GLOBAL MAPPING OF DARK HALO CRATERS ON THE MOON. *B. M. Checketts[1], *I. L. Hampton[1], K. Izquierdo[1] and M. M. Sori[1] [1]Purdue University, West Lafayette, IN *Contributed equally to this abstract

Introduction: Cryptomaria are buried layers of lunar basalts located below felspathic highlands material [e.g., 1]. The present-day volume and distribution of the visible maria and cryptomaria provide important constraints on past lunar volcanism, including internal heating and melt sources [2]. Dark halo craters (DHCs) are geologic evidence of cryptomaria. DHCs expose the buried volcanic material that had been covered by impact ejecta over time [3, 4]. The "halo" surrounding a DHC is the ejecta containing the excavated volcanic material. The volume of hidden volcanic material has been found to be significant compared to the visible volcanic material [2], which makes finding the global population of DHCs and measuring their size vital for fully understanding the thermal history of the Moon.

The DHCs that have been cataloged have been used to provide evidence for and constrain the thickness of cryptomare [5]. However, previous mapping of DHCs are local, and to our knowledge a global database of DHCs from Lunar Reconnaissance Orbiter (LRO) datasets is not available in peer-reviewed literature. Previous work [1,3–5] has searched for and found DHCs in areas of interest, constraining the presence of cryptomaria locally.

Different criteria have been considered for a crater to be classified as a DHC beyond the presence of a lower albedo halo around the crater. As outlined by [2], surface roughness, topography, soil maturity, and iron content serve as additional identifiers of a DHC. Because of the different criteria that can be used to identify them and the lack of a global dataset in the literature, there is a significant variation in the number of DHCs previously proposed at different regions on the Moon [2].

In this work, our goal is to provide a global map of DHCs with the aim of using them to infer the presence and properties of cryptomare deposits. We define a DHC as a crater with a dark ejecta pattern having a locally high iron signature relative to the surroundings. We find this criterium more useful for interpreting cryptomaria than using low albedo halo alone, supporting [2], because mare deposits typically have higher iron content than lunar highlands crust. We map DHCs globally and record the diameter of the found DHCs to be able to constrain the thickness of the potential cryptomare layer.

Data and software: The software used to map the DHCs was Lunar QuickMap [6]. The albedo images were a combination of narrow angle camera (NAC) and wide angle camera (WAC) [7] images from the Lunar Reconnaissance Orbiter Camera (LROC). The data for the iron content of the ejecta was found both the Kaguya (Selene) [8] and Clementine [9] missions.

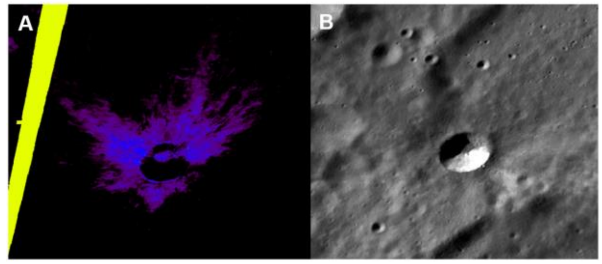

Figure 1: Image A shows FeO abundance of a DHC, with blues as higher abundance (blues and purples have >10% abundance, black has <10%). Image B shows the same crater and the low albedo halo is visible around the crater. This crater is located at -37.90°S, 16.95°E with diameter 7 km, and we identified it as a DHC because of the elevated iron content and low albedo seen in the ejecta.

Methods: We determined a crater to be a DHC if it had an ejecta pattern with visibly higher iron content than the surrounding rock. All of the counted DHCs exhibited this quality. We omitted craters that had elevated iron inside the crater rim (as opposed to in the ejecta) because the iron signature inside might result from visible mare that filled in the crater subsequent to impact. Areas associated with visible lunar maria were ignored for this particular study, as we are interested in cataloging regions of hidden cryptomaria.

We identified and mapped craters globally that had a minimum diameter of 1 km. Determining whether the ejecta had an iron content pattern that is significantly different and distinctive from the surrounding rock is subjective, so we mapped craters conservatively. We only considered craters with a clearly identifiable ejecta pattern, and we required that the ejecta had to surround at least 25% of the crater. We allowed cases with asymmetrical ejecta because, as described by [2], several DHCs have been found to have asymmetrical ejecta as a result of initial crater formation at a highly oblique angle or subsequent modification by the Moon's constant impact bombardment.

