THE CHANG'E-5 MISSION TO YOUNG MARE BASALTS: GEOLOGICAL CONTEXT AND EARLY RESULTS. Yuqi Qian[1,2], Long Xiao[1*], and James W. Head[2*], [1]Planetary Science Institute, China University of Geosciences, Wuhan, 430074, China (longxiao@cug.edu.cn), [2]Department of Earth, Environmental, and Planetary Sciences, Brown University, Providence. 02912, USA (James_Head@brown.edu)

Introduction: The Chang'e-5 (CE-5) mission, China's first lunar sample return mission [1], landed in Northern Oceanus Procellarum at 43.1°N, 51.8°W on December 1, 2020, and collected 1731 g of lunar samples, including ~1480 g of scoop samples and ~251 g of drill samples (~1 m) [2], returning these to Earth on December 17, 2020. The CE-5 landing site is ~170 km ENE of Mons Rümker, and is characterized by some of the youngest mare basalts (Em4/P58) on the Moon [3, 4]. Young mare basalts have significant scientific importance for improving our understanding of recent lunar thermal evolution and impact history [5]. We describe the geologic background and setting of the CE-5 site in order to provide context for the ongoing sample analyses and report some early results based on the CE-5 samples.

Northern Oceanus Procellarum: Northern Oceanus Procellarum is on the northwest lunar nearside, to the west of the Imbrium basin, and in the center of the Procellarum KREEP Terrane (PKT) [7], which is characterized by elevated heat-producing elements and prolonged volcanism. This region exhibits a huge volcanic complex, i.e., Mons Rümker [8], and two episodes of mare eruptions, i.e., Imbrian-aged low-Ti mare basalts in the west and Eratosthenian-aged intermediate-Ti mare basalts (Em3 and Em4/P58) in the east (Fig. 1) [3]. CE-5 landed on the Em4/P58 unit [5], superposed on the Imbrian-aged basalts and the PKT highland crust (Fig. 2).

The Em4/P58 unit, on which CE-5 landed, is one of the youngest mare basalts on the Moon [4]. Various researchers have reported somewhat different CSFD results; however, all of them point to an Eratosthenian age for Em4/P85 (1.21 Ga [3], 1.33 Ga [4], 1.53 Ga [5], 1.91 Ga [9]), and minor age variations are observed across Em4/P58 [5]. Em4/P58 mare basalts have intermediate-Ti and high-Th abundances [5]. Em4/P58 mare basalts cover an area of ~37,000 km^2, with a mean thickness of ~51 m and a volume of ~1450-2350 km^3 [5].

No specific volcanic source vents (e.g., fissures, cones, domes) were found within the unit, except for sinuous rilles and their source vents. Rima Sharp extends across Em4/P58, only ~15 km east of the landing site. CE-5 basalts collected at the site most likely originated from the source vent of Rima Sharp in Sinus Roris, described in detail in [10, 11].

Provenance of Lunar Regolith: We have investigated impact craters than can potentially contribute nonnegligible ejecta to the CE-5 landing site [12] and found only 48 craters that are predicted to provide >1 cm ejecta thickness, with the parent crater formation ages mainly < 200 Ma. More than half of the ejecta predicted to be at the site is from Xu Guangqi (~37%) and IC-265 (~29%), which are 424 and 89 m away from the site. CE-5 landed on the continuous ejecta of Xu Guangqi (Fig. 3) (diameter of ~419 m [12]). Xu Guangqi could excavate ~35 m deep into the subsurface, a depth insufficient to punch through the ~51 m thickness estimated for the Em4/P58 basalts; therefore, we interpret the CE-5 samples to be dominated by Em4/P58 basalts fragmented by the Xu Guangqi impact.

Early Results: CE-5 returned samples have been distributed to scientists chosen from competitive proposals beginning in July, 2021, and early results have been reported since then.

Remote sensing observations of the CE-5 basalts are consistent the returned sample analyses (TiO_2, ~6-8 wt%; FeO ~22-25 wt%; MgO, ~5 wt%; Al_2O_3, <11 wt%; K, <2000 ppm; Th, ~4.7 ppm) [2, 13], strengthening the interpretation that the CE-5 samples primarily represent the mare unit on which it landed. The Mg# of the CE-5 basalts is extremely low (<35), interpreted to indicate that CE-5 basalts formed by evolved magma [2, 13].

The CE-5 mare basalts have an age of ~2.0 Ga based on Pb-Pb isochrons of basaltic clasts [13, 14]; this suggests that the lunar chronology function does not need major revision for the age range of 1.0-3.0 Ga. The CE-5 basalts have a mantle source region characterized by a low $\mu(^{238}U/^{204}Pb)$ value (677±320 [13]; 684±40 [14]), indicating that the CE-5 basalts were produced by melting of a KREEP-poor source. The Sr-Nd isotopes and REE patterns further suggest that the CE-5 basalts experienced low-degrees of partial melting (2-3%) and extensive fractional crystallization (43-78%) [15]. The ~51 m lava flow unit from Rima Sharp may provide the thick lava flow and slow cooling rate necessary to explain the observed extensive fractional crystallization [10, 11].

