

SURFACE PROCESSES. J. B. Plescia¹, M.S. Robinson², R. Clegg-Watkins³, W. Fa⁴, R. Ghent⁵, J. Haryuma⁶, H. Hiesinger⁷, N. Hirata⁶, G. Kramer⁷, S. Lawrence⁸, P. Mahanti², L. Ostrach⁹, W. Patterson¹, P. Spudis⁷, J. Stopar⁷, M. Siegler³, E. Spreyer², A. Stickle¹, J.-P. Williams¹⁰, M. Zanetti¹¹, N. Zellner¹², ¹Johns Hopkins University, Applied Physics Laboratory, Laurel MD, ²School of Earth and Space Exploration, Arizona State University, Tempe AZ, ³Planetary Science Institute, Tucson AZ, ⁴Peking University, Beijing China, ⁵University of Toronto, Toronto Canada, ⁶Japan Aerospace Exploration Agency, Sagamihara, Japan, ⁷Westfälische Wilhelms-Universität, Münster Germany, ⁸Lunar and Planetary Institute, Houston TX, ⁹NASA Johnson Space Center, Houston TX, ¹⁰U.S. Geological Survey, Flagstaff AZ, ¹¹University of California, Los Angeles CA, ¹²University of Western Ontario, London, Canada, ¹²Albion College, Albion MI.

Introduction: Surfaces Processes chapter is one of the chapters in the *New View of the Moon 2* volume (www3.nd.edu/~cneal/NVM-2/). The chapter focuses on the primary processes of surface formation and evolution: cratering, volcanism, tectonism, and mass wasting and how those processes shape the physical properties of the regolith. The chapter will also address how the regolith interacts with the space environment and lunar volatiles.

Chapter Outline: The chapter will review the present stage of our understanding of the properties of the lunar regolith and active surface processes [1, 2]. It will then explore in detail the major advances that have occurred since the Apollo era. A particular point of focus will be the change of the view of the regolith as a layer composed of a range of particles that idly lay on the surface, bounced about by the occasional impact, and generally just keeping the interior warm, to a view of a dynamic regolith that is source for and a medium of transport for lunar volatiles, a storage place for volatiles, a surface that is dynamic and changing on timescale must faster than previously thought and one that may breathe on diurnal timescales.

The chapter will examine the questions that were posed in the *New Views of the Moon 1* volume and the extent to which those questions have been answered. It will also discuss the new questions that have been posed and what might be required to answer them (e.g., data analysis, new measurements, samples).

What's New? As a result of new data our view has significantly changed since the Apollo.

The turnover rate and the lifetime of blocks on the surface may be, respectively, faster and shorter than previously recognized [3-6]. Locating and measuring craters that have formed over the life of the LRO mission has lead to estimates that regolith gardening occurs on a timescale about 100x previous estimates [7]. The concept of the destruction of boulders by thermal fatigue, in addition to bombardment, suggests that thermal fatigue may be more a efficient mechanism, shortening the expected lifetime.

Thermal data allows a more detailed analysis of the density / thermal conductivity profile with depth [8, 9].

Using diurnal and eclipse data, the structure of the regolith at various depths has been determined. An intriguing observation is that the ejecta of many fresh craters is colder than the surrounding terrain at night [10].

Volatiles are of interest not only for the scientific aspect of their origin and evolution, but also from the perspective of resources. We have begun to recognize that H distribution is not simply a function of latitude and permanent shadow. Regolith H appears to be spatially variable at the poles [10, 11]. Surface volatiles, OH and H₂O, appear to vary as a function of latitude and time of day [12, 13]. Existing data are, however, insufficient to define the mobility. It is also unclear exactly what is moving across the surface. Perhaps only H is moving, ephemerally attaching to the surface to form OH or H₂O and then moving on. There is also the suggestion that H moves into and out of the regolith on a diurnal timescale [14, 15]. This has implications for the permeability and porosity of the regolith to 10s cm but also the nature of the driving force.

Various processes shape the large-scale lunar surface including cratering, volcanism, tectonism and mass wasting. We will examine each of these processes, as it relates to the formation and evolution of the regolith. Detailed examination of these processes will be found in other chapters of the volume.

Finally, we will examine the list of outstanding questions and how those questions might be addressed.

References: [1] Jolliff, B. et al. (2006) *New Views of the Moon 1*, Rev. Min. Geochem., 60, 721 pp. [2] Heiken, G. et al. (1991) *Lunar Source Book*, 736 pp. [3] Delbo M. et al. (2014) *Nature*, 508, 233-236. [4] Molaro J. et al. (2015) *JGR*, 120, 255-277. [5] El Mir C. et al. (2016) *LEAG*, #2073. [6] Speyerer E. et al. (2016) *Nature*, 538, 213-218. [7] Gault, D. et al. (1974) *Proc. 5th Lunar Sci. Conf.*, 2365-2386. [8] Hayne P. et al. (2016) *NVM 2*, #6065. [9] Greenhagen, B. et al. (2015) *LPSC XLVI* #2949. [10] Bandfield, J. (2014) *Icarus*, 221-231. [11] Mitrofanov, I. (2011) *Science*, 330, 334- [12] Feldman W. et al. (2000) *JGR*, 105, 4175-4195. [13] Pieters, C.M., et al. (2009) *Science*, 326, 568-582, [14] Sunshine J. et al. (2009) *Science*, 326, 565-568. [15] Livengood T.A. (2015) *Icarus*, 255, 100-115. [16] Schwadron, N. et al. (2016) *Icarus*, 273, 25-35.