LUNA 24: A CASE STUDY FOR THE VALUE OF ACCURATE CALIBRATED IMPACT FLUX CURVES FOR PREDICTING ABSOLUTE AGE. Joseph M. Boyce[1], Gerald G. Schaber[2], and Thomas Giguere[1], [1] University of Hawaii, Honolulu, Hawaii, 96826; [2] U.S. Geological Survey (Emeritus) Flagstaff Az. 86001.

Introduction: In an effort to predict the absolute age of material collected by Luna 24 before radiometric ages were available for these samples, [1] counted impact craters in the area of the Luna 24 landing site. To estimate absolute ages from crater density, [1] used C_s [2] (i.e., the predicted diameter where steady state occurs for that density of impact craters with a particular absolute age) calibrated with Apollo data [3]. At the time, Cs values were not well calibrated because of the lack of detail knowledge of the impact flux history and the difficult nature of measuring steady state diameter for a particular impact crater density (e.g., [4]). However, at the time, the impact flux curve based only on crater density was only marginally much better, if at all, so [1] chose to use Cs. In this research, we use the same crater count data we collected in 1977 [1] but this time use the much improved knowledge of lunar impact flux (e.g., [5]) to revisit this prediction, and to test the ability for crater size density data to produce accurate results given a much more accurately calibrated lunar impact flux history. We also check these results using LROC NAC images for new crater counts at the Luna 24 landing site.

Luna 24 Radiometric Ages: The Luna 24 mission returned 0.17 kg from the southeastern rim of Mare Crisium in August 1976. Much of our understanding of the timing of Crisium basin-filling comes from eight ^{40}Ar-^{39}Ar age determinations from seven rock fragments of which only two ages have errors (la) < 0.1 Ga [6]. Most of the ^{40}Ar-^{39}Ar ages are in the range 3.2-3.3 Ga [7-9] for very-low-Ti basalts, which are the dominant rock types within the core. These ages are in good agreement with a single Sm-Nd isochron age obtained from a gabbro sample of 3.30 ± 0.05 Ga [7]. However, three Luna 24 basalts have given ^{40}Ar-^{39}Ar ages that are significantly outside this range. These include two dolerites, which are considerably younger at 2.3 ± 0.15 Ga and 2.4 ± 0.2 Ga [9], and an older age of 3.65 ± 0.12 Ga has been reported for an undescribed fine-grained lithic fragment [10].

Results: Crater Count Data: The cumulative size frequency (CSFD) curve obtained for the Luna 24 site from Apollo panoramic and metric images by [1] cross the Cs line between the age of the Apollo 11 and Apollo 15 values with the value closest to Apollo 15. This caused [1] to suggest that the age of the Luna 24 site is similar to Apollo 15 and that Luna 24 landing site has an absolute age of ~3.5 +/- 0.1 Ga. Boyce et al [1] also obtained counts that suggested an older and younger unit nearby with ages of ~3.75 +/-0.1 Ga and ~2.5 +/- 0.3 Ga respectively, and that samples of these may also may be included in the returned samples. Using the data from [1] we replotted their CSFD curve for the Luna 24 landing site in Fig. 1, but this time employed the impact flux history curve of [5] to estimate a model age of ~ 3.27 ± 0.04 Ga.

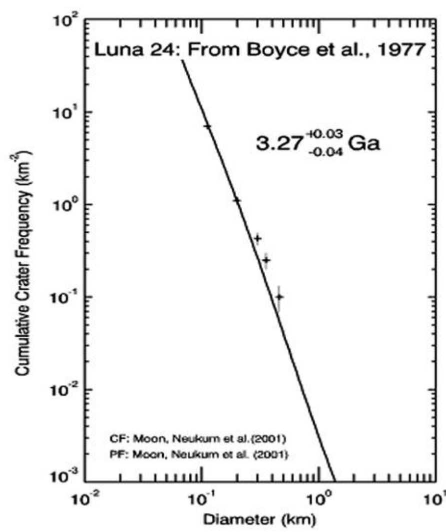

Fig. 1. CSFD of impact craters at the Luna 24 landing site from the original data of [1].