Figure 1 shows an example of an identified DHC, including ejecta with low albedo and high iron content. Figure 1a shows a crater with elevated iron weight percentage in the ejecta. Figure 1b shows the same crater in an LROC image that shows the dark halo that is typically attributed to DHCs. From this figure, one can observe the utility of using the iron signature of a crater to be able to categorize it as a DHC compared to using its lower albedo signature alone.

Results: The global distribution of DHCs that we mapped is shown in Figure 2. A vast majority of the DHCs were found on the nearside of the Moon, matching previous knowledge on cryptomaria [2]. We found that there are 199 DHCs on the nearside and 22 DHCs on the farside of the Moon, for a total of 221 DHCs. Most DHCs (197 craters) closely surround the edges of the visible maria. Many of the 24 craters that were found farther away from visible mare regions tend to be large (diameter > 4 km), while the 197 craters around the edges of the visible mare regions average a diameter approximately 1.78 km. That relationship between the size of the DHCs and their location on the surface of the Moon with the depth of the crater will aid us in constraining the thickness of the cryptomare regions in future research. Figure 3 shows a histogram of the distribution of sizes of DHCs. The histogram shows that the peak of diameter size is 1 km with only 22 craters with diameter larger than d > 4 km.

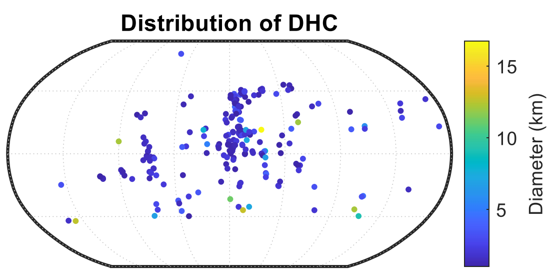

Figure 2: A global map of the distribution of lunar dark halo craters found in this work. The map is centered at 0°N, 0°E. The color of the dot represents the size of the crater.

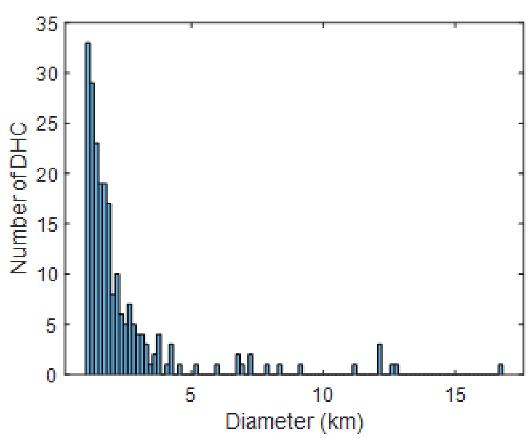

Figure 3: A histogram showing the size distribution of dark halo craters found, with a peak around 1 km in diameter.

Discussion: We interpret the fact that our histogram peaks at 1 km diameter craters to mean that it is likely that many smaller DHCs exist and are not mapped. Additionally, it is possible that the ejecta of old DHCs has been mixed by more recent impacts, making it very hard to identify a higher iron ejecta pattern. Our dataset likely preferentially represents the subset of the largest and youngest DHCs. Future work could map regions using LROC NAC images to identify DHCs at smaller diameters.

Our dataset of DHCs has a spatial distribution across the nearside of the moon with concentrations around of the outskirts of visible mare regions which is like Salisbury et al. found [3]. Antonenko [4] also found DHCs in the southern regions of the moon like our dataset. Those DHCs found in the southern regions also had larger diameters than the average DHC in both Antonenko's data [4] and our own. Other mappings and our own show a concentration of DHCs around the visible mare regions [3,4], and other DHCs around suggested cryptomare regions like the Schiller-Schickard area [4,10]. Our dataset is across the entire globe and is not limited to or focused on only a certain region of interest on the Moon to avoid any bias.

Our global dataset of DHCs show regions of potential cryptomare deposits. Our results are being integrated with GRAIL gravity inversions [11] to quantify cryptomare volume.

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