IMPACT MELT DEPOSITS AT TSIOLKOVSKIY CRATER: CONSTRAINTS ON CRATER AGE. C. D. Neish[1], B. T. Greenhagen[2], G. W. Patterson[3], J. T. S. Cahill[3], J. L. Bandfield[4], N. E. Petro[1], B. R. Hawke[5]. [1]NASA Goddard Space Flight Center, Greenbelt, MD, 20771 (catherine.d.neish@nasa.gov), [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109, [3]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, 20723, [4]The University of Washington, Seattle, WA, 98195, [5]The University of Hawai'i at Manoa, Honolulu, HI, 96822.

Introduction: Tsiolkovskiy is a ~180 km diameter mare-filled impact crater on the far side of the Moon (20.4°S, 129.1°E). The Diviner instrument on the Lunar Reconnaissance Orbiter (LRO) has observed Tsiolkovskiy to have an unusually high rock abundance for a crater of its reported age, 3.5 ± 0.1 Ga [1, 2]. The location of the enhanced rock abundance to the southeast of the crater is consistent with the location of an impact melt deposit first identified by Hawke and Head [3] (Figure 1). We suggest that the area of enhanced rock abundance near Tsiolkovskiy crater is related to the large impact melt deposit. The degradation of massive, coherent impact melt deposits is likely a slower process than the degradation of their surrounding ejecta blankets, and so observations of impact melt may provide relative ages for lunar craters older than Copernican (< 1.1 Ga). One interpretation for the high rock abundance is that Tsiolkovskiy is younger than previously thought, perhaps Erastothenian (1.1 – 3.2 Ga) in age [4]. These and other hypotheses are explored in [5].

Observations: In this work, we compare the Diviner rock abundance [6] and Mini-RF S-Band (12.6 cm) backscatter data of Tsiolkovskiy crater to two other large craters, Humboldt and Theophilus, which also have exterior melt deposits as identified by [3].

Humboldt crater (27.2°S, 80.9°E) is a ~200 km diameter crater, dated as Late Imbrium (3.2 – 3.8 Ga) in age [7]. Hawke and Head [3] identified exterior melt deposits to the ENE and SE of the crater, although no enhancement in radar backscatter or rock abundance is observed in either the Mini-RF or Diviner data (Figure 1). Theophilus crater (11.4°S, 26.4°E) is a ~100 km diameter crater, dated as Erastothenian (1.1 – 3.2 Ga) in age [7]. Hawke and Head [3] identified melt deposits to the NE of the crater, and lobate regions of high radar backscatter have been observed north of the crater by Mini-RF (Figure 1). The Diviner rock abundance of this particular melt deposit is, however, low compared to Tsiolkovskiy crater – on the order of 0.5%, compared to an average of 1% at Tsiolkovskiy and a background value of 0.2 – 0.4%. These observations are consistent with previous observations of melt deposits by the Mini-RF instrument, which has detected ponds and flows around more degraded, Erastothenian-aged craters (~1.1 – 3.2 Ga) [8], but no deposits around craters of Imbrium age (> 3.2 Ga) [9].

The morphology of the region of enhanced radar backscatter near Tsiolkovskiy is consistent with the presence of impact melt at this crater. Sharp, lobate margins are observed in the Mini-RF data, and closer inspection of these regions with LROC NAC data also reveal evidence of impact melt (Figure 2).

Discussion: We propose that the enhanced rock abundance near Tsiolkovskiy is directly correlated with the presence of a large exterior impact melt deposit. The preferential enhancement of rock abundance in the melt deposit can be explained by the presence of blocky ejecta, excavated by small impact craters in the massive, coherent melt sheet (Figure 2). Given that impact melt is emplaced as a coherent flow, melt deposits will likely degrade more slowly than their surrounding ejecta blankets, explaining the lack of enhancement elsewhere around Tsiolkovskiy. Observations of Humboldt suggest that melt sheets will eventually degrade to the point where they are no longer distinct in the Mini-RF or Diviner data, but observations of Theophilus suggest that this process may take up to ~3 Gyr. Buried rocks are detectable with Mini-RF data but not with Diviner rock abundance data, so impact melts may appear to persist for longer in the Mini-RF data, as is observed at Theophilus [10].

