MARE FRIGORIS: WINDOW INTO THE EVOLUTION OF THE LUNAR MANTLE. G. Y. Kramer[1], B. Jaiswal[2], B. R. Hawke[3], T. Öhman[1,4], T. A. Giguere[3,5], and K. Johnson[1], [1]Lunar and Planetary Institute, Houston, Texas, USA, [2]ISRO Satellite Centre, Bangalore, India, [3]Hawaii Institute of Geophysics and Planetology, University of Hawai'i at Manoa, Honolulu, Hawaii, USA, [4]Arctic Planetary Science Institute, Rovaniemi, Finland, [5]Intergraph Corporation, Kapolei, Hawaii, USA.

Introduction: We recently completed a detailed investigation of Mare Frigoris and Lacus Mortis using remote sensing data from Clementine, Lunar Prospector, and Lunar Reconnaissance Orbiter, with the objective of mapping and characterizing the compositions and eruptive history of its volcanic units [1]. With the exception of two units in the west, the basalts in Mare Frigoris and Lacus Mortis are low-Fe, low- to very low-Ti, high-Mg, and high-Al, relative to typical lunar mare compositions [1-6]. In addition to several basalt units that make up the mare, the region hosts a variety of geologic features including light plains deposits, pyroclastic deposits, cryptomare, volcanic vents, rilles, graben, wrinkle ridges, lobate scarps, and gravity anomalies [7-9]. Mare Frigoris is crossed by numerous crater ejecta rays delivered from laterally distant impact events in the surrounding highlands, as well as more locally: from large impacts that penetrated the smooth basaltic crust and ejected underlying feldspathic materials. While these are all excellent reasons for future investigations of Frigoris, this abstract discusses the three most compelling reasons.

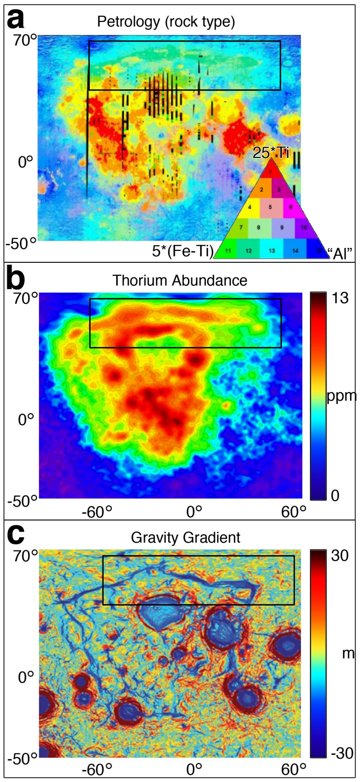

Figure 1: Black box shows location of Frigoris region. (a) Petrology map from [14]. Feldspathic, anorthositic highlands appear in blue colors, high-Ti mare basalts are red, low and intermediate-Ti units are yellow and orange. Most of Mare Frigoris is green: very low-Ti and very low-Fe, and is very different from other maria. (b) Thorium abundance from LP-GRS. (c) GRAIL Gravity Gradient map. From [13].

High-Al Basalts: The relatively low-Fe and high-Al abundances of the Frigoris basalts suggest they are high-alumina (HA) mare basalts - a unique group in the lunar sample collection. Basalt sample geochemistry demonstrates an inverse correlation between Al_2O_3 and FeO, which, compared to other mare basalts, indicates higher modal proportions of plagioclase and lower proportions of pyroxene and olivine [10]. Some HA basalts represent the oldest sampled mare basalts. Their aluminous nature suggests their sources contained significant plagioclase, which has implications regarding the efficiency of plagioclase separation in the crystallizing Lunar Magma Ocean (LMO) and hence the heterogeneity of the lunar mantle [11,12]. Identifying HA basalt exposures is important as they may represent outcrops of pre-4 Ga volcanism and be a window to early processes within and compositions of the lunar mantle.

Compositional Influence of PKT: Thorium abundances of most of the mare basalts in Frigoris are low, although much of the mare surface appears elevated due to contamination from impact gardening with the surrounding high-Th Imbrium ejecta. There are, however, a few regional thorium anomalies that are coincident with cryptomare units in the east, the two youngest mare basalt units, and some of the scattered pyroclastic deposits and volcanic constructs.

Gravity Anomaly: [13] mapped a pattern of linear gravity gradients that frames the Procellarum KREEP Terrain (PKT), the northern extent of which is coincident with the northern boundary of Mare Frigoris. [13] interpreted these gravity anomalies as a vast magma plumbing system for many of the basalts in Oceanus Procellarum. The unique signature of positive gravity anomaly and narrow belts of negative gravity gradient is consistent with thinning and rifting of the crust. The elevated heat flux in the PKT coupled with decreased pressure from mantle ascent into the rifts facilitated widespread partial melting and volcanism [13]. The relationship between this deep-reaching magma conduit and the largest extent of high-Al basalts on the Moon makes Mare Frigoris an intriguing location for further investigation. A sample-return mission to Frigoris would yield a diversity of geologic specimens most unlike those sampled by Apollo and Luna.

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