

PRELIMINARY RAMAN SPECTROSCOPIC OBSERVATION OF CHANG'E-5 SOIL SAMPLE. H. J. Cao¹, Q. Wang², J. Chen¹, X. C. Che², C. Q. Liu¹, X. H. Fu¹, M. Z. Ma², D. Y. Liu², Z. C. Ling^{1*}. ¹Shandong Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, School of Space Science and Physics, Institute of Space Sciences, Shandong University, Weihai, Shandong, 264209, China. ²Beijing SHRIMP Center, Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China (zcling@sdu.edu.cn).

Introduction: Chang'E-5 (CE-5), as China's first lunar sample return mission, has collected ~1.73 kg of lunar materials from one of the youngest mare basalt units in the northern Oceanus Procellarum [1-2]. Orbital data have demonstrated that this landing site has distinct composition, mineralogy, and geochronology [3] and the CE-5 lunar samples can regard as the mixing product of weathering local rocks with minimal ejecta materials [4]. Therefore, the CE-5 soils can contribute to understanding the diverse mineralogy and lateral mixing for the contamination of highland ejecta.

Methods: One breccia clast (CE5-B006) was selected from the CE-5 soil (CE5C0400) allocated by the China National Space Administration. Analysis of CE5-B006 were performed on a polished thick section about 1 × 1 mm. Petrographic characterization was employed using the Zeiss Merlin Compact Scanning Electron Microscope (SEM) coupled with an Oxford X-Max^N 150 Energy Dispersive Spectroscopy (EDS) at the Beijing SHRIMP (Sensitive High Resolution Ion MicroProbe) Center, Institute of Geology, Chinese Academy of Geological Sciences, Beijing. Spectroscopic measurements were performed by the Horiba LabRAM HR Evolution Raman spectrometer, with a 532 nm laser line, ~1 μm spot size, 600 grooves/mm, and the range of 50-4000 cm⁻¹.

Petrography and mineral chemistry: The lithic clast (CE5-B006) from the lunar soil (CE5C0400) is a fine-grained breccia (Figure 1), comprising of 47.2 vol.% pyroxene, 19.8 vol.% olivine, 12.3 vol.% plagioclase, 7.5 vol.% ilmenite, 9.4 vol.% feldspathic glass, and 3.8 vol.% basaltic glass based on equally spaced-grid (~100 μm) Raman point-counting measurements. Compared to modal abundance of the CE-5 soils and basalt fragments [6-11], this breccia is composed of relatively higher modal mineralogy in olivine but has lower abundant plagioclase feldspar (Table 1).

Pyroxene are zoned from Mg-rich cores to Fe-enriched rims (Figure 4a and 4b) with small crystal size (up to 100 μm in diameter). Some fine-grained ferrosilite have intergrowth texture with needle-shaped ilmenite and plagioclase (Figure 4d). Chemical composition of pyroxene exhibits the similar trend to CE-5 basalt fragments (Figure 2) ignoring a small amount of Mg-rich pyroxene. Olivine grains consist of euhedral forsterite with 100 μm in size, skeletal Mg-rich forsterite (Fo₈₂) within olivine vitrophyric glass (Figure 4c), and some fine-grained fayalite, exhibiting variable

composition than other CE-5 basalt fragments (Figure 2). Plagioclase have partly transformed into maskelynite with highly fractured texture (feldspathic glass, Figure 3 and 4f), suggesting local shock pressures up to 30 GPa and potential impact events at the CE-5 landing site [5]. The accessory minerals are comprised of K-feldspar, OH-rich apatite (evidence from Raman spectra), cristobalite, baddeleyite (~1 μm), chromite, troilite, and various glasses (Figure 3 and 4).

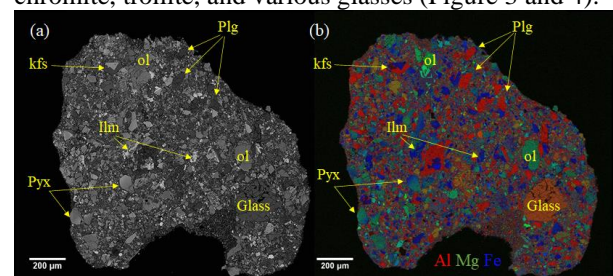


Figure 1. Back-scattered electron (BSE) image and false-color element map (Al=red, Mg=green, Fe=blue) of CE5-B006 sample. Pyx = pyroxene, Ol = olivine, Plg = plagioclase, Ilm = ilmenite, kfs = K-feldspar.

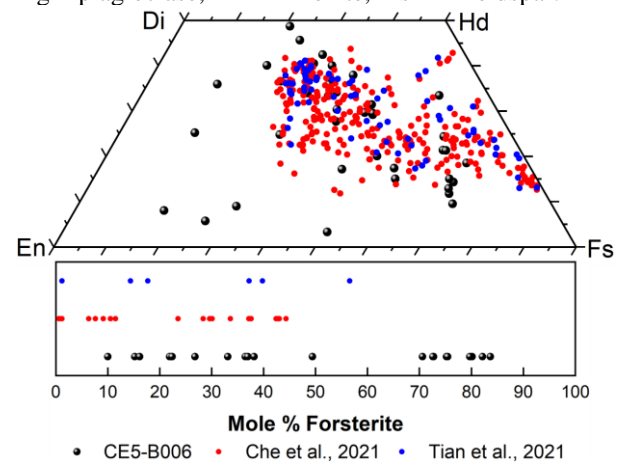


Figure 2. The calculated chemistries from Raman spectra of pyroxene and olivine in CE5-B006 sample based on the equations in previous works [12-13]. Data are compared with other CE-5 basalt fragments [9, 11].

