NEW GEOLOGICAL MAPS OF THE APOLLO LANDING SITES: TOOLS FOR ADVANCING LUNAR SCIENCE AND EXPLORATION. W. Iqbal[1], H. Hiesinger[1], C. H. van der Bogert[1], D. Borisov[1], and T. Gebbing[1], [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149, Münster, Germany, iqbalw@uni-muenster.de.

Introduction: The Apollo program has played a significant role in advancing our knowledge of lunar geology [1] via its scientific goals and sample collection. Modern lunar data [2-7] has recently offered us an opportunity to reanalyze and improve our understanding the lunar geology in further details. Thus, in the last four years, we have used a combination of newer lunar datasets to revisit the Apollo landing sites and produce new, more detailed geological maps to aid in the interpretation of lunar sample analyses, the calibration of the lunar cratering chronology, and the dating of unsampled surfaces [e.g., 8-14].New detailed geological maps of the Apollo landing sites not only provides improved understanding of the lunar stratigraphy, it also aids in supporting new scientific queries and technology development for future missions [15].

Methods: We used Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle (WAC; 100 m/pixel) and Narrow Angle (NAC; ~0.5-1.2 m/pixel) images [2] along with the Selene/Kaguya image mosaics. Albedo differences were mapped mainly using the LRO WAC data. The topographic differences were mapped using various digital elevation models (DEM), including LRO WAC derived DEM (100 m/pixel) [3], LOLA DEM (100 m/pixel) and LOLA/Kaguya merged DEM (60 m/pixel) [4]. We used Clementine [5], Chandrayann-1 Moon Mineralogy Mapper (M^3) [6], and Kaguya Multiband Imager (MI) data [7] to identify and map the spectral differences of various geological units.

We adapted the stratigraphic scheme of Wilhelms (1987) [1]. The used symbology follows the standards of Federal Geographic Data Committee (2006) [16], and the used nomenclature is consistent with the Gazetteer of Planetary Nomenclature (1999) [17].

Geological units: Following the Wilhelms (1987) [1] stratigraphic scheme, the generations of the craters were mapped as *Cc* (Copernican craters), *Ec* (Eratosthenian craters), *Ic* (Imbrian craters), and *Nc* (Nectarian craters) or *pIc* (pre Imbrian craters). The highlands around the landing sites includes the Fra Mauro Formation Imbrium basin ejecta units: *Ifm* (Imbrian Fra Mauro formation) and *Ifs* (Imbrian Fra Mauro smooth plains); *Ip* (Imbrian plains); in addition to older units like *IpIt* (Imbrian pre-Imbrian terrains). Units similar to *IpIt* are older terrains covered mostly by Imbrian material. Mare units were mapped on the basis of spectral differences [e.g., 5-7], thus the mapped boundaries are marked as approximate spectral contacts [e.g., 18]. The stratigraphy of the mare units is based on the crater densities derived from crater size-frequency distribution measurements [e.g., 18-23].

Implications: Detailed geological mapping is essential for the definition of homogeneous areas, which are required to measure CSFDs and deriving AMAs for the unsampled geological units of the planetary bodies [e.g., 8-14,18-23]. In our ongoing systematic studies [18-23], we used our detailed geological mapping to test the lunar cratering chronology [24].

The recent developments of new technology require profound lunar geological knowledge for fulfilling scientific goals. Van der Bogert (2020) [15], studies show the use of our detail geological map as a tool to detect safe resource deposits for the demonstration of the In-situ resource utilization (ISRU) missions.

Our new comprehensive geological maps are also being used for the recognition of the origin of the collected samples [e.g., 25], which improve the understating of the geological processes that occurred throughout in the history of the Moon.

References: [1] Wilhelms (1987) *USGS Prof paper*: 1348. [2] Robinson et al (2010) *Space Sci. Rev. 150*, 81-124. [3] Scholten, et al. (2012). *JGR. 117*, E00H17. [4] Barker et al. (2016) *Icarus 273*, 346-355. [5] Pieters et al. (1994) *Science 266*, 1844-1848. [6] Isaacsom, et al. (2013). *JGR Planets. 118*, 369-381. [7] Ohtake, et al (2013) *Icarus 226*, 364-374. [8] Neukum, et al. (1975) *The Moon 12*, 201-229. [9] Neukum, (1983) *Habil. thesis, U. of Munich.* [10] Neukum, et al. (2001) *Space Sci. Reviews 96*, 55-86. [11] Stöffler, et al. (2006) *Reviews in Mineral. & Geochem. 60*, 519-596. [12] Hiesinger, et al. (2000) *JGR 105*, 29239-29275. [13] Hiesinger, et al. (2003) *JGR 108*, E001985. [14] Hiesinger, et al. (2012) *JGR 11*, E00H10. [15] van der Bogert, et al. (2020) *LPSC 51, #*1876. [16] FGDC (2006). *FGDC-STD-013-2016.* [17] Blue, J. (1999) Gazette. of Planet. Nomen. *USGS.* [18] Iqbal, et al (2019) Icarus 333, 528-547. [19] Iqbal, et al (2018) LPSC 49, 1002. [20] Iqbal, et al (2019) LPSC 50, 1005. [21] Borisov, et al (2019) LPSC 50, 2323. [22] Gebbing, et al (2019) LPSC 50, 2337. [23] Iqbal, et al. (2020) *LPSC 51, #* 1073. [24] Hiesinger, et al. (2020) *LPSC 51, #* this conference. [25] Haber, et al (2018) *AGU*, P31G-3785.

