DIVERSE VOLCANIC ACTIVITY IN AND AROUND THE LUNAR FARSIDE CRATER ROSSELAND.
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Introduction: We investigated 28 volcanic mare deposits in and around Rosseland crater at the southern lunar farside. Rosseland Crater is a complex impact crater of about 65 km in diameter and is located between the Australe and South Pole-Aitken basins, south of Tsiolkovsky crater at 130.8° E and 40.7° S. In the map of Wilhelms and El-Baz from 1977 [1], this region is dominated by craters and basin materials of Pre-Nectarian and Nectarian age. The most prominent mare basalts are located inside Pauli crater in the east and Tsiolkovsky crater in the north. The geological map of Wilhelms and El-Baz [1] also shows some small mare patches in Roche and Bolyai craters and west of Rosseland.

We chose this area as a starting point to investigate all mare basalts on the lunar farside, to compare with the nearside to help us to understand the volcanic history of the Moon. While the lunar nearside is dominated by mare volcanism, the farside shows only isolated mare deposits in large craters and basins, such as the South Pole-Aitken basin and Tsiolkovsky crater [e.g., 1-4]. This difference in volcanic activity between the near- and farside is of crucial importance for understanding the volcanic evolution of the Moon [e.g., 9]. The extensive mare volcanism of the lunar nearside has already been studied in great detail by numerous authors [e.g., 4-8] on the basis of Lunar Orbiter and Apollo data. New high-resolution data obtained by the Lunar Reconnaissance Orbiter (LRO) [10] and the SELENE Terrain Camera (TC) [11] now allow us to investigate the lunar farside in great detail.

Basaltic volcanism on the lunar nearside was active for almost 3 Ga, lasting from ~3.9-4.0 Ga to ~1.2 Ga before present [5]. In contrast, most eruptions of mare on the lunar farside ceased much earlier, ~3.0 Ga ago [9]. However, [9] also found mare deposits that show much younger ages of ~2.5 Ga. Consequently, [9] concluded that farside volcanism might have occurred episodically, around 2.5 Ga and 3.0-3.6 Ga. However, they pointed out that the absence of volcanic deposits 2.5-3.0 Ga might also be explained as continuous resurfacing by younger deposits. It has been argued that the relatively large difference in the cessation of volcanic activity between the nearside (1.2 Ga) and farside (2.5 Ga) might be related to a greater crustal thickness on the lunar farside, which hinders lava eruption [9].

However, new data from the Gravity Recovery and Interior Laboratory (GRAIL) mission now show that the crustal thickness of the lunar farside is much thinner than previously thought [12]. Crustal thicknesses in our study area are 25 km to 35 km [map of 12], similar to crustal thicknesses beneath the lunar nearside mare basalts. In addition, [13] identified a possible ancient vertical tabular intrusion or dike, which stopped ~10 to 15 km below the surface in our area (Fig. 1).

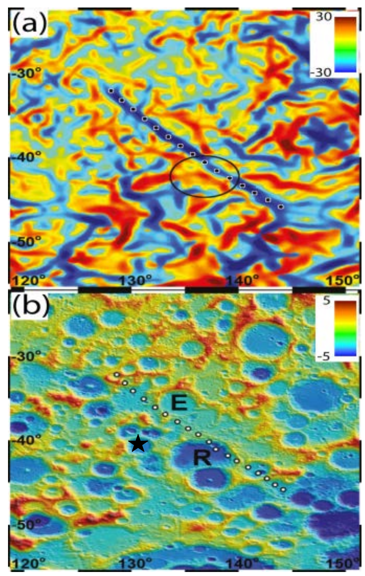

Figure 1: Modified figure from [13]. **(a)** Horizontal Bouguer gradient (in Eötvös units). **(b)** Topography (in km). Eötvös (E) and Roche (R) craters are labeled, Rosseland crater is marked with a black star. The dotted line shows the location of a potential dike [13].

Data: We used data from the LRO Wide Angle Camera (WAC: 100 m/pixel), Narrow Angle Camera (NAC: 1 m/pixel), and the Kaguya Terrain Camera (TC) (10 m/pixel) to identify and map individual volcanic deposits and to perform crater size-frequency distribution (CSFD) measurements. The combination of the global WAC mosaic with the FeO map of Lucey et al. (2000) [14] (100 m/pixel) based on Clementine data was used to identify and map individual basaltic deposits.

Absolute model ages: On the basis of WAC and TC images, we mapped the crater floor of Rosseland crater in more detail than Wilhelms and El-Baz [1]. We found seven separate FeO-rich volcanic deposits (FeO: 12-18 wt%) inside Rosseland crater between the central crater floor and the crater wall. The absolute model ages of six of these deposits vary between 1.5 and 2.9 Ga. We also identified FeO-rich volcanic deposits (FeO: 10-17 wt%) inside a crater north of Rosseland crater with an absolute model age of ~2.2 Ga.

We also mapped volcanic deposits west of Rosseland Crater, which exhibit absolute model ages of 2.1-3.8 Ga and show a FeO content of up to 18 wt%.

Another FeO-rich (14-18 wt%) volcanic deposit was identified south of Rossland crater. Our CSFD measurements of this unit show an absolute model age of 3.3 Ga, which is similar to the deposits on the western side of our study area. The volcanic deposits inside Bolyai crater have an absolute model age of 3.5 Ga. The relatively large mare basalts in Pauli crater show FeO contents of about 12-20 wt%, and our CSFD measurements reveal an absolute model age of ~3.2 Ga. The mare basalts in Roche crater are much smaller, but have similar FeO contents (13-18 wt%). The absolute model ages of these deposits show significantly younger ages of ~2.3 Ga. We also mapped the volcanic deposits north of Roche crater, previously mapped by [1], in much more detail. We identified seven separate mare deposits with ages of 1.9-3.1 Ga. Their FeO contents (10-17 wt%) are similar to all other deposits investigated.

