USING ArcGIS TO IDENTIFY LANDING SITES WITH DIVERSE MARE BASALT COMPOSITIONS.

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Introduction: The Moon and the early Earth have closely linked compositional and thermal histories during formation [1]. The integration of petrographic, chemical, isotopic, and age studies of basalts guides our understanding of the magmatic evolution of these bodies. Due to the multifaceted nature of studying basalt petrogenesis, a spatially and chemically diverse set of samples is needed to resolve discrepancies between petrogenetic models [e.g., 2].

Samples returned by the Apollo and Luna missions include several types of basalts, but global remote sensing data produced by the Clementine and Lunar Prospector missions suggest a much broader range of compositions exist on the lunar surface. Therefore, a strategic assessment of potential landing sites suitable for sampling additional basalts is needed. We compiled detailed global compositional information using ArcGIS to identify key basalt units that remain unsampled, and to locate sites where those basalts are interstratified in an interpretable geologic context. Carlini D crater, located in Imbrium Basin, is an example landing site that can provide access to multiple compositionally distinct and previously unsampled basalt flows in possible stratigraphic context.

Methods: Chemical criteria for locating unsampled basalt units were compiled from the literature and available compositional datasets. Remote sensing data from the Clementine and Lunar Prospector missions provide global geochemical information of the lunar surface. The three datasets used to produce maps of possible landing sites are (i-ii) weight percent FeO and TiO_2 values derived from the LPI Clementine Mapping Project using the *Lucey et al.* [3] method and a resolution of 0.5 km/pixel and +/- 1wt. %; and (iii) Th abundances derived by the Lunar Prospector mission in half degree intervals and with less than 1 ppm margin of error [4]. Global compositional information was compiled in a spatial context using ArcGIS. We also quantitatively combined compositional global maps with possible stratigraphic and volcanic features [5], pyroclastic deposits, and geologic surface ages [6]. The compiled information was utilized to find an example location where multiple compositionally diverse, and interstratified basalt flows could be studied [7].

ArcGIS Fe-Ti-Th Ratio Maps: The combination of Fe, Ti, and Th concentrations provides more comprehensive constraints on the global distribution and variability of lunar basalts. Several authors [e.g., 8-13] have used elemental ratios with different techniques and programs to identify various rock types and regions, which have produced significant findings. However, due to the varying techniques and programs employed, it is difficult to compare the results quantitatively. ArcGIS allows for qualitative and quantitative comparison of multiple types of datasets as well as universal accessibility of created layers, thus supplying easy-to-use files for future mission planning. The ArcGIS created ratio maps reveal regions of potentially unsampled basalt compositions. Figure 1 shows Clementine FeO divided by Clementine TiO_2 concentrations in each pixel. Several areas of additional diversity are outlined with black ellipses. Major areas of potentially unsampled basalts include Mare Frigoris, northern Mare Imbrium, Oceanus Procellarum, Aristarchus, and a cryptomaria region south of Mare Humorum. Compared to the Apollo and Luna landing site compositions, these unsampled regions have different compositional values of FeO and TiO_2.

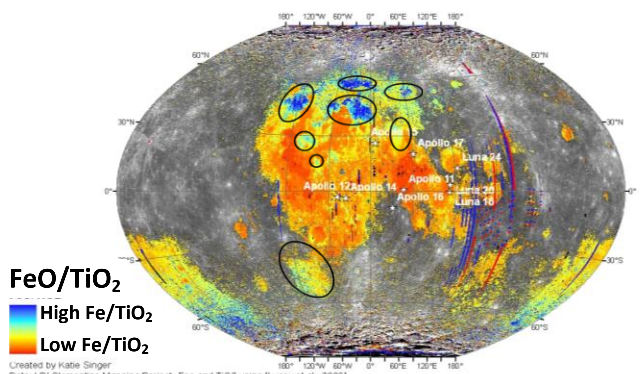

Figure 1. Fe-Ti ratio map for tentative volcanic compositions. Black ellipses represent example regions of unsampled FeO/TiO_2 ratios. The color scale represents relative compositions.

