ABSOLUTE AGE SCENARIOS FOR AN EXPANDED INVENTORY OF LARGE LUNAR BASINS: THE IMPORTANCE OF NECTARIS H.V. Frey, Planetary Geodynamics Lab, Goddard Space Flight Center, Greenbelt, MD 20771, Herbert.V.Frey@nasa.gov and M.J. McBride, Florida Institute of Technology, Melbourne FL 32901.

Summary: Different absolute age (AA) scenarios for an expanded inventory of lunar basins demonstrate the importance of the age of Nectaris. Two peak distributions of AAs mirror the two peak distribution of N(50) Crater Retention Ages if Nectaris is 3.9 BY old. If Nectaris is 4.2 BY old, the AA distribution is more complex with the strongest peak older than 4.2 BY in all cases considered. Much weaker peaks occur at around 4-4.1 and again at 3.7-3.8 BY.

Introduction: N(50) Crater Retention Ages (CRAs) for an expanded inventory of large lunar basins [1-3] (based on superimposed Quasi-Circular Depressions (QCDs) in LOLA data [2,3] and Circular Thin Areas (CTAs) from model crustal thickness [4,5] show two peaks, even when weaker candidates are eliminated [6] (Figure 1). The break between older and younger impact basins is pre-Nectarian [6], as others suggested based on a smaller number of basins [7]. This two peak distribution suggests the possibility of both an Early Heavy Bombardment [6] as well as the generally recognized Late Heavy Bombardment [8-10].

We explore possible absolute ages for these basins based on "known" ages for Orientale, Imbrium, Serentitatis and Nectaris [12,13], using these to calibrate the N(50) ages for the other candidate basins in our inventory. We show secenarios for Nectaris being 3.9 or as much as 4.2 BY old. For all scenarios two cases are considered: a large inventory (N=90) which includes several new candidate basins [11] suggested by one of us (MJM) and a much reduced inventory which keeps only the very strongest candidates (N=56). Figure 1 shows the N(50) CRAs for each of these inventories. Both show the two peak distribution previously noted: the greatly reduced inventory has a dimished older peak because those older candidates in general are the weaker cases.

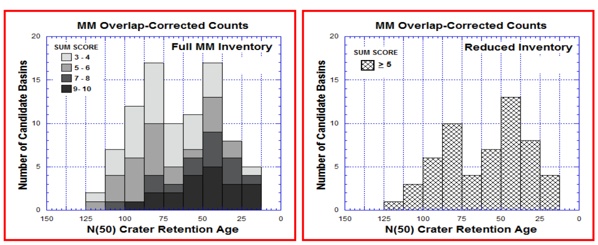


Figure 1. Distribution of Overlap-Corrected N(50) CRAs for the full MM inventory (left) of 90 candidate basins, and for a much reduced inventory of 56 basins (right). Full inventory also shows distribution of summary scores (sum of topographic expression and crustal thickness expression scores) in grayscale. Weaker candidates shown in lighter shades. Reduced inventory eliminates new candidates and all candidates with summary scores <5 out of a possible 10. Both inventories show an obvious two-peak distribution.

Absolute Age Scenarios. To determine absolute ages for the candidate basins shown in Figure 1, we use published ages for Orientale, Imbrium, Serentiatis and Nectaris, and plot these absolute ages versus the Overlap-Correceted N(50) CRAs we find for these basins. We consider two cases for Nectaris, a 3.92 BY "Young Nectaris" [12] and an extreme 4.2 BY "Old Nectaris" [13]. We also assume an AA of 4.5 BY for the oldest inter-basin crust. MJM has located several such areas and these have N(50)~155, substantially older than the basin CRAs (Figure 1).

"Young Nectaris" Scenario. Figure 2 shows AA vs N(50) CRA assuming Nectaris is 3.92 BY old [12], i.e., not that much different from the other basins with "known" ages. The AAs for the four basins and the Assumed Oldest Age (AOA) crust are all well fit with a linear relation, as shown, with a correlation of 0.995.