The melt sheet at Tsiolkovskiy, however, has a higher rock abundance and radar backscatter than the melt at Theophilus, even though Tsiolkovskiy has been dated as Late Imbrium in age. Possible interpretations of this observation include (1) a high velocity impact event produced more melt at Tsiolkovskiy than is typical for a crater of its age and/or (2) Tsiolkovskiy is younger than Theophilus, perhaps < 3 Ga. Updated crater counts of the mare interior support a younger age for Tsiolkovskiy [4]. New age estimates will allow us to put tighter constraints on the timing of far-side mare volcanism.

References: [1] Greenhagen B. T. et al. (2012) *EPSC 7,* Abstract #712. [2] Tyrie A. (1988), *Earth, Moon, and Planets*, *42*, 245-264. [3] Hawke B. R. and Head J. W. (1977) In: *Impact and explosion cratering,* Pergamon Press, pp. 815. [4] Williams J.-P. et al. (2013), *LPSC XLIV*. [5] Greenhagen B. T. et al. (2013), *LPSC XLIV*. [6] Bandfield J. L. et al. (2011), *JGR*, *116*, E00H02. [7] Wilhelms D. (1987), *USGS Professional Paper*, 1348. [8] Carter L.M. et al. (2012), *JGR*, *117*, E00H09. [9] Shankar B. et al. (2012), *Canadian Journal of Earth Sciences,* in press. [10] Ghent R.R. et al. (2012) *AGU,* Abstract #P42A-07.

