MINERALOGY AND PETROLOGY OF BASALTIC FRAGMENTS IN CHANG'E-5 SAMPLE CE5C0400. X. Che[1*], J. F. Snape[2], R. Tartèse[2], J. Head[3], B. Jolliff[4], K. H. Joy[2], T. Long[1], A. Nemchin[1,5], M. D. Norman[6], C. R. Neal[7], S. Xie[1], M. J. Whitehouse[8], Z. Bao[1], Y. Shi[1], D. Liu[1,9], [1]Beijing SHRIMP Center, Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China (Corresponding author: cxc@bjshrimp.cn), [2]Dept. of Earth & Environmental Sciences, The University of Manchester, Manchester, M13 9PL, UK, [3]Dept. of Earth, Environmental, & Planetary Sciences, Brown Univ., Providence 02912, USA, [4]Dept. of Earth & Planetary Sciences & The McDonnell Center for the Space Sciences, Washington University in St. Louis, One Brookings Drive, St. Louis, MO, USA, [5]School of Earth & Planetary Sciences, Curtin University, Perth, GPO Box U1987, WA 6845, Australia, [6]Research School of Earth Sciences, The Australian National University, Canberra ACT 2601 Australia, [7]Dept. of Civil & Env. Eng. & Earth Sciences, University of Notre Dame, Notre Dame, IN 46556, USA, [8]Dept. of Geosciences, Swedish Museum of Natural History, SE-104 05 Stockholm, Sweden, [9]Shandong Institute of Geological Sciences, Jinan, Shandong 250013, China.

Introduction: The Chang'e-5 mission returned 1731 g of lunar soil samples from the Mons Rümker region of Oceanus Procellarum. Recent analyses of the Pb isotope systematics for multiple basaltic fragments have yielded a ~2 Ga crystallization age for the basalt flows from which the samples originated [1,2]. The textural characteristics, mineralogy, and bulk major and minor element compositions of a further 28 basaltic fragments from sample CE5C0400 are being investigated and summarized here.

Analytical Methods: Back-scattered electron (BSE) images and Energy Dispersive Spectroscopy (EDS) X-ray element maps were acquired on polished basalt fragments using the Zeiss Merlin Compact Scanning Electron Microscope, which was followed by *in situ* mineral Pb isotope analysis using the SHRIMP II-e MC instrument, both at the Beijing SHRIMP Center, following the methodology described by [1].

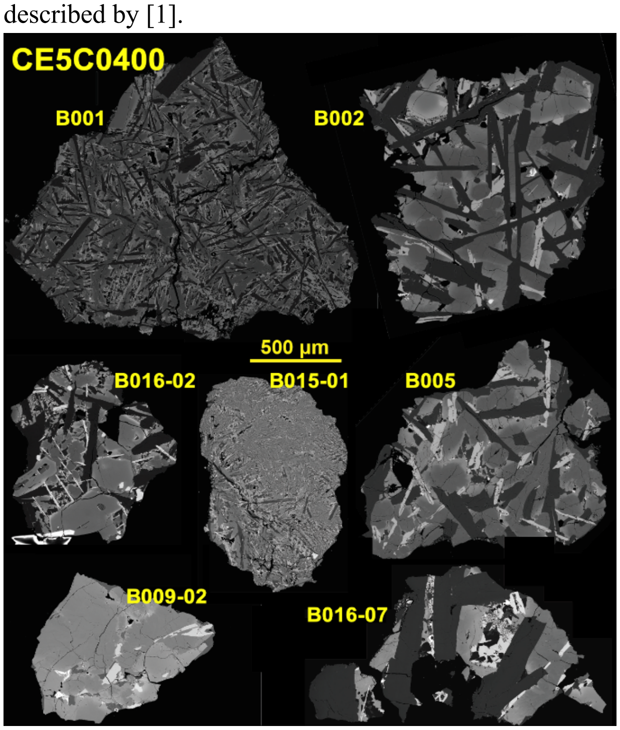

Figure 1. BSE images of selected basalt fragments.

Results: Basaltic fragments are the main lithic clasts in soil CE5C0400 , which also consists of breccias, agglutinates, and glass beads [3-4]. For this study, 28 basaltic fragments were selected from a 1.5 g scooped soil sample.

