LRO INVESTIGATIONS OF REGOLITH AND IMPACTS. C. M. Elder[1], N. E. Petro[2], J. Keller[2], A. M. Stickle[3], J. Stopar[4], M. Banks[2], and the LRO Science Team; [1]Jet Propulsion Laboratory, California Institute of Technology, [2]NASA Goddard Space Flight Center, [3]Johns Hopkins University Applied Physics Laboratory, [4]LPI/USRA.

Introduction: Impact bombardment at all scales has been the primary geologic process modifying the lunar surface for over 1 Gyr. This has led to the development of fine-grained regolith blanketing nearly the entire lunar surface. Studying regolith formation and evolution is therefore necessary for understanding the geologic evolution of the lunar surface. As a result, observing the consequences of bombardment at all scales has been central to the LRO mission, including crater formation, crater degradation, regolith overturn rates, and space weathering. Here we discuss some of the recent progress and possible objectives for another LRO extended mission.

Recent and Ongoing Investigations: During the ongoing extended mission 4 (ESM4), LRO is making observations to address four key questions relating to regolith and impacts:

Q1. What is the abundance of impact melt in proximal and distal ejecta deposits of impact craters at all scales? What is the nature of putative basin melt and antipodal deposits?

Q2. How has the impact flux varied over the past billion years, and what are the implications for lunar chronology and for solar system dynamics?

Q3. How, and how fast, are the albedo and texture of newly exposed materials altered at late Copernican craters?

Q4. How does the small-scale structure of the lunar surface affect the photometric and thermal properties we observe? How do variations in the surface texture and thermophysical properties produce anomalous features, such as swirls and distal ejecta deposits?

Some of the many efforts from LRO ESM4 include analysis of Mini-RF and Diviner data that revealed that the rims of km-sized impact craters remain rocky for the lifetime of the lunar maria suggesting that boulders are continually being exhumed at crater rims [1]. LROC NAC images were also used to characterize boulder populations at craters. Specifically, a study of 6 small, young impact craters near spacecraft landing sites constrained how crater age and size affect the size and density of ejected boulders as a function of distance from the crater [2]. Diviner rock abundance in the proximal ejecta blankets of cold-spot craters (<1 Myr old) is not consistent with an abrupt transition between fine-grained regolith and underlying coherent rock but could be explained by a volume fraction of coherent rock that increases exponentially with depth [3]. In 2019 and 2020, 103 unique targets were observed with the LOLA-LR including Copernican-aged craters, large cold-spot craters, swirls, maria, and pyroclastic deposits [4]. Preliminary results from these observations suggest that Reiner Gamma may be smoother than the surrounding maria on sub-mm to sub-cm scales [4]. LRO data was also used to identify possible outcrops of intact Crisium impact melt which could serve as a target for a future lunar sample dating mission [5]. Mapping of Tsiolkovskiy crater and its surrounding ejecta blanket revealed that the initial phase of ballistic ejecta emplacement was followed by a separate melt-bearing ejecta emplacement event [6]. On a larger scale, a global map of lunar light plains (from LROC), suggests that ~70% of light plans are related to the Orientale and Imbrium basins with the stratigraphic extent of an individual basin extending to at least four basin radii, suggesting that basins modified a significant fraction of the lunar surface [7].

Plans for ESM5: LRO is still observing the Moon with LROC, Diviner, Mini-RF, LOLA, CRaTER, and LAMP, but its ESM4 will end in Sept. 2022. Extended mission 5 (ESM5) will be proposed for Sept. 2022-Sept. 2025, and would enable both continued campaigns for which a long baseline of observations is necessary and investigations of new targets. For example, the detection of additional impact craters formed during the span of the LRO mission will further constrain the present-day impact flux at the Moon. New observations of geologically young landforms observed early in the mission could provide a lower limit on the time-scale of detectable space weathering. Much of the Moon has not been observed in the X-band, and new observations at this wavelength could help constrain how the rock size frequency distribution of crater ejecta changes over time. Furthermore, the time frame of proposed LRO ESM5 overlaps with the planned landings of several Commercial Lunar Payload Services (CLPS) providers and the Artemis III South Pole landing. Observations of these proposed landing sites by LRO could provide valuable scientific context and data for landing hazard assessment.

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