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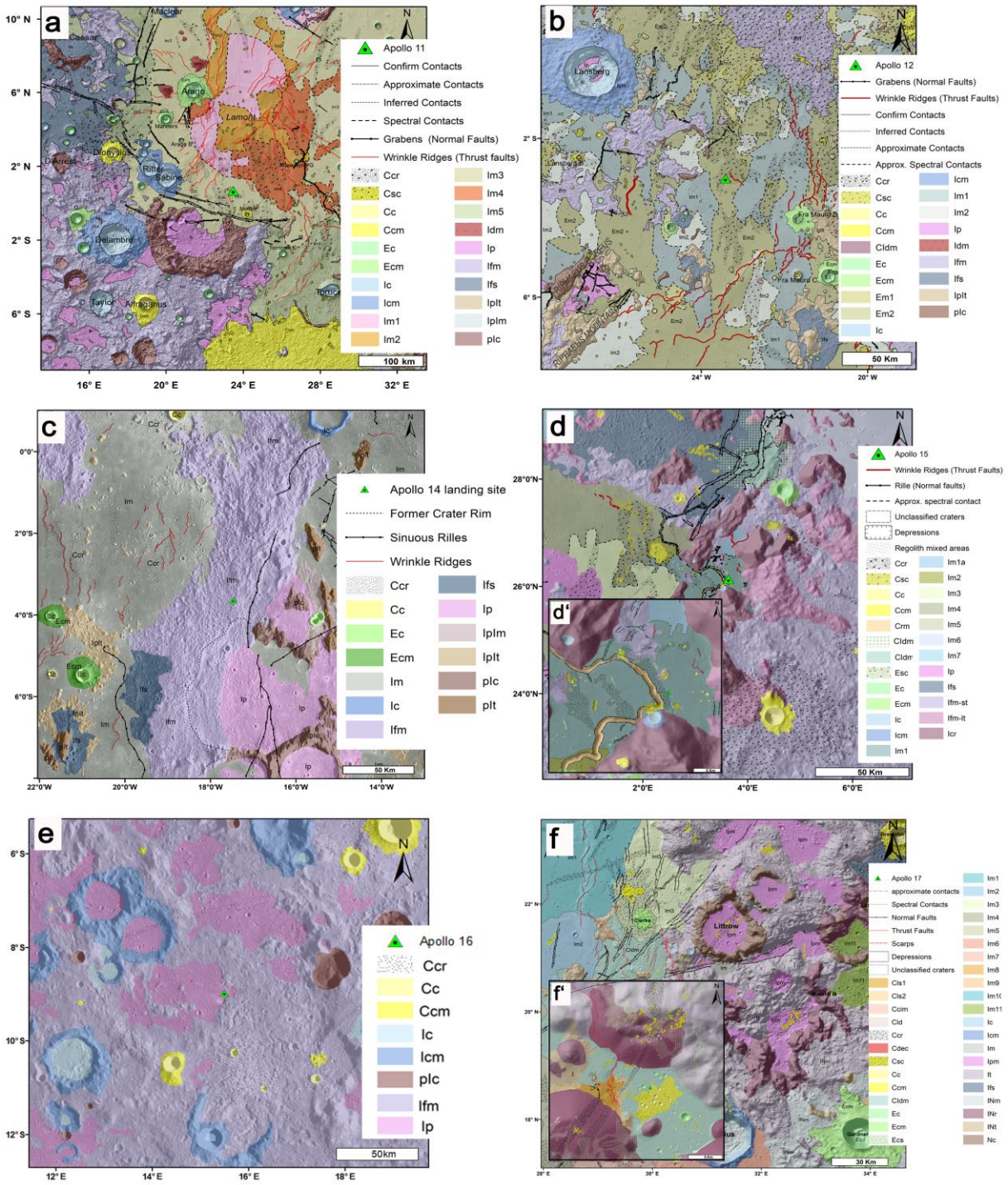

Figure 1. *New detailed geological maps of the Apollo landing sites. (a) The Apollo 11 landing site region in southwestern Mare Tranquillitatis [18]. (b) The Apollo 12 landing site in Oceanus Procellarum, south of Copernicus crater [19]. (c) Preliminary map of the Apollo 14 landing site in the Fra Mauro formation (Ifm) [21]. (d) The Apollo 15 landing site, at the eastern rim of the Imbrian Basin [25] (d') preliminary local geological map around the Apollo 15 landing site. (e) Preliminary map around the Apollo 16 landing site*
[22]. (f) The Apollo 17 landing site near the eastern rim of Serenitatis basin [20] (f') the local geological map of the Tarus littrow valley around the Apollo 17 landing site. The green triangle shows the locations of the landing sites. (g) Legend of the mapped geological units.