Hydration states and Contamination of Silicate Minerals: Raman spectra of pyroxene, olivine, and feldspar exhibit the occurrence of H₂O/OH vibrational modes around 2800-3600 cm⁻¹, indicating diverse hydration states as adsorption water or interlayered molecular water. However, nominal lunar silicate minerals in the Apollo collections and lunar meteorites are anhydrous, demonstrating the possibility of solar wind

protons implanted to lunar regolith or due to residual rocket engine exhaust. Lines of evidence from Raman spectra near 1200-1500 cm^{-1} (Figure 3, assigned to vibrational modes of polycyclic organic matters) further suggest the presence of organics. These spectroscopic observations highlight the exotic contaminant at CE-5 landing site.

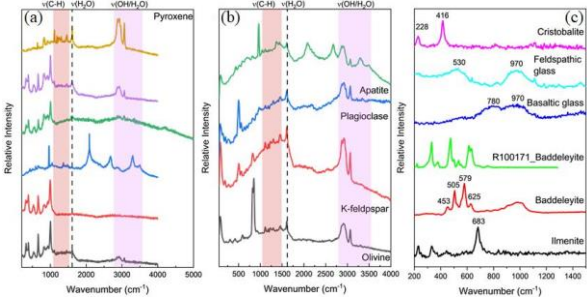


Figure 3. Raman spectra of minerals from CE5-B006 breccia. The multiple Raman peaks around 1200-1500 cm^{-1} result from vibrational modes of C-H bond, demonstrating organic candidates of poly (ethylene glycol) methacrylate, poly (vinyl alcohol-co-vinyl butyral), poly (ethylene glycol) monooleate, poly (dimethylsiloxane) ethoxylate/propoxylate, and poly (bisphenol-A-co-epichlorohydrin).

Potential ejecta of highland minerals and polymorphic glasses: Remote observations suggest that the CE-5 landing site has slightly affected from the impact ejecta in the surrounding craters. The Mg-rich olivine (Fo₇₂₋₈₅) and minor high-temperature pyroxene removed from the compositional field of CE-5 basalt, as well as highly fractured feldspathic glasses (Figure 4) in B006 breccia, suggest the complicated mixing of

weathering local basalt fragments with ejecta materials during consolidating lunar soil in the surface. In addition, individual basaltic glass (Figure 4g) and olivine vitrophyric glass (Figure 4c) exhibit similar fractured textures to feldspathic glass, but the latter have been quenched rapidly following the crystallization of Mg-rich olivine. In contrast, feldspathic glasses are indicative of impact events at the CE-5 landing site. The diverse mineral fragments in CE5-B006 breccia imply the complicated mixing effects and evolution of lunar regolith near lunar surface.

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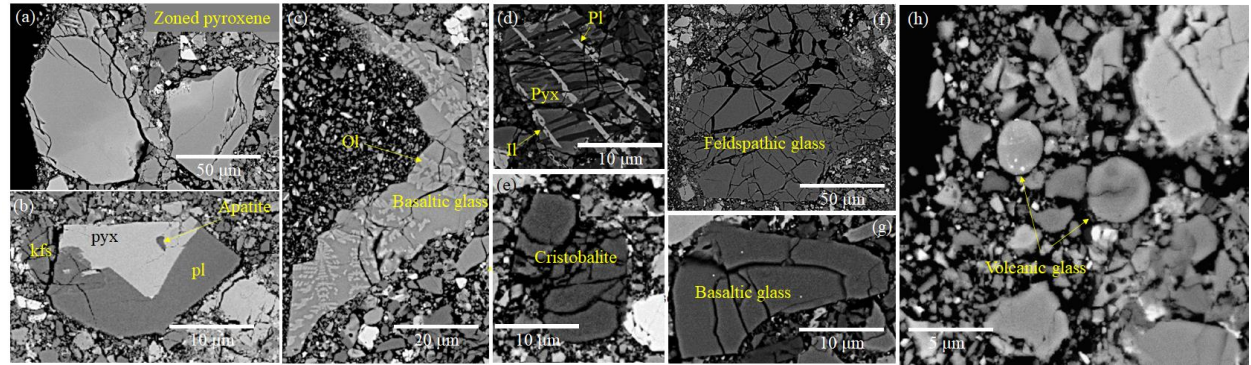


Figure 4. BSE images of minerals in CE5-B006 breccia. Olivine vitrophyres in (c) consist of Mg-rich olivine crystals with a skeletal appearance. kfs = K-feldspar, pl = plagioclase, pyx = pyroxene, Ol = olivine, Il = ilmenite.

Table 1. Modal abundance of CE5-B006 and other CE-5 basalt fragments and soils.

Mineral	CE5-B006		CE-5 soils		CE-5 basalt fragments		
CPX/Augite	47.2	30.9	44.5	46.76	51.2-64.5	54.5	14.2-65.6
OPX/Pigeonite		11.1					
Plagioclase	12.3	30.1	30.4	8.75	20.0-34.4	25.4	17.7-81.2
Olivine	19.8	5.7	3.6	5.55	1.8-1.9	1.3	1.4-19.4
Ilmenite	7.5	4.5	6.0	3.51	6.7-9.3	17.8	Trace-11.9
Glass/amorphous	13.2	16.6		7.58			
Reference	This study	[6]	[7]	[8]	[9]	[10]	[11]