PETROGENESIS OF THE CHANG’E-5 MARE BASALTS: IMPLICATIONS FOR THE ORIGIN OF THE YOUNGEST SAMPLED LUNAR MAGMAS. S. Hoyos¹ and T. L. Grove¹, ¹Massachusetts Institute of Technology, Department of Earth, Atmospheric and Planetary Sciences, 77 Mass Ave, 02139, MA (shoyos@mit.edu).

Introduction: Mare basalts returned by the Chang’E-5 (CE5) mission from northern Oceanus Procellarum are the first returned mare basalts in more than four decades after the Apollo and Luna missions [1]. The CE5 basalt fragments and glasses represent the youngest mare basalts reported so far, dated at ~1.96 Ga [1-2]. These young lunar mare basalts provide a window into the late-stage thermal and magmatic evolution of the Moon and the northwestern Procellarum KREEP Terrane (PKT). The study of the late-stage magmatism in the PKT region is of fundamental importance for constructing a complete picture of the Moon’s long-lived and highly asymmetric volcanic activity [3-5]. Recent work has provided important insights into the age, geochemistry, and petrology of the mare basalts returned by the CE5 probe [1-5]. However, a better understanding of the complex processes and geochemical features occurring on the Moon during the last 2 Ga is needed to explain the mantle source of the CE5 sampled regolith. CE5 mare basalts have chemical characteristics that suggest a different petrological evolution from older basaltic lavas in this region of the PKT [3, 5-6]. The returned samples have a wide range of TiO₂ compositions, low Sr⁸⁷/Sr⁸⁶, and high εNd values that indicate a mantle source with a minor KREEP component [6]. As a result, an in-depth petrological study of these uniquely young basalts is crucial to refining lunar thermal evolution models.

To determine the role of fractional crystallization and the extent of melting on the young mare basalts, we have conducted equilibrium melting and crystallization experiments on the most MgO-rich samples collected by the CE5 lander. Assessing the pressure-temperature-composition conditions of the CE5 samples will allow us to understand the low-pressure crystallization sequence and determine their relationship with primitive magma sources. We have performed 1-atm experiments on a selected primitive composition to determine the percentage of partial melting, residual mineralogy at the source, and the extent of major element variation due to fractional crystallization upon ascent.

We use experimental constraints and petrological modeling to characterize the sequence of magmatic processes that occurred after the solidification of the Lunar Magma Ocean (LMO) [7], leading to remelting of the LMO cumulates and the late lunar magmatism in the PKT that produced the CE5 basalts.

Starting composition and experimental methods: The reported compositions for the CE5 basalts show wide compositional variability and relatively low Mg# numbers compared to other mare basalts (Fig. 1) [1-3, 8]. For our experiments, we chose the most primitive composition calculated from two basalt fragments with the highest Mg# (103-001007 and 103-001002) [3]. To explore its relationship with the more evolved compositions, experiments and numerical modeling were conducted using this composition, which most closely resembles a primary melt for the CE5 samples.

Figure 1. Composition of reported Chang’E-5 basalt fragments and soil samples.

The starting material was synthesized from reagent-grade oxides and carbonates. The oxide mix was ground in an agate mortar under ethanol to ensure homogenization. The synthetic starting material was packed into iron capsules, closed with friction-fitted lids, and placed in sealed evacuated silica glass tubes. One-atm experiments have durations of 24 hours and an imposed oxygen fugacity close to IW-1, relevant to the source region of these mare basalt magmas [9]. Temperature was varied to constrain the liquidus temperature and crystalline phase appearances. Experimental products were analyzed by electron microprobe.
Preliminary results: Our preliminary results indicate olivine appears first, followed by plagioclase, and finally by clinopyroxene. Olivine is the liquidus phase at 1150°C. The experiments near the liquidus, where olivine is the only phase present, have 98% liquid and 2% olivine. Olivine (Fo65) and glass have an equilibrium exchange coefficient between Fe and Mg, $K_{D_{Ol-Liq}}^{Fe-Mg}$, of 0.3. Plagioclase comes in at 1130°C as anorthite. This experiment contains 77% liquid, 13% anorthite, and 10% olivine (Fo61). With decreasing temperature, the KD is lower, and the FeO content in the olivine increases.

Discussion: Compositional differences between olivine and plagioclase saturated experimental liquids and the intermediate Ti, high-Al, and low-K CE5 basalts suggests extensive modification by fractional crystallization at low crustal-level pressures or in surface lava flows. Another indication of the differentiation from the primary liquid is the wide range of Fo content on the CE5 samples (Fo29-80) compared to olivine present in our experiments (Fo65-60).

Our experimental results show that melts of the calculated CE5 primitive composition represent at least two different source regions. Our experiments show higher TiO$_2$, higher Mg#, and lower Al$_2$O$_3$ compared to the majority of basaltic samples with lower TiO$_2$. Therefore, our primitive composition cannot produce these lower TiO$_2$ liquids through fractional crystallization (fig 2.). The most primitive composition of this high Al$_2$O$_3$ source region has an evolved magma (Mg# 0.3) as the most primitive sample in the suite.

The second source is represented by our primitive compositions and seven more samples that underwent low-pressure olivine + plagioclase crystallization (fig 3.) This parental magma has lower Al$_2$O$_3$, higher TiO$_2$, and higher Mg#. One-atm experiments at lower temperatures and with different compositions are underway to determine how secondary processes may have altered the primary magmas to produce these evolved compositions and the genetic relationships between the two magmatic sources. Results from these experiments will be reported at the meeting.

References: