Intrusions Below Volcanically Buried Craters in Mare Fecunditatis Indicated by Extrusive Features Associated with Mare Ridge Ring Structures. F. Zhang[1], M. -H. Zhu[1], [1]Space Science Institute, Macau University of Science and Technology, Taipa, Macau (fezhang@must.edu.mo).

Introduction: Mare ridge ring structures (MRRSs) are deformed surface features and have long been studied on the floors of the maria since the early exploration of the Moon [1, 2, 3]. They are ridge segments having the form of rings (circular, elliptical or irregular in shape) with the size varing from 1-2 km to over 80 km in diameter [1]. The analogical structures were also found in the northern plains of Mercury [8-10] and in the ridged plains volcanic units throughout Mars [11-13]. Several mechnisms have been proposed to explain the formation of MRRSs on the Moon, including: (i) volcanic in nature and occur in association with mare wrinkle ridges [1, 14]; (ii) the interaction of (impact) craters with molten lavas [4, 5, 15], as well as those similar analogs found on Mercury and Mars [8-13]; and (iii) more than one processes (volcanism and tectonism), including modification by endogenic processes [3]. However, the direct evidence which requires more confidence in linking subsurface magmatism to MRRSs is still lacked.

In this work, we highlight a category of mare ridge ring structures in Mare Fecunditatis that was not reported before and use the topographical and geometrical features to gain insight into the subsurface geology of Mare Fecunditatis.

Data and method: The overall characteristics and detailed small geologic features associated with MRRSs are investigated from the high-resolution images derived from LRO [16] and Kaguya [17]. Small surface feature which was not covered by LROC NAC image will be studied by using Kaguya Terrain Camera (TC) data [18]. At 10 m/pixel globally, the Kaguya TC data effectively bridges the gap of the resolution between the WAC (100 m/pixel) and the NAC (~1 m/pixel) data of LROC and thus provide an invaluable contextual information.

A Moon Mineralogy Mapper (M^3) mosaic of Mare Fecunditatis has been created at a resolution of 280 m/pixel by using 10 orbits of data from Optical Period 2C (OP2C) [19]. The level 2 reflectance M^3 data products that were derived from the level 1B reflectance data products with spectral resolutions of 20 and 40 nm, total 85 bands in global mode. Because the coverage of the Fecunditatis region is incomplete or absent from other observation period, the 280 m/pixel OP2C data are used to detect spectral properties of the volcanic features, though its resolution is two times lower than OP2A and OP1B. The detailed information of the calibration of M^3 can be found in previous studies [19, 20]. We obtained M^3 IBD color composite using the method adopted by the M^3 science team [21-23]. The color shown on the composite depends on relative ferrous band strengths and/or band centers that result from differences in mineralogy and optical maturity [21]. Thus, the composite can reveal useful information of geologic units with different composition.

Results: In this study, more than 50 MRRSs in the Fecunditatis basin were identified. Here, we present several typical examples from Fecunditatis MRRSs, which were not reported before. These MRRSs retain a series of volcanic landforms along their circular rings indicating extrusive features resulted from post-crater-formation magmatism. These structures are circled ridge segments with the diameter varied from ~12 to 30 km, ranked into the mid-size complex impact structures (e.g., ~15-30 km).

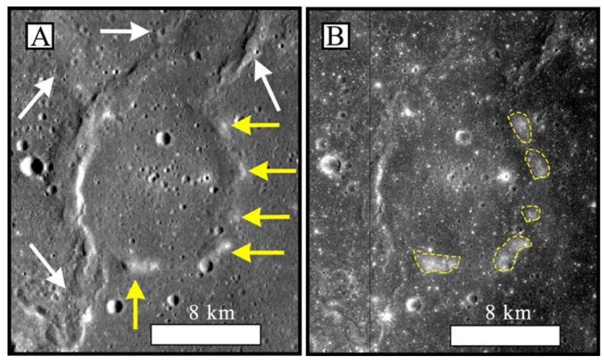

Fig. 1: A typical MRRS with five bright hills that compose the southeast part of a ring, the base maps are (A) Low illumination LROC WAC Mosaic and (B) Kaguya TC map, respectively.

Numerous bright hills on mare ridges have a higher albedo than the surrounding maria and exhibit a similar morphological and reflectivity characteristic as that on the highlands. Their occurrences are commonly interpreted to be volcanic in origin [1] or merely remnants of a former ejecta rim [3]. They range in height from a few tens of metres to over 0.5 km. The long axis of the hills follows the direction of the ridge ring (Fig. 1), suggesting a genetic relation to the ridge. The bright yellow color (Fig. 2B) of these hills shown on the M^3 IBD composite indicate that they have a different composition from the surrounding mare basalts.