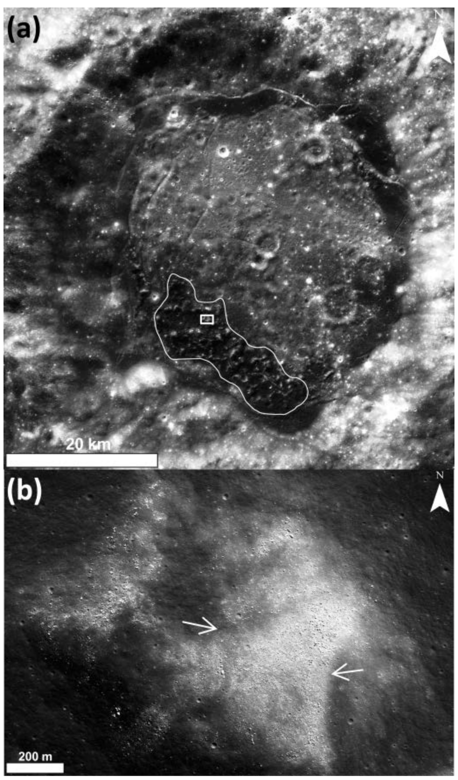

Figure 2: (a) Rosseland crater exhibits flat mare deposits in the east and north, and potential pyroclastic deposits in the south (white) [TC image]. The white box indicates the location of the NAC image in (b). **(b)** At higher resolution, bright boulder-strewn hills are mantled by dark material (contacts indicated by white arrows) [NAC image] We interpret the underlying bedrock, which might be responsible for the hilly topography, as megablocks of the crater wall.

Pyroclastic Deposits: One of the dark and FeO-rich deposits inside Rosseland crater has different morphology than the flat mare basaltic deposits (Fig. 2). In WAC images, the unit has a homogenous hilly appareance, but in TC and NAC images, we could identify relatively bright mountain peaks covered with meter-size boulders and a dark mantle material that seems to be superposed on the bright hills (Fig. 2). A 16 km long graben that cuts the hilly unit in north-west direction could be a possible vent. Thus, we interpret the dark mantle material to be pyroclastic deposits. The bright mountain tops themselves could be remnants of megablocks that slid down the crater wall during the crater modification stage.

The presence of possible pyroclastic deposits shows the diversity of the volcanic activity inside Rosseland crater.

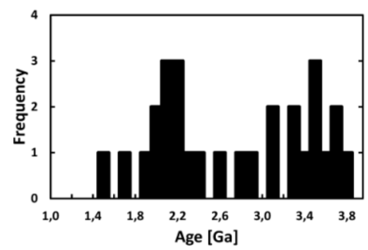

Figure 3: Histogram of model ages of the volcanic deposits in our study area. The youngest age at 1.5 Ga might be related to tectonic deformation of the respective volcanic deposit.

Discussion and Conclusions: Our investigation shows that the studied area was volcanically active over a very long time period (1.7-3.8 Ga). In general, this is in good agreement with studies by [9, 13] of other volcanic regions on the farside. [9] and [13] found absolute model ages of farside mare basalts, such as those in Moscoviense and Apollo crater, to range from 2.1 Ga to 3.8 Ga. While the oldest volcanic activity in our study area is in the same range, the youngest activity is younger by ~300 Ma. In addition, most of the mare basalts investigated by [9, 15] have ages of about 3.4 Ga, while the volcanic deposits in our study area show peaks at ~2.2 and 3.4 Ga (Fig. 3).

It might be possible that the pressumed dike [13] underneath our study area and the relatively thin crust [12] could have affected the volcanic activity in this area, which might explain the relative young absolute model ages in our study area. We identified several tectonic grabens that might have overprinted the volcanic deposit with the youngest absolute model age of 1.5 Ga. However, these tectonic grabens are probably not related to the dike underneath this area, because [13] pointed out that the possible dike might be much older.

References: [1] Wilhelms and El-Baz (1977) Geologic Map of the East Side of the Moon, *I-948.* [2] D. E. Stuart-Alexander, U.S. Geol. Surv. Map I-1047 (1978). [3] A. S. Walker, F. El-Baz, *Moon Planets* 27, 91 (1982). [4]Wilhelms D.E. (1987) *USGS Prof. Pap. 1348*, 302 pp. [5] Hiesinger H. et al. (2011) *The Geol. Soc. of A. Spec. Paper 477.* [6] Hiesinger H. et al. (2000) *J. Geophys. Res, Vol. 105.* [7] Hiesinger H. et al. (2003) *JRL, 108.* [8] Bugiolacchi R. and Guest J.E. (2008) *Icarus, 197*, 1–18. [9] Haruyama et al. (2009) *Science Vol. 323.* [10] Robinson et al. (2010) *Space Sci. Rev.*, 150, 81–124. [11] Haruyama et al. (2008) *Earth Planets Space*, 60, 243–255. [12] Wieczorek et al. (2013) Science, 339. [13] Andrews-Hanna et al. (2013) *Science*, 339. [14] Lucey P. G. et al. (2000) *J. Geophys. Res. 105.* [15] Morota et al. (2011) *Earth Planets Space, 63*, 5-13. [16] H. Hiesinger et al. (2012 *J. Geophys. Res.*, 117.