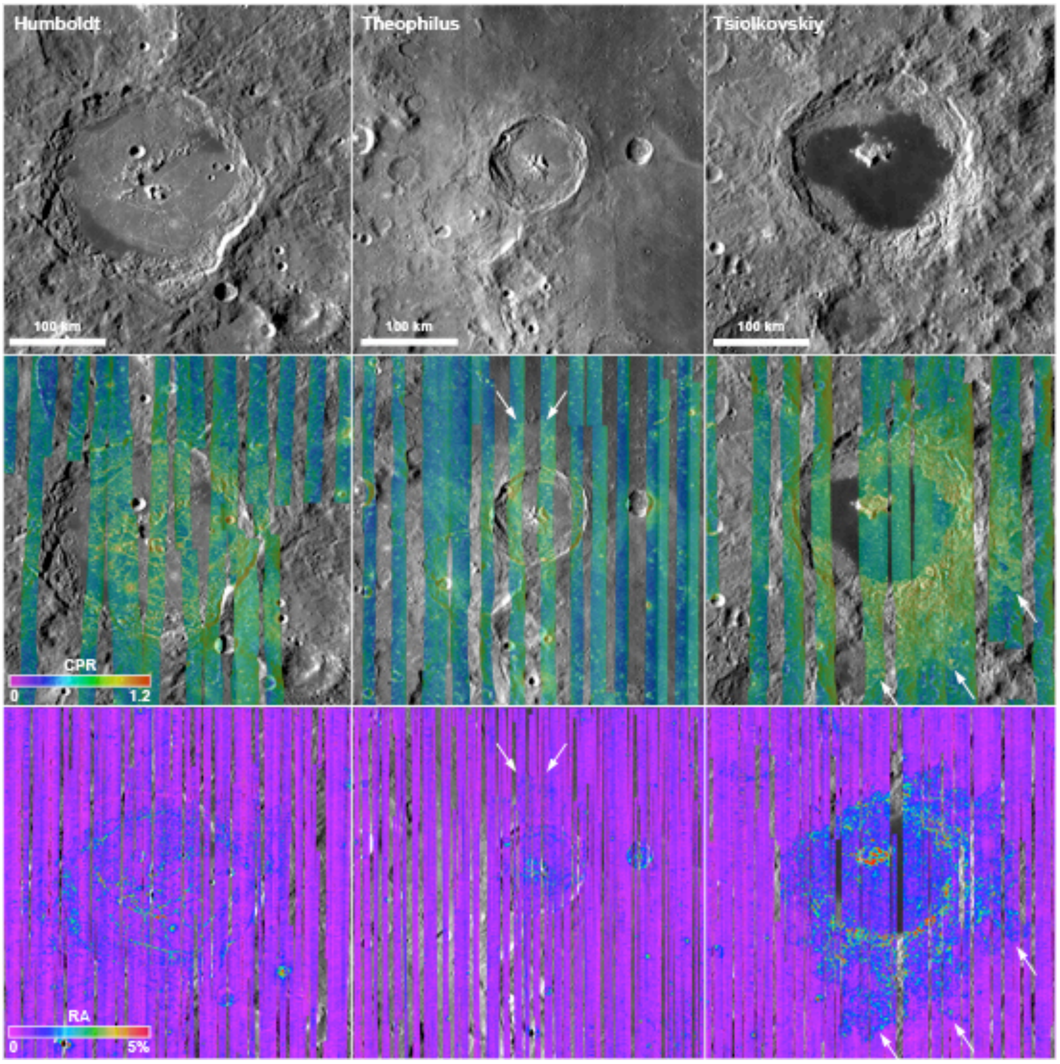

Figure 1: LROC WAC (top), Mini-RF (middle), and Diviner rock abundance data (bottom) of three representative craters: Humboldt, Theophilus, and Tsiolkovskiy. Impact melt deposits are known to have high radar backscatter and circular polarization ratios (CPR), and we have highlighted the edge of likely melt deposits north of Theophilus and southeast of Tsiolkovskiy with white arrows. As with other fresh melt deposits, the impact melt exterior to Tsiolkovskiy crater has an enhanced rock abundance in the Diviner data. No obvious melt deposits are observed exterior to Humboldt crater, although Hawke and Head (1977) suggest the presence of melt ponds southeast and east-northeast of the crater rim.

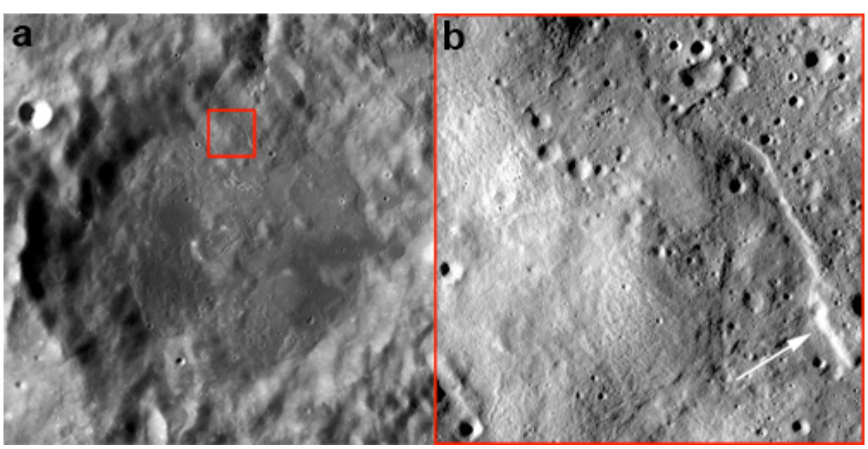

Figure 2: (a) A portion of the Tsiolkovskiy melt deposit as observed by the LROC WAC. (b) A NAC image of the region indicated by the red box shows the lobate texture of the deposit, indicated by a white arrow. There is an abundance of small, blocky impact craters located on the melt sheet. These craters likely account for the increased rock abundance observed in this region.