelms, D.E. (1987) *U.S.G.S. Professional Paper 1348,* 190-191. [5] Schmitt, H.H. (1991) *American Mineralogist,* 76, 778. [6] Shearer, C. K., and H. E. Newsom (1999) *Lunar and Planetary Science Conference 30*, Abstract #1362. [7] Schmitt, H.H. (2000) *Lunar and Planetary Science Conference 31,* Abstract #1691. [8] Wilhelms, D.E. (1987) *U.S.G.S. Professional Paper 1348,* 224. [9] Schmitt, H.H. and Feldman, W. (2000) Personal discussion. [10] Wilhelms, D.E. (1987) *U.S.G.S. Professional Paper 1348.* [11] Bell, J., and B. Hawke (1984) *Journal of Geophysical Research*, 89, 6899-6910. [12] Schmitt, H.H. (1989) in G.J. Taylor and P.H. Warren, Eds., *Workshop on Moon in Transition: Apollo 14, KREEP, and Evolved Lunar Rocks*, Technical Report #89-03, Lunar and Planetary Institute, Houston, 111-112. [13] Wolfe, E. W., and co-workers, *The Geologic Investigation of the Taurus-Littrow Valley: Apollo 17 Landing Site,* Geological Survey Professional Paper 1080, 1981, p 205. [14] Consortium Indomitable, (1975) *The Moon*, 14.