Mineralogy. The majority of the basaltic fragments have ophitic to subophitic textures, with elongated plagioclase grains (>500-1000 µm; see B001, B002, and B005 in Fig. 1), and pyroxene and olivine exhibiting prominent compositional zoning towards Fe-rich rims (Figs. 2 and 3). The fragments have a range of grain sizes that suggest variable cooling rates with a trend of continuous change from aphanitic to holocrystalline-texture (Fig. 1). Ilmenite laths (~1-100 µm in width) are common and numerous interstitial mesostasis areas contain fayalite, silica, and various late-stage accessory phases (e.g., K-rich glass, Ca-phosphates, Fe-sulfides, and Zr-rich minerals). Many of the basalts also contain anhedral to subhedral grains of more forsteritic olivine that occasionally contain melt inclusions and subhedral to anhedral phenocrysts of spinel (~30-70 µm; e.g., B002, B016-02). The spinel grains have Cr-rich cores and Ti-rich rims, and in some samples are also present outside the olivine grains, occasionally forming glomerophyric clusters.

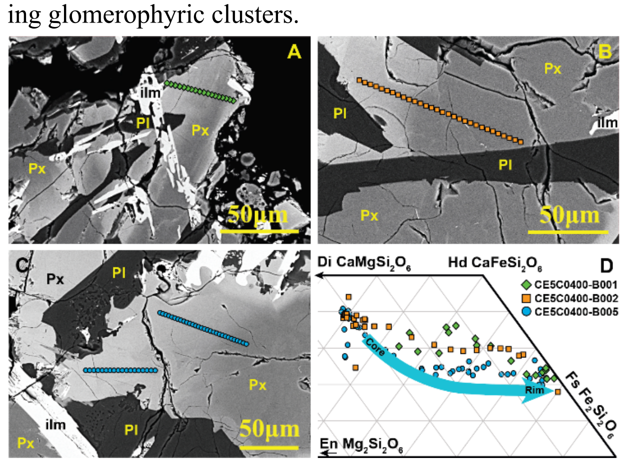

Figure 2. Compositional zoning of pyroxene in B001 (A), B002 (B), and B005 (C), summarized in a pyroxene quadrilateral (D).

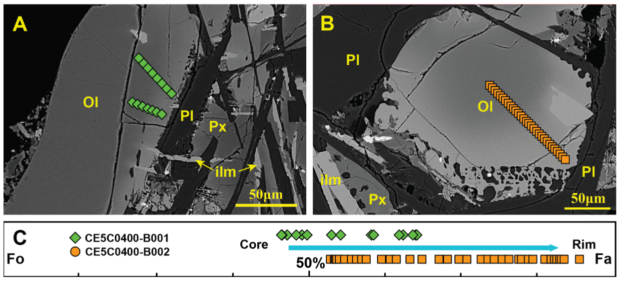

Figure 3. Compositional zoning of olivine in B001 (A) and B002 (B), summarized in a Fa% value plot (C).

Fragment B009-02 has a coarse-grained (>500 μm) texture dominated by pyroxene (exhibiting complex compositional zoning between higher- and lower-Ca concentrations, as well as Fe-rich rims). A large (~300 μm) olivine grain is present on one side of the fragment. There is less plagioclase in this fragment, and it typically forms less elongated grains than in the other fragments. The interstices between pyroxene grains include several occurrences of K-rich glass that hosts various other late-stage phases (as in the other fragments). The fragment contains several ~40 μm sized grains of Fe-sulfide.

Fragment B016-07 is also notable for its coarse grain size (>1000 μm), dominated by plagioclase grains up to ~1 mm in length. The fragment also contains large (100-300 μm) assemblages of fayalitic olivine, silica, and various accessory phases such as Ca-phosphates, Fe-sulfides, and Zr-rich minerals.

Fragment B015-01 has a finer-grained texture (Fig. 1), although the overall mineralogy is similar to the other fragments. The fragment is cross-cut by a broken band of forsteritic olivine crystals and needle-like ilmenite laths, which lie approximately perpendicular to the band of olivine crystals. To one side of this band the sample has a generally coarser grain size. The overall mineralogy of this fragment is similar to that of the other fragments.

