ANALYSIS OF THE RUMKER HILLS REGION: CHANG'E 5 LANDING SITE ASSESSMENT. T.A. Giguere[1], J.J. Gillis-Davis[1], D. Trang[1], and B. L. Jolliff[2]. [1]Hawaii Institute of Geophysics and Planetology, Univ. of Hawaii, Honolulu, HI 96822, [2] Department of Earth & Planetary Sciences and the McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130. (giguere@hawaii.edu).

Introduction: The China National Space Administration (CNSA), building on several recently successful lunar Chang'e (CE) missions [1-3], has ambitious plans for future CE missions to the Moon. CE4, back up mission to CE3, is targeted for landing on the farside with a rover [4]. CE5 is planned to return a sample from the nearside. The most likely launch date is 2019 (owing to recent booster issues), with a mission goal of returning up to 2 kg of regolith from a depth of up to 2 meters [10]. Site selection must consider the fact that CE5 has no rover. Although multiple sites have been put forth, consensus is that the best science potential lies in northern Oceanus Procellarum on [5-7] or in the vicinity of Mons Rumker, 40.8° N, 58.1° W [8,9]. Samples from this region would have compositions and ages different than any material currently in the lunar sample collection. While remote spectral methods are highly capable at determing bulk chemical/mineralogy properties, a sample returned from this region is a high priority for three reasons: 1) laboratory analyses would provide measurements of trace element and major element chemistry/mineralogy of various regolith components, 2) ages for these returned materials would potentially fill in gaps in the lunar thermal evolution time scale, and 3) age determination by geochronologic methods is most precise with lab samples [8].

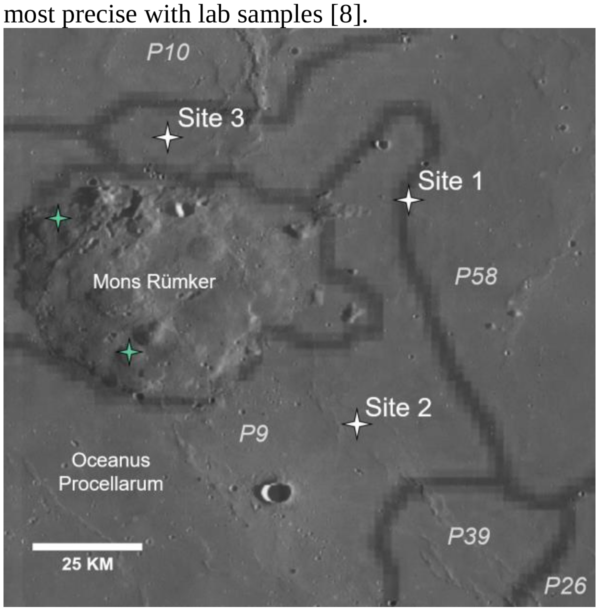

Figure 1. *Potential Chang'e 5 landing sites, white stars. Spectrally defined units, light black outlines, Hiesinger et al, [12,13]. Landing sites suggested by other workers, green stars [7]. North is up.*

Previous workers [6,7] focused on the geology of the Mons Rumker volcanic complex. Based on their crater counts, three plateau-forming units were identified on the complex as Upper Imbrian [11] with ages that vary from 3.51–3.71 Ga. The youngest units identified (3.04 and 2.91 Ga) were located on steep-sided domes on the southern part of the complex. A sample from Rumker Hills, while valuable for potentially sampling a different mare composition would only sample that composition because of the edifice height.

Investigators have also focused their attention on basalt flows surrounding the Mons Rumker volcanic complex. Basaltic units defined by [12,13] based on Clementine multi-spectral data were reexamined with M^3 hyperspectral data [9]. The youngest mare unit was found to contain unusually high olivine content [9,14].