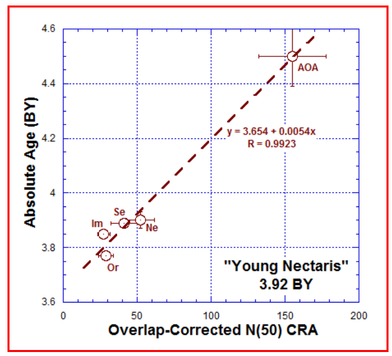
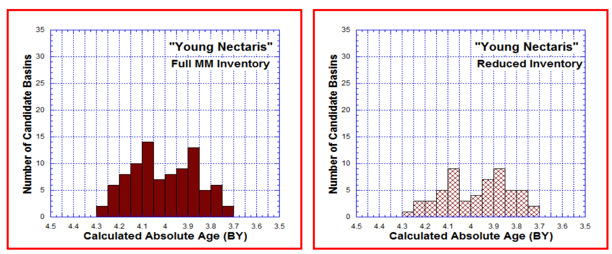


Figure 2. AA vs N(50) CRA for Nectaris = 3.92 BY. With an Assumed Oldest Age (AOA) of 4.5 BY, the points are well fit by a linear relation between AA and CRA, used to convert CRAs to AAs.

A linear relationship between AAs and N(50) CRAs preserves the two peak character of calculated absolute ages for both the larger and the reduced inventory of basins, as shown in Figure 3 below. The two peaks are at ~ 4.1 and 3.9 BY.



Figue 3. Absolute ages (AAs) determined for the large (left) and reduced (right) inventories shown in Figure 1, using the linear relationship in Figure 2. Vertical scales in Figure 1 and Figure 3 are different. For the reduced inventory, the two AA peaks are more nearly comparable than in Figure 1. The oldest candidate basin in this scenario is ~ 4.26 BY.

"Old Nectaris" Scenarios. If Nectaris is 4.2 BY old, i.e. the source of the Apollo 16 impact breccia described by [13], the situation is more complex (Figure 4). The 4 basin points and the AOA point cannot be fit by a single straight line. A log(x) fit to the points (shown by A) has a correlation of 0.959 but misses the assumed high AA of Nectaris. B shows a two branch straightline fit through Nectaris and the other basins and Nectaris and the AOA point. C extends the branch from the four basins to N(50) = 65, the trough in the CRA distribution (Figure 1), with a second branch from here to the AOA point. These are discussed below.

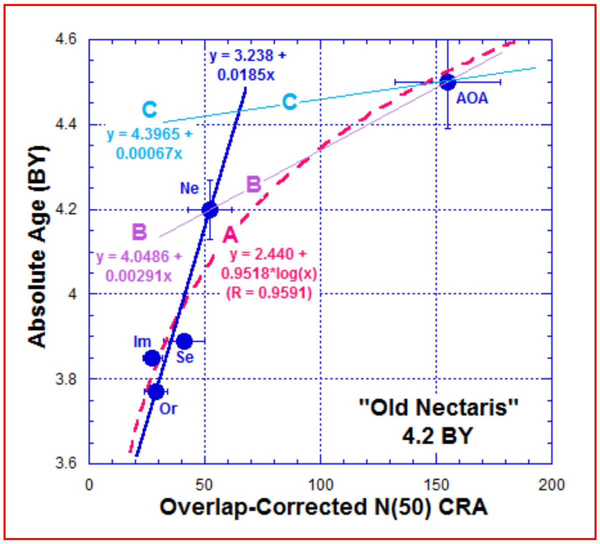


Figure 4. AA vs N(50) CRAs for Nectaris = 4.2 BY old. A = log(x) type fit to the 4 basins with known AAs and the Assumed Oldest Age (AOA) of 4.5 BY. B = two branch linear fit through Nectaris. C = two branch linear fit through the AA value on the younger branch at N(50) = 65 (the trough in the two-peak distribution of CRAs in Figure 1).

Case A. The log(x) fit in Figure 4 yields the AAs shown in Figure 5A for the candidate basins in Figure 1. The simple two-peak distribution of absolute ages is different from the "Young Nectaris" case (Figure 3): The most prominent peak is at ~4.25 +/- 0.15 BY and is stronger than the secondary peak at roughly 4.0 +/- 0.1 BY with a very weak possible third peak at 3.8 BY. Both the reduced inventory and the larger inventory show the same pattern.

Case B. The two branch, straightline fits through Nectaris push more basins to older ages and spread out the younger ages more evenly (Figure 5B). A peak occurs at ~4.3 BY but is much more prominent than in A in both inventories (note the vertical scale is the same for all plots in Figure 5 and matches that in Figure 3). The very much weaker peak at ~4.0 to 4.1 is shifted slightly to older ages compared with A, and a peak half this high shifts slightly younger to ~3.7 BY.

Case C. A two branch straightline fit through the AA on the younger branch at N(50) = 65 (the trough in the distribution of CRAs in Figure 1) results in a very large number of candidate basins with AAs of 4.4-4.5 BY. The younger portion of the distribution is the same as in Case B, because the curve used over this CRA range is the same. Case C emphasizes the likely two population nature of the N(50) CRAs, but, like Case A and B, does NOT have a prominent and narrow peak at 3.9 BY. In all cases the older peak is more prominent, even for the reduced inventory.

