Crater Size-Frequency Distributions on the Ejecta of Giordano Bruno

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Introduction: Radiometric and cosmic-ray exposure ages of Apollo and Luna samples, correlated with crater populations, anchor the lunar crater chronology and enable systems of crater retention age isochrons to be developed (e.g. [1]). Isochrons represent the predicted SFD of a crater population for a given surface age. The youngest ages of the lunar chronology ($<$ 1 Ga) are tied to crater counts conducted on the continuous ejecta of craters where Apollo samples have provided exposure ages. Crater counts conducted on the ejecta of Giordana Bruno (GB), a young 22 km diameter crater on the lunar far side, exhibit significant discrepancies initially reported by [2]. Since the latter half of the lunar chronology rests entirely on crater counts conducted on the ejecta of larger craters, we take a closer look at the discrepancies observed in the crater SFDs on the ejecta of GB.

Rock abundance: Images from the Lunar Reconnaissance Orbiter Camera (LROC) and data from the Diviner Lunar Radiometer Experiment reveal the heterogeneous nature of the ejecta of GB (Fig 1). Rock abundance (RA) derived from Diviner [3] shows significant variability with values exceeding 30% in places, some of the highest values observed on the Moon. The highest RA values correspond to area comprised of large blocks of material. These regions appear nearly devoid of craters (Fig 1b). The SFD of craters in areas of high RA versus low RA (Fig 1c) show that craters with diameters smaller than the blocks are absent implying impact energy from these smaller events goes into breaking down the blocks without generating craters. Larger crater diameters however exhibit a similar SFD.

Impact Melt: Impact melt deposits with fresh morphologies are also observed on the ejecta (Fig 2). RA of the melt deposit is $\sim 9-10\%$ implying, in spite of its fresh appearance, it has already accumulated a layer of fine material. However, the ejecta of a $\sim$ 30 m diameter crater on the melt deposit is comprised of blocks of material indicating the deposit remains a competent rock layer. Crater counts conducted on the melt deposit and the adjacent underlying ejecta produce different crater SFDs.

Surface ages: We model the ages of the crater SFDs by scaling the observed terrestrial fireball population to the Moon, an approach detailed in [4]. Crater isochron models are generated for different target properties [5]. We compare the model isochrons to counts conducted on the ejecta of North Ray crater and Cone crater, two craters used to anchor the lunar chronology with exposure ages of 50.3 ± 0.8 Ma and 25.1 ± 1.2 Ma, respectively [6]. Assuming nominal regolith properties we obtain similar ages to the exposure ages. The isochrons however yield ages that differ by a factor $\sim$ 10 between the melt deposit and the adjacent underlying ejecta at GB even though these deposits formed near-contemporaneously. If we assume a hard rock target for the melt deposit, then this discrepancy is reduced indicating the crater diameters scale differently on the melt deposit (Fig 3). Additionally,

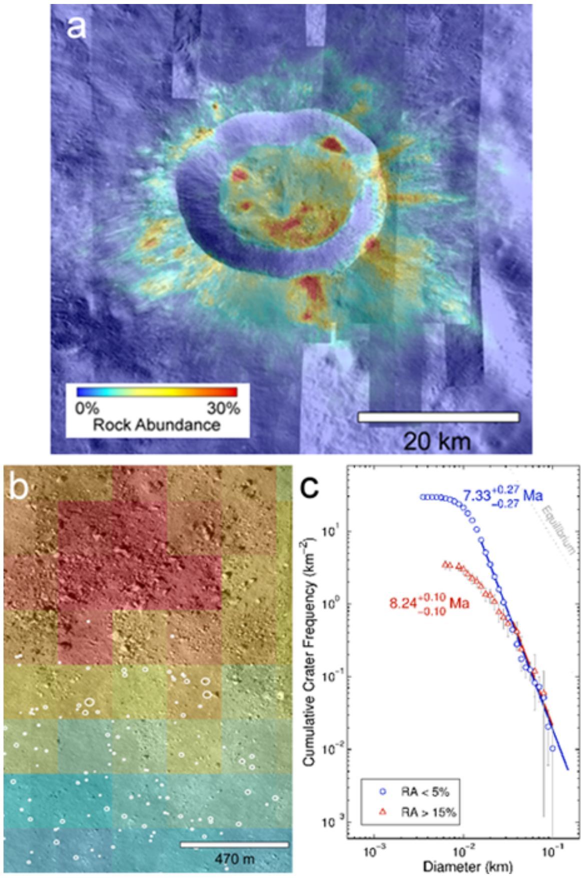

Figure 1: (a) Diviner RA overlaying LROC NAC mosaic. (b) RA overlaying LROC NAC with craters outlined in white. (c) Cumulative crater frequency of high RA ($> 15\%$) and low RA ($< 5\%$) areas.