References: [1] Zhou C. et al. (2021) *Adv. Sp. Res. 69*, 823–836. [2] Li C. et al. (2021) *Natl. Sci. Rev.* nwab188. [3] Qian Y. et al. (2018) *JGR-Planets*, *123*(6), 1407-1430. [4] Hiesinger H. et al. (2011) *Spec. Pap. GSA, 477*, 1-47. [5] Qian Y. et al. (2021) *EPSL*, 555, 116702. [7] Jolliff B. L. et al. (2000) *JGR*, *105*, 4197–4216. [8] Zhao J. et al. (2017) *JGR*, 122, 1419–1442. [9] Morota T. et al. (2011) *EPSL*, *302*, 255–266. [10] Qian Y. et al. (2021) *GRL*, 48, e2021GL092663. [11] Wilson L. (2022) *53rd LPSC*. [12] Qian Y. et al. (2021) *GRL*, *48*, e2021GL095341. [13] Che X. et al. (2021) *Science*, *374*, 887-890. [14] Li Q. et al. (2021) *Nature*, *600*, 54-58. [15] Tian et al. (2021) *Nature*, *600*, 59-63.

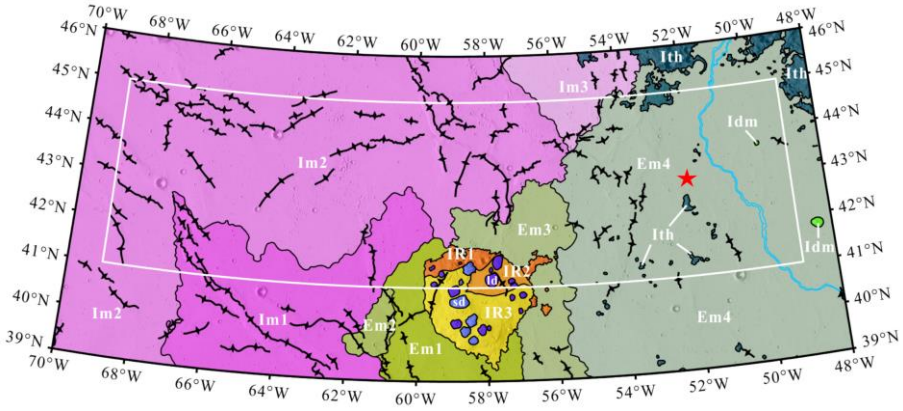

Figure 1. Geological map of the Chang'e-5 landing site, modified from [3]. The red star indicates the CE-5 landing site. The blue lines indicate Rima Sharp.

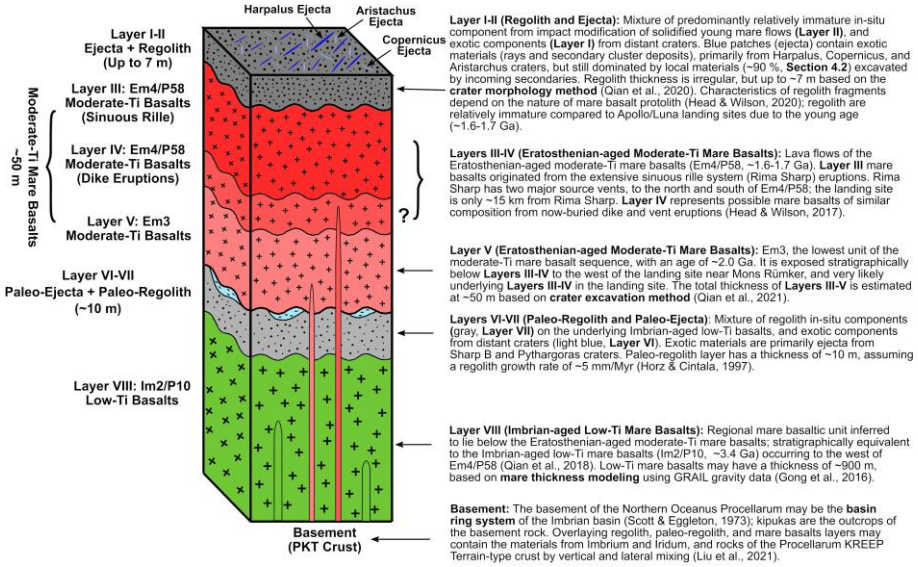

Figure 2. Geological column for the CE-5 landing site in Northern Oceanus Procellarum. CE-5 landed on the Eratosthenian-aged mare basalts (Em4/P58), overlying Imbrian-aged mare basalts.

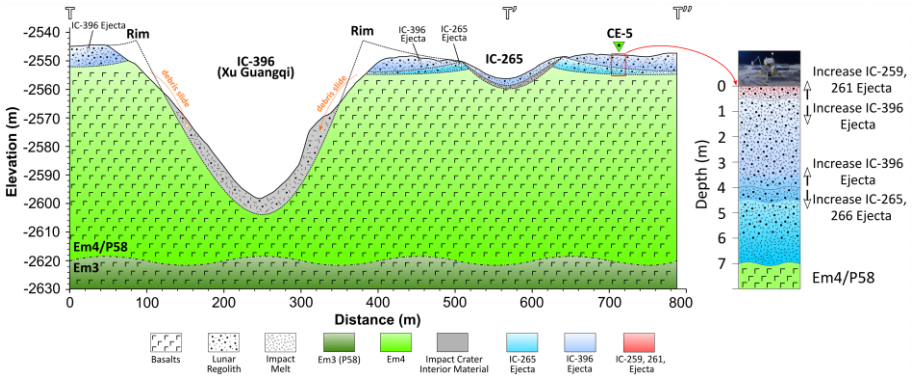

Figure 3. Stratigraphy of the CE-5 landing site. CE-5 landed on the continuous ejecta of Xu Guangqi crater. CE-5 samples are interpreted to represent the ejecta material of Xu Guangqi, dominated by Em4/P58 basalts largely fragmented by the Xu Guangqi impact event.