LAVA FLOW EMPLACEMENT AND RELATED SURFACE FEATURES ON THE MOON. D.H. Needham[1,2], J.E. Bleacher[2], W.B. Garry[2], N.E. Petro[2], P.L Whelley[1,2], K.E. Young[2]. [1]Univ. Space Research Assoc., [2]NASA Goddard Space Flight Center, 8800 Greenbelt Dr., Greenbelt, MD 20771, debra.m.hurwitz@nasa.gov.

Introduction: Most lava flows on the Moon were emplaced via effusive, voluminous eruptions of low viscosity lavas (e.g., [1]), forming the mare basalts. Data of unparalleled resolution and coverage collected during recent lunar missions have facilitated improved observations of known, localized volcanic features as well as the identification of new features. Such features include pyroclastic vents, cones, irregular mare patches, and sinuous rilles, as well as the confirmed presence of non-mare volcanic features (silicic domes).

Volcanic Features and their Implications:

Pyroclastic vents: Pyroclastic materials indicate that local eruptions of lava contained an abundance of volatiles. A global survey had been compiled with 20th century data sets [2], but the high resolution and global coverage of Lunar Reconnaissance Orbiter (LRO) data have been used to identify new, smaller vents [3], and the high spatial and spectral resolution of Chandrayaan's Moon Mineralogy Mapper (M^3) data have been used to characterize the mineralogy of those deposits [e.g. 4]. Recent laboratory studies of returned pyroclastic beads have confirmed the high volatile content of these materials [5,6], indicating the Moon's interior is not as depleted in volatiles as once thought.

Silicic domes: "Red spots" with high Th and low FeO contents had been identified previously on the Moon [7-13], but data from LRO's Diviner instrument indicates a high silica content in the Compton Belkovich complex, Gruithuisen Domes, Aristarchus Plateau, Hansteen Alpha, and Lassell Massif [14-15], indicating evolved, silicic lavas erupted on the Moon.

Cones and shield volcanoes: Previous studies of lunar cones have indicated that cones may have formed as the result of strombolian eruptions at the terminal stages of effusive mare eruptions [e.g. 16]. Recent studies using M^3 data have indicated the Marius Hills have a weaker 1 µm absorption band than surrounding mare, a difference interpreted to indicate higher silica content, more opaque minerals, and/or a weaker olivine content in the cone lavas [17]. These compositional differences indicate a long and complex volcanic history of the region. Other work using GRAIL gravity data has suggested the Marius Hills formed atop a large low-lying shield volcano ([18]), a feature not previously identified on the Moon.

Irregular Mare Patches: Anomalous lava flows with bulbous, irregularly shaped mounds have long been identified on the lunar surface (e.g., Ina, [7,19-20]). These features have typically been interpreted to indicate small effusions of lava along a fissure [19] or episodic outgassing of subsurface volatiles [20]. Analyses of new LRO imagery have suggested instead that these textures arose from lava flow inflation, such as that in McCartys flow, NM [21], and may represent the youngest volcanism on the Moon [22].

Sinuous rilles: Lava channels have been observed on the Moon since Lunar Orbiter [23], but the specifics of their formation are still debated: Are these features formed by construction [24-26], mechanical erosion [27-28], thermal erosion [e.g. 29-36], or a combination of the two erosion regimes [34-37]? LRO imagery and altimetry data have indicated both leveed and incised lava channels formed on the lunar surface [37]. These interpreted origins indicate some lava flows were emplaced during brief eruptions of slightly more viscous lavas that formed levees, while other lava flows were emplaced during long-lived eruptions of hot, low-viscosity lavas that incised into the substrate [37]. On-going analyses using LRO's suite of new data are evaluating whether previously calculated discharge rates are representative of eruption dynamics or of localized "fill and spill" channel flow dynamics [38].

Concluding Remarks: Observations of new types of volcanic features and of finer-scaled details of known features have shown the Moon to be more complex than previously considered and, thus, these features should be incorporated into a volcanism chapter in New Views of the Moon 2.

References: [1] Schaber, G.G. (1973) *LPS IV*, 73. [2] Gaddis, L.R. et al. (2003) *Icarus*, *161*, 262. [3] Gustafson, J.O. et al. (2012) *JGR–Planets*, *117*(E12). [4] Mustard, J.F. et al. (2011) *JGR–Planets 116*(E6). [5] Saal, A.E. et al. (2008) *Nature*, *454*, 192. [6] Hauri, E.H. et al. (2011) *Science*, *333*, 213. [7] Whitaker, E.A. (1972) *Moon*, *4*, 348. [8] Malin, M. (1974) *EPSL*, *21*, 331. [9] Head, J.W., McCord, T.B. (1978) *Science*, *199*, 1433. [10] Gillis, J.J. et al. (2002) *LPSC*, *33*, #1967. [11] Lawrence, D.J. et al. (2003) *JGR*, *108*(JE002050). [12] Hagerty, J.J. et al. (2006) *JGR*, *111*(E06002). [13] Hagerty, J.J. et al. (2009) *JGR*, *114*. [14] Glotch, T.D. et al. (2010) *Science*, *329*, 1510. [15] Jolliff, B.L. et al. (2011) *Nature Geosci.*, *4*, 566. [16] Weitz, C.M., Head, J.W. (1999) *JGR–Planets*, *104*(E8), 18,933. [17] Besse, S. et al. (2011) *JGR–Planets*, *116*(E6). [18] Spudis, P.D., et al. (2013) *JGR–Planets*, *118*(5), 1063. [19] El-Baz, F. (1973) *Apollo 17 Prelim. Sci. Rep.*, NASA SP 330, 28-1–28. [20] Schultz, P.H. et al. (2006) *Nature*, *444*, 184. [21] Garry, W.B. et al. (2012) *JGR-Planets*, *117*(E12). [22] Braden, S.E. et al. (2014) *Nature Geosci.*, *7*, 787. [23] Oberbeck, V.R. et al. (1969), *Mod. Geol.*, *1*, 75. [24] Spudis, P.D. et al. (1988) *LPS XVIII*, 243. [25] Komatsu, G., Baker, V.R. (1992) *LPI Contrib. 789*, 60. [26] Gregg, T.K.P., Greeley, R. (1993) *JGR*, *98*, 10,873. [27] Siewert, J., Ferlito, C., *Contemp. Phys.*, *49*, 43. [28] Bleacher, J.E. et al. (2015) *LPS XLVI*, #2182. [29] Hulme, G. (1973) *Mod. Geol.*, *4*, 107. [30] Hulme, G. (1982) *Geophys. Surv.*, *5*(3), 245. [31] Carr, M.H. (1974) *Icarus*, *1*, 1. [32] Head, J.W., Wilson, L. (1980) *LPS XI*, 426. [33] Wilson, L., Head, J.W. (1980) *LPS XI*, 1260. [34] Williams, D.A. et al. (2000) *JGR-Planets*, *105*(E8), 20,189. [35] Hurwitz, D.M. et al. (2012) *JGR-Planets*, *117*(E12). [36] Hurwitz, D.M. et al. (2013) *PSS*, *79-80*, 1. [37] Fagents, S., Greeley, R. (2001) *Bull. Volc.*, *62*, 519. [38] Hamilton, C.W. et al. (2015) *LPS XLVI*, #1072.