To reaffirm the counts from 1977, we used NAC LROC images as a data base for crater counts to measure the density of impact craters at the Luna 24 landing site area. The resultant CSFD curve is plotted in Fig. 2, and shows a model age of ~ 3.25 ± 0.15 Ga, in excellent agreement with the crater counts of [1] and with sample ages for the site.

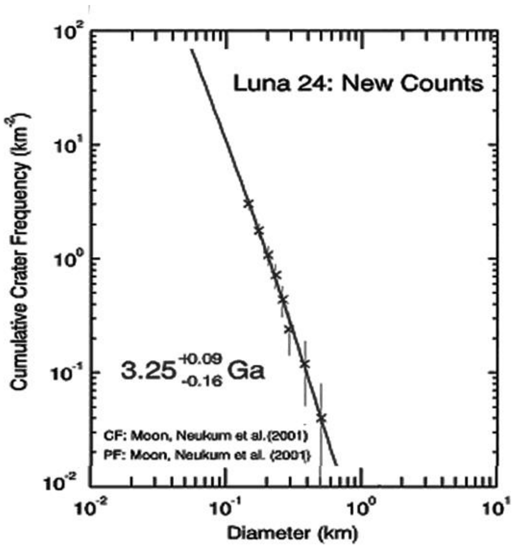

Fig. 2. CSFD of impact craters at the Luna 24 landing site constructed from LROC NAC data.

Discussion: This test clearly shows the value of having a carefully calibrated impact flux history (as well as carefully obtained crater counts) when establishing the absolute age of a lunar surface from impact crater density data. However, the impact flux after the time of the youngest sampled landing site of Apollo (i.e., Apollo 12) is controversial (see [12]). This is because of the assumption that some regolith samples from Apollo 12 contain ray material from Copernicus crater, which dated at ~ 800 my [13]. However, the Copernicus age date has been called into question based on the production rate of impact generated spheroids found in the regolith at the Apollo landing site is inconsistent with this date [14]. Furthermore, the Copernicus age does not seem to fit into the pre-3.0 Ga lunar impact flux history because CSFD and exposure ages of Cone and North Ray craters and Tycho (inferred from Apollo 17) are consistent with constant cratering rate over the past 3 Ga, which would mean that cumulative crater frequencies of Copernicus are too high [5, 15]. This controversy makes the Chang'e 5 mission critical to calibrating the young part of the flux curve because it is likely to land on basalt flows that are younger than 3 Ga (using the flux curve of [5]). For example, based on the calibration impact curve of [5], [16] measured an age of 1.33 Ga in the area where Chang'e 5 may land, [17] measures a model age of 3.1 Ga in an area nearby, as did [18] using impact flux calibrated crater morphology estimated an age of 3.1 ± 0.1 Ga. However, if the assumed Copernicus age is in error, then these ages could be older (i.e., ~ 2.4 Ga, ~ 2.65 Ga and ~ 2.65 Ga respectively). Hence, the Chang'e 5 return samples could have profound implications to our understanding of the Moon and history of the Solar System because of its effects on calibrating the impact flux history.

Conclusions: The value of a well-calibrated impact flux history is critical to estimating the absolute age of a lunar surface from impact crater counts. This is demonstrated by the work of [1] whose crater count data, when compared with the current impact flux data for the Moon [4] accurately predicts the age of the Luna 24 site, although in 1977 based on primitive impact flux data, [1] overestimated the age by ~ 1 Ga. Hence, our reevaluation of the data of [1] confirms the value of well-calibrated impact crater density in providing accurate model ages for terrain that has not been sampled. Furthermore, a critical part of establishing the accuracy of the impact flux history is obtaining samples younger than the Apollo and Luna samples, which may be done by the Chang'e 5 mission.

Acknowledgments: This work was supported by NASA through JPL/ASU LROC contract 11-599.

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