Mineral chemistry. Silicate mineral compositions have been determined for B001, B002, and B005 (Figs. 2-3), and overall show a high degree of consistency with those in the multiple basaltic fragments from CE5C0000 and CE5C0100 lunar soils investigated previously (Fig. 4).

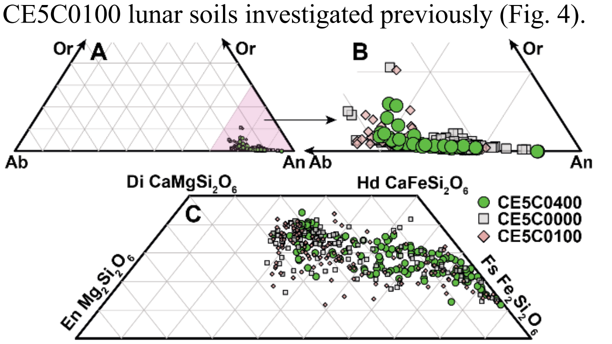

Figure 4. Plagioclase (A-B) and pyroxene (C) chemistry in CE5C0400 basalts, compared with CE5C0000 and CE5C0100 (data from [1,5]).

Pyroxene in all three samples exhibit complex compositional zoning from Mg- and Ca-rich cores to Fe-rich and Ca-poor rims (B001: En_{1-26}, Fs_{44-80}, Wo_{12-36}; B002: En_{2-37}, Fs_{39-80}, Wo_{18-44}; B005: En_{2-37}, Fs_{35-71}, Wo_{20-41}; Fig. 2), trending toward pyroxferroite compositions that suggest rapid crystallization. Olivine in B001 has a compositional range of Fa_{45-68} (Fig. 3A), while the grain analyzed in B002 appears to have a more Fe-rich composition (Fa_{53-94}; Fig. 3B).

Bulk chemistry. The majority of the studied Chang'e-5 basaltic fragments have intermediate bulk TiO_2 concentrations from about 2.4 wt.% to 7.5 wt.% (as calculated by EDS mapping of whole fragments), similar to Apollo 12 ilmenite basalts and Apollo 16 basalts from 60639 [6,7].

Pb isotopes. The mineral Pb isotope compositions in fragment B002 is consistent with the *ca*. 2 Ga isochron obtained in previous studies (Fig. 5).

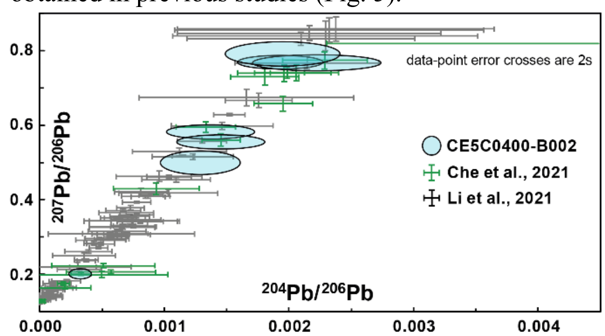

Figure 5. Mineral Pb isotopes in CE5C0400-B002.

Discussion: The mineralogy, chemistry, and Pb isotope compositions of basaltic fragments in CE5C0400 are consistent with those of other CE5 scooped samples, suggesting most basalt fragments derived from a single basaltic eruption event [8]. As such, the variable textures most likely indicate different cooling rates, with coarser grained textures from the interior of the flow and finer grained subophitic textures from the exterior.

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References: [1] Che X. et al. (2021) *Science, 374,* 887–890. [2] Li Q. et al. (2021) *Nature, 600,* 54–58. [3] Shi Y. et al. (2022) *LPSC, LIII*. [4] Xie S. et al. (2022) *LPSC, LIII.* [5] Tian H. et al. (2021) *Nature*, 600, 59-63. [6] Neal C. R. et al. (1994) *Meteoritics*, *29*, 334-348. [7] Fagan A. L. and Neal C. R. (2016) *GCA, 173*, 352–372. [8] Qian Y. et al. (2021) *Geophys. Res Lett*. 48 e2021GL092663.