A Fe and Th ratio map (Fig. 2) shows potential locations where KREEP basalts might be found, as well as presenting a more comprehensive comparison for determining locations with additional chemical diversity. The majority of unsampled Fe/Th compositions are located in Oceanus Procellarum, southern Mare Imbrium, Mare Serenitatis, Mare Nubium, and Mare Humorum. Some of the regions with unsampled Fe/Th and Fe/Ti overlap, which make them particularly interesting targets for exploration. Ultimately, combining many high resolution datasets will provide the best constraints on potentially unsampled basalt types.

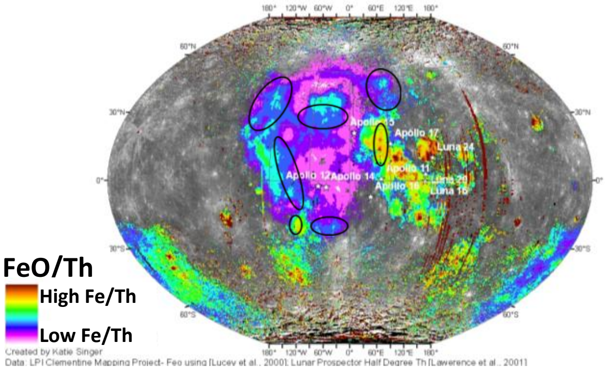

Figure 2. Fe-Th ratio map for tentative volcanic compositions. Black circled regions represent areas of unsampled FeO/Th ratios. The color scale represents relative compositions.

A Potential Landing Site: A candidate site with multiple flows in temporal context is located in the northern Mare Imbrium region. The northern portion of the area contains two separate flows (Fig. 2): a younger flow (orange color) on top of an older flow (blue color), based on crater ages, photogeologic methods such as albedo and flow margins, and remote sensing data [e.g., 14-15, 8]. After a detailed survey of this region, we determined that the crater Carlini D (diam. ~9 km; 33°N, 16°W) provides the best location for astronauts to sample potentially three different basalt flows in stratigraphic context, either by sampling exposed layers in the crater wall (rim to floor depth of crater is 1170 m) [16] or by sampling the ejecta in a radial traverse towards the crater rim (Fig. 3). The compositions within the center of Carlini D are similar to an older northern Mare Imbrium flow (blue color (Fig. 2) and Mare Frigoris; therefore, Carlini D may provide samples similar to both of these major unsampled regions. These samples have KREEP features (like those at Apollo 15 landing site), but are chemically distinct. As higher resolution spectral data is collected and more precise chemical data becomes available, the techniques outlined in this report can be expanded to provide more detailed, user-friendly, and accessible information for determining potential landing site locations.

Summary: 1) ArcGIS provides detailed global compositional information in a spatial context and allows for quantitative combination of global maps with stratigraphic features, volcanic features, and pyroclastic deposits that will assist mission planners in locating sites with unsampled volcanic products. 2) Regions on the Moon where previously unsampled and diverse basalts may be found include Mare Frigoris, Mare Imbrium, Oceanus Procellarum, Aritarchus including the Harbinger region [7], Mare Serenitatis, Mare Nubium, Mare Humorum, and the cryptomaria region south of Mare Humorum. 3) Carlini D provides multiple, compositionally distinct potential basalt flows in possible stratigraphic context, including possible KREEP volcanic samples.

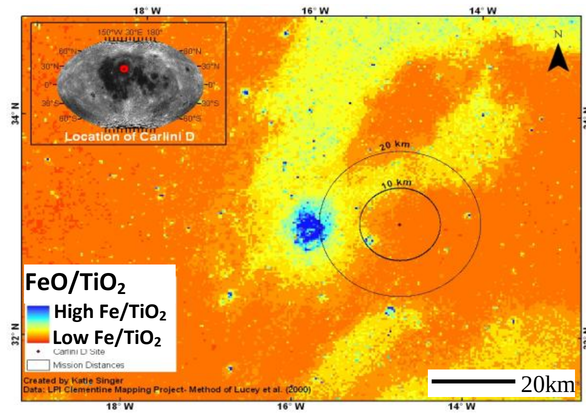

Figure 3. Map of potential landing site, Carlini D, showing FeO/TiO_2 variations within nominal traverse limits of 10 and 20 km. The Fe-Ti ratio data of tentative Mare is from Clementine using the *Lucey et al.* [2000] method. Inset map shows location of the small crater in northern Mare Imbrium.

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