NEW AGES FOR BASALTS IN MARE FECUNDITATIS BASED ON CRATER SIZE-FREQUENCY MEASUREMENTS

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Introduction: The pre-Nectarian Fecunditatis Basin, located at 4°S and 52°E, is defined by three possible ring structures. Within this basin are exposed mostly Imbrian-age basalts that cover an area of about 600 km in diameter [1]. The Russian Luna 16 spacecraft touched down in northeastern Mare Fecunditatis (0.7°S, 56.3°E) and returned moderately-high-Ti, high-Al basalts with an age of about 3.41 b.y. [2]. We performed crater size-frequency distribution measurements in order to date mare basalts exposed within the Fecunditatis Basin. Having the Luna 16 landing site in the study area allows us to independently verify the accuracy of our derived model ages.

Technique: A detailed description of our approach to derive model ages of lunar mare basalts with crater size-frequency distribution measurements is given for example in [3-5]. As for our previous studies, we defined spectrally homogeneous areas on a high-resolution Clementine color ratio composite, transferred the unit boundaries onto high-resolution Lunar Orbiter IV images, which were then used for crater counts. On the basis of our experience with crater counts, it is crucial to identify and define homogeneous units in order to obtain reliable age determinations with crater size-frequency distribution measurements. Compared to previous age determinations with remote sensing techniques [e.g., 6], our approach ensures that our data fit spectral and lithological units and represents a major improvement in accuracy (Fig. 1). We assume that each of our spectrally homogeneous units was formed within a short period of time with, to a first order, homogeneous major mineralogy, such as a single eruptive phase.

Data: On the basis of our spectral map of mare basalts, we performed crater counts for 16 units on Lunar Orbiter images IVH53, IVH60, IVH65, and IVH66. Table 1 is a compilation of ages from the geologic maps [7-12] compared to our ages derived from crater counts. Our crater counts indicate that all units dated in Mare Fecunditatis are Imbrian in age, hence they are generally consistent with ages assigned in previous geologic maps [e.g., 7-12]. For example, unit F1, which is exposed in central Mare Fecunditatis, was mapped by Elston [7] as Imbrian (Im) in age, and this was confirmed by our data. However, there are differences in crater size-frequency ages compared to ages in the geologic maps. The geologic maps of Elston [7] and Stuart-Alexander and Tabor [8] show unit F15 to be of Eratosthenian (Em) age. However, our counts show that this unit is 3.56 b.y. old and Imbrian in age. Similarly, the western parts of unit F16 were mapped by Elston [7] to be of Eratosthenian age, but our new data reveal an Imbrian age of 3.54 b.y. Our crater counts also reveal an Imbrian age (3.62 b.y.) for unit F14, which was mapped as Imbrian and Eratosthenian in age by Stuart-Alexander and Tabor [8]. Unit F3 was partially mapped as the youngest Imbrian mare unit (Im3) and as somewhat older Imbrian smooth terra unit (Its). The origin of Its is uncertain, but Wilhelms [12] suggested that it might consist of a thin veneer of mare basalts on top of smooth highland material. Our crater counts indicate an age of 3.67 b.y. for unit F3.

Unit	Geologic Maps	Model Age [b.y.]
F1	Im	3.47/3.69
F2	Im	3.68
F3	Im_3/Its	3.67
F4	Im_3	3.61
F5	Im	3.53
F6	Im	3.67/4.04
F7	Im	3.34/3.62
F8	Im/Em	3.36
F9	Im	3.58
F10	Im	3.63
F11	Im	3.14/3.68
F12	Im	3.71
F13	Im	3.61/3.69
F14	Im/Em	3.62
F15	Em	3.56
F16	Im/Em	3.54

Table 1: Surface model ages of mare basalt units in Mare Fecunditatis and adjacent areas.

Unit F8 contains the Luna 16 landing site. We derived a surface model age of 3.36 b.y., which is in excellent agreement with the radiometric ages of 3.41 b.y. of the returned Luna 16 samples, as well as with the geologic map of Hodges [9], which shows an Imbrian age for this unit. A few of our units show evidence for resurfacing, indicating that volcanism lasted over extended periods of time in the Fecunditatis Basin. Unit F11 possibly has a relatively young resurfacing age, but this age (3.14 b.y.) is not very well developed. If true, this age would represent the youngest volcanic event in Mare Fecunditatis and could indicate that volcanism was active until the beginning of the Eratosthenian Period.