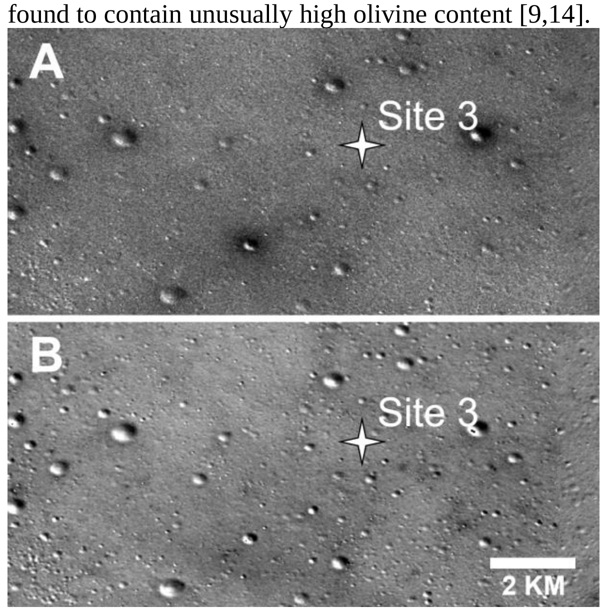

Figure 2. *Kaguya MI geochemical values for potential Chang'e 5 landing site #3, white stars. A) TiO_2 distribution for the landing site and surrounding areas. B) FeO distribution. Lighter shades indicate higher values, see text for discussion. North is up.*

We concur with some previous authors [8,9] that sampling the younger mare units in the area around Mons Rumker is a key science goal. This study identifies three candidate CE5 landing sites in support of the CNSA lunar mission; at each location we 1) characterize the chemical composition and stratigraphy of mare basalts and nearby Mons Rumker material, which provides insight into the compositional evolution of erupted material over time, 2) determine the absolute model age of mare surfaces in the area, 3) assess the resource potential of the soils at each candidate landing site, 4) determine the optical maturity of the regolith at each location based on remote means [15], and 5) provide an analysis of the topography and expected obstacles for the safety of the lander. These pre remote sensing data will place the return samples into a regional geologic context.

Data and Methods: Both Lunar Reconaissance Orbiter (LRO) Wide Angle Camera (WAC) (high and low incidence) and Narrow Angle Camera (NAC) images were used in this study [16,17]. Topographic data were provided by the WAC GLD100 [18] digital topographic model (DTM). The LRO Diviner Lunar Radiometer Experiment surface rock abundance map data at 128 m/pixel [19,20] were used to characterize the abundance of blocks >1 m in size on and near the sites. The Clementine 5-color UV-VIS digital image model (DIM; [21]) was used to produce Optical Maturity, FeO and TiO_2 maps [22,15]. Image data from the SELENE "Kaguya" monochromatic Terrain Camera (TC) [23] and the Multi-band Imager (MI) [24] visible and near-infrared multispectral camera were used for detailed surface and geochemical analysis.

Results and Discussion: We select three sites with the intension that each site would sample a span of ages and compositions. The regolith at each landing site will consist of a complex mix of both local and distal material [27,28,29] via impact cratering. Site #1 is on unit P58 (the youngest basalt in region) would also sample P9. Site # 2 is on P9, could also sample P26, P39, and P58. Site #3 would sample P58 and P10. Each of the sites is within range of sampling some material ejected by impacts into the elevated Mons Rumker complex.

One of the first science assessments is the age of the basalts. Model age dates of Clementine spectrally defined units (Fig. 1) surrounding Mons Rumker exhibit a range of ages [12,13] (Table 1). At some point it may be useful to define new units based on updated spectral boundries (e.g., M^3, Chandrayaan-1). Depending on landing site, returned mare samples could have absolute ages that span from the Upper Imbrian to the late Eratosthenian; and, if particles from the Mons Rumker complex are fortuitously collected, the age span could reach to the Lower Imbrian [11]. Age results for these youngest basalts would provide precise absolute dates for the end of lunar volcanism (e.g., 25,26).

***Table 1** Model ages of spectral units in Fig. 1*

Unit[12]	Age (Ga)[12,13]	Unit[12]	Age (Ga)[12,13]
P9	3.47	P26	2.96/3.49
P10	3.44	P39	2.19
P13	3.40	P58	1.33

Our focus is on the northernmost candidate landing site #3 (Fig 1). The Kaguya [24] and Clementine [22, 15] geochemical datasets were examined to characterize the composition of the mare basalts at the site (Fig 2). The surface regolith FeO values are fairly uniform, varying only about 0.5 wt. % from the mean of 16 wt. %. Similarly, the TiO_2 values averaged 4 wt. % and also varied 0.5 wt. %. The other two landing sites had similar FeO values (<1 wt. % higher) and higher TiO_2 values (1-2 wt. % higher). Higher values of TiO_2 in the soil, coupled with increased maturity, provides for greater availability of helium-3 (^{3}He), which is a potential non-radioactive fusion fuel. Ilmenite ($FeTiO_3$) retains helium more effectively than other lunar minerals [30,31].