Note: If Nectaris is actually only 4.1 BY old [12, 14, 15] the log(x) Case A in Figure 4 would be a close representation of the likely AA distribution, and the oldest peak is less dominant than in the B and C cases..

Summary: Absolute age scenarios for an expanded inventory of lunar basins depend critically on the absolute age of Nectaris. If Nectaris is 3.9 BY old, a two peak AA distribution of roughly equal magnitudes results, with peaks at 4.1 and 3.9. BY. If Nectaris is 4.2 BY old, the situation is more complex. But in all cases considered there is one strong peak older than 4.2 BY and two much weaker peaks at ~ 4.1 and 3.8 BY. The "Old Nectaris" scenarios favor a more intense Early Heavy Bombardment and a more spread out, less intense (and perhaps pulsed?) Late Heavy Bombardment.

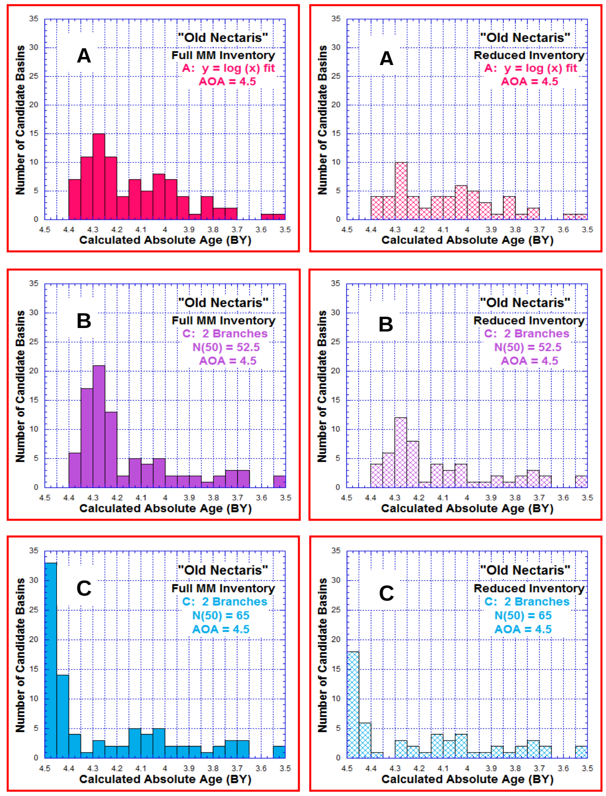


Figure 5. Absolute age distributions for the full inventory (left) and the reduced inventory (right) for the three different "Old Nectaris" scenarios shown in Figure 4. See text for details. All three scenarios make the oldest peak the most prominent, and spread out the ages of basins younger than the 4.2 age for Nectaris into two weak peaks at ~ 4.1 and 3.7 BY.

References. [1] Frey, H.V. (2012) LPSC 43, abstract #1852. [2] Romine, G. and H. Frey (2011) LPSC 42, abstract #1188. [3]] Frey, H. V., H. M. Meyer and G. C. Romine (2012a) *Early Solar System Impact Bombardment II,* Abstract #4005. [4]] Wieczorek, M.A. (private communication). [5] Meyer, H.M. and H.V. Frey (2012) LPSC 43, abstreact #1936. [6] Frey, H.V. and E.E. Burgess (2013) LPSC 44 abstract #1606. [7] Fassett, C.I. et al., JGR (Planets) LRO special issue. [8] Tera, F. et al. (1974) Earth Planet. Sci. Lett. 22, 1-22. [9] Ryder, G. et al. (2002) in R.M. Canup and K. Righter (eds) Origin of the Earth and Moon, 475-492, Un. AZ Press, Tucson. [10] Ryder, G. (2002) JGR 107, 5022, doi: 10.1029/2001JE001583. [11] McBride, M.J. and H.V. Frey (2014) LPSC 45 (this meeting). [12] Stoffler, D. et al. (2006) Chapter 5 in New views of the Moon, Rev. Mineralogy and Geochem., vol. 60. [13] Norman, M.D. et al. (2007) LPSC 38, abstract # 1991. [14] Korotev, R.L. (2002) Workshop on Moon Beyond 2002, PLI, Houston, abstract # 3029. [14] Warren, P.H. (2003) Workshop on Large Meteorite Impacts, LPI, Houston, abstract #4129.