Synthesis: In previous studies [3-5], we dated more than 290 basalt units on the lunar nearside, including Oceanus Procellarum, Imbrium, Serenitatis, Tranquillitatis, Humorum, Nubium, Cognitum, Frigoris, Nectaris, and others. We found that most of our units were emplaced in the Late Imbrian Period. The new data support this finding as all surface units in Mare Fecunditatis are younger than 3.71 b.y. and only one unit (F6) shows evidence for resurfacing of an older underlying unit of Nectarian or pre-Nectarian age, depending on the stratigraphy used [i.e., 1, 13, 14, summarized in 4].

Implications for LROC: The two cameras (LROC) on board the Lunar Reconnaissance Orbiter mission (LRO) are scheduled for launch in October 2008 [15]. The wide-angle camera (WAC) will deliver global high-resolution images of less than 100 m/pixel resolution, and the narrow-angle camera (NAC) will deliver images of about 1 m/pixel. As the illumination condition were chosen to emphasize subtle morphologic surface features, these data will be extremely useful for crater counts. While Clementine images nominally have spatial resolutions of ~100 m/pixel, their high-sun illumination makes them less useful for the identification and exact measurements of crater diameters [4]. Compared to Lunar Orbiter data, the new LROC images will expand the coverage to areas that are currently only imaged at unfavorable lighting conditions or at lower, medium resolution. This will not only allow us to get better ages for areas such as Mare Crisium, but it will also allow us to update and improve the standard distribution of small lunar impact craters.

Conclusions: From our crater counts we conclude that: (1) most basalts of Mare Fecunditatis are of Late Imbrian age, (2) there is evidence for extended periods of active volcanism as indicated by resurfacing ages, and (3) there is an excellent agreement with radiometric ages obtained from Luna 16 samples. (4) The new ages for the investigated Fecunditatis basalts support our previous finding that most basaltic units now exposed on the lunar surface were formed during the Late Imbrian Period. (5) Data from the two cameras of the Lunar Reconnaissance Orbiter mission will allow us to extend our crater counts to areas such as Mare Crisium and will also enable us to improve the lunar standard distribution for small crater diameters.

References: [1] Wilhelms, 1987, USGS Prof. Paper 1348; [2] Spudis and Pieters, 1991, Lunar Source Book; [3] Hiesinger et al., 2000, JGR 105; [4] Hiesinger et al., 2003a, JGR 108; [5] Hiesinger et al., 2003b, LPSC #1257; [6] Boyce and Johnson, 1978, PLPSC 9; [7] Elston, 1972, USGS I-714; [8] Stuart-Alexander and Tabor, 1972, USGS I-720; [9] Hodges, 1973, USGS I-734; [10] Olson and Wilhelms, 1974, USGS I-837; [11] Wilhelms and McCauley, 1971, USGS I-703; [12] Wilhelms, 1972, USGS I-722; [13] Neukum and Ivanov, 1994, Univ. of Arizona Press; [14] Stöffler and Ryder, 2001, Space Sci. Rev. 96; [15] Robinson et al., 2005, LPSC #1576

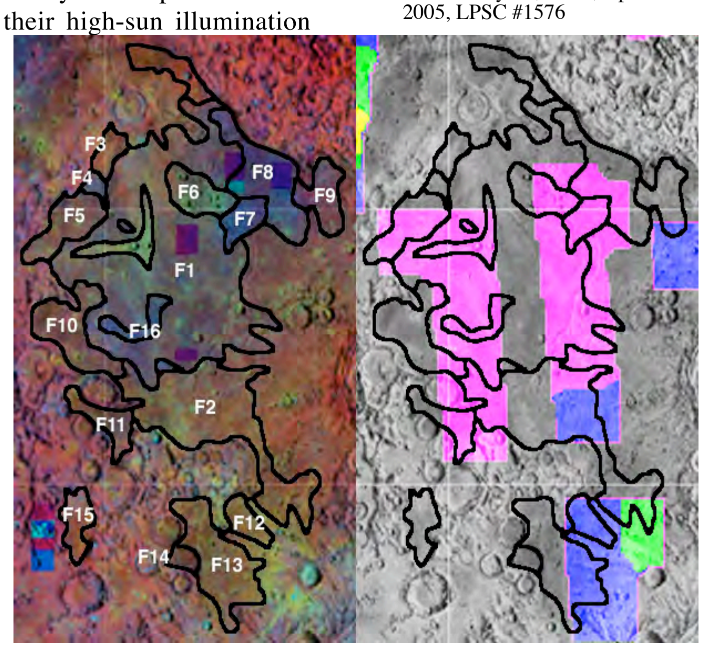

Fig.1: Clementine color ratio composite with superposed spectral units (left). The right image shows data from Boyce and Johnson [6], indicating ages of 3.2±0.2 b.y. (pink), 3.5±0.1 b.y. (blue), and 3.65±0.05 b.y. (green). Note that these ages do not fit spectral and lithological boundaries.