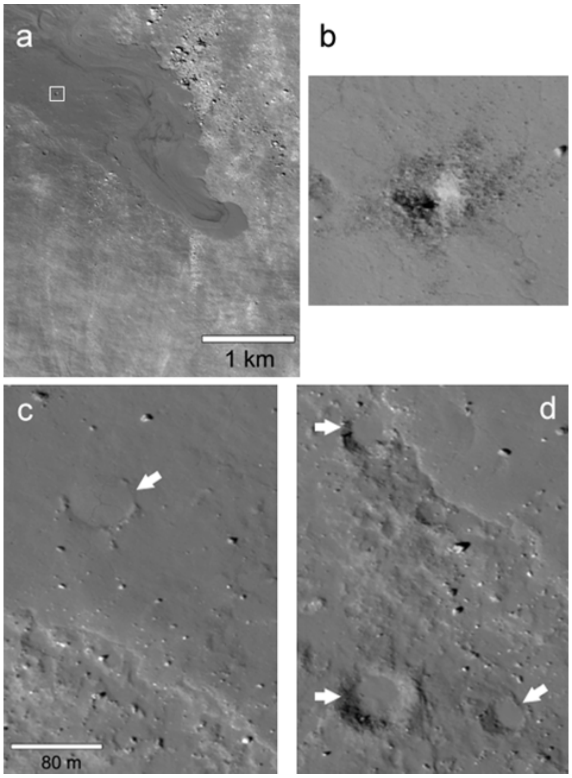

Figure 2: (a) Impact melt deposit on the ejecta of GB. White box is location of (b) a 30 m crater excavating coherent blocks. (c) Ring structure in melt deposit and (d) adjacent craters with melt deposited in floors.

craters appear to have been formed on the ejecta prior to the emplacement of the melt deposit implying self-secondary craters [7] may have populated the ejecta of GB. A ring structure in the melt deposit is observed that is interpreted to be a buried crater and craters near the melt deposit contact appear to have smooth, flat floors that may be deposits of melt indicating the surface had preexisting craters.

Discussion: This raises the question then of whether crater populations on the ejecta of larger craters are reliable for anchoring the lunar chronology. We do obtain ages consistent with exposure ages for North Ray and Cone craters. This could imply that the ejecta of craters are homogenized on times scales of tens of Myrs. Alternatively, North Ray and Cone craters are much smaller, 1 km and 340 m diameter respectively, and were lower energy events. They may not have be as prone to secondary cratering and the ejecta may not have started as heterogeneously as GB.

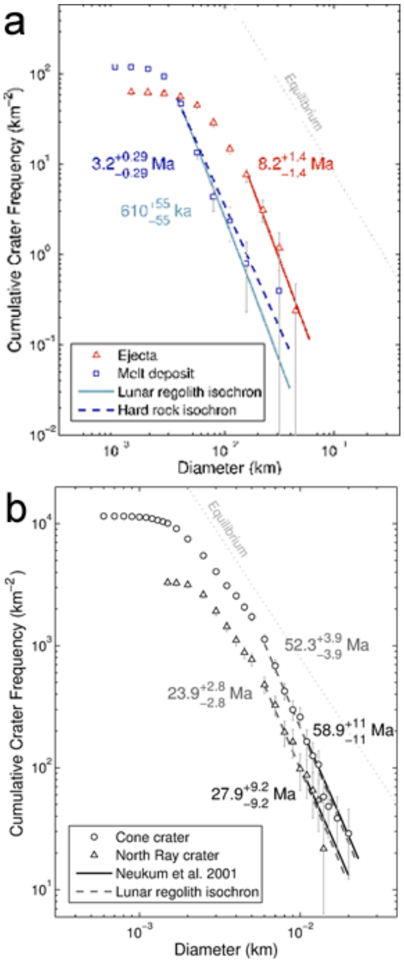

Figure 3: (a) Crater SFD of ejecta and melt deposit on GB fit with lunar regolith and hard rock isochrons. (b) SFD of craters on ejecta of North Ray and Cone craters.

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