Bright hills over MRRSs exhibit distinct variation in composition, indicated by M^3 reflectance spectra signatures. At least two common distinct colors are presented on the M^3 IBD composite: blue and bright yellow (Fig. 2). Each is fundamentally the result of differences in composition and optical maturity, with blue hue meaning having more similar composition with highland material resulting from higher near-infrared reflectance and lower mafic band strength [21]. Bright yellow hills show a different color from their surrounding 'red' basalts, suggesting their difference in composition. We initially interpret the bright hills to be (1) remnants of original crater rim crests or foreign material ejected from highland, and/or (2) later eruptive features subsequent to the MRRS's formation.

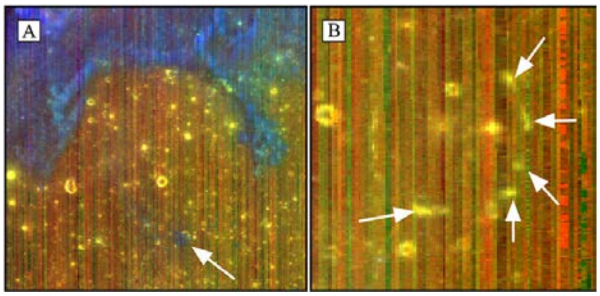

Fig. 2: Two distinct MRRSs with overlying bright hills showing 'blue' (A) and 'bright yellow' (B) colors on the M^3 composite, respectively.

Fig. 3 shows another typical MRRS (~ 36.62 km in diameter) with one side marked by circular wrinkle-ridge pattern and meanwhile, a chain of volcanic cone-like hills spatially arranged along its SE circular arc, marking the position of potential ring/arcuate fracture system. The rim crest of the impact crater has been almost completely flooded by lava. These cone-like hills (most are pitless cones) are elongated along the ring trend and have a height range from about 20 to 40 meters, which resemble in many respects several of the volcanic cones and domes in the Marius Hills [24]. The flow-like features at the base of these hills exhibit that they overlay surrounding mare surface, suggesting an extrusive origin of these cone-like hills.

Unlike the bright hills discussed above, these cone-like hills show the red hue from M^3 observation, spectrally identical to the surrounding mare, suggesting their basaltic composition in nature. Consequently, these cone-like hills may share a common magma source region with mare basalts around them. Thus, they may be most likely interpreted to be the result from volcanism along the circular/arcuate fracture near or over the original crater rim crest.

Discussion and Future Work: The detailed investigation on the volcanic features relevant to MRRSs can help provide deep insight into the internal magmatism beneath the original craters. The remote sensing data have provided us with solid evidence to prove the existences of extrusive and intrusive features associated with MRRSs, revealing lava ascent along ring fractures. This typical MRRS may have experienced multiple magmatic and tectonic stages including intrusion bellow the crater floor, spreading of the intrusive body, subsequent crater flooding, tectonic activity, and extrusion along the ring fracture. Meanwhile, it also implies that Mare Fecunditatis have a different geologic history from other basins, more complicated than we have thought. The detailed study of the formative mechanisms of varies of MRRSs in Mare Fecunditatis is required to reconstrcture the basin's geologic setting and understand the early magmatic and thermal history of the Moon.

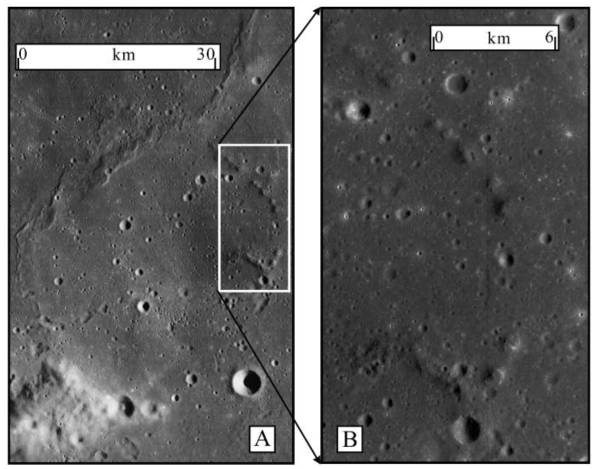

Fig. 3: A MRRS (A) with a series of volcanic cone-like hills (B) along its NE arc-shaped rim.

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