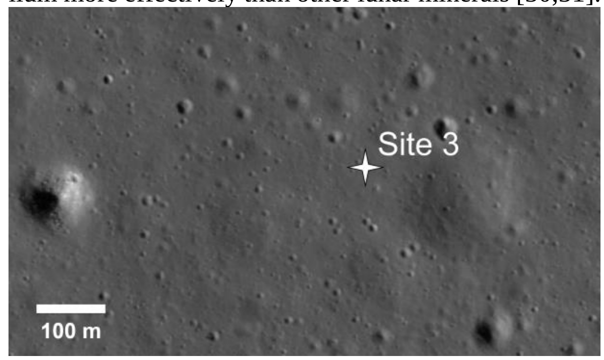

Figure 3. *Obstacle free site 3, north of Mons Rumker. NAC frame M1173450139R, resolution: 1.4 m, inclination: 74°.0. North is up.*

Hazard avoidance is key to the safety of the lander. A sample area for site 3 was selected to determine the surface rock abundance using Diviner data; the area excluded fresh craters. The mean surface rock abundance for the area is 0.5% with a std. deviation of 0.18%. This surface rock abundance value is comparable to the modal rock abundances for average highlands, and maria, which are 0.4, and 0.5%, respectively [20]. A visual inspection was conducted using high resolution LROC NAC frames. There are small craters (<10m) in the vicinity, however, no boulder fields were observed (Fig 3). In addition, ghost craters (older craters that were subsequently filled with lava) are observed, which suggests the presents of an older basalt unit that could be sampled by verticle crater mixing.

Summary: Several mare areas in Oceanus Procellarum near Mons Rumker meet the requirements for a safe, scientifically productive sample return mission. We offer 3 landing sites that provide crucial ground-truth testing of remotely determined composition, model age, and optical maturity as well as assessment of sample resource potential and determination of the age for the end of lunar volcanism.

References: [1] Huixian et al. (2005) Jrnl earth system sci. 114(6). [2] Zhu et al. (2013) Sci. Rpts, 3. [3] Xiao (2014) Nat. Geosci., 7(6). [4] Stooke (2017) Plan. Rpt. [5] Li et al. (2012). AGU. [6] Zhao et al. (2016) LPSC XLVII #1758. [7] Zhao et al. (2017) JGR. [8] Jolliff et al. (2017) LDSE. [9] Ling et al. (2017) LPSC 48, #2079. [10] Zou & Li (2017) LPSC 48, #1730. [11] Wilhelms et al. (1987) Geol. Hist. Moon (1348). [12] Hiesinger et al. (2003), JGR, 108(E7). [13] Hiesinger et al. (2011) GSA Spec. Prs, 477. [14] Staid et al. (2011) JGR 116(E6). [15] Lucey et al. (2000) JGR, 105 (E8), 20,377. [16] Robinson et al. (2010) Spac Sci. Rev. 150, 81. [17] Speyerer et al. (2011) LPSC 42, #2387. [18] Scholten et al. (2012) JGR, 117. [19] Paige et al. (2010), Space Sci. Rev., 150. [20] Bandfield et al. (2011), JGR, 116. [21] Eliason et al. (1999) LPS 30, #1933. [22] Lucey et al. (2000) JGR, 105 (E8), 20,297. [23] Haruyama et al. (2008) Earth Plan. Space, 60. [24] Ohtake et al. (2008) Earth Plan. Space, 60. [25] Schultz & Spudis (1983) Nature 302(5905). [26] Head (1976) Rvws of Geophys. 14(2). [27] Arvidson et al. (1975) EMP 13(1). [28] Li & Mustard (2000) JGR, 105(E8). [29] Huang et al. (2017) JGR. [30] Johnson et al. (1999) GRL, 26(3). [31] Fa & Jin (2010) Chinese Sci. Bul. 55(35).