MINERALOGY OF LUNAR METEORITE NORTHWEST AFRICA 10480 BY RAMAN SPECTROSCOPIC STUDIES.

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Introduction: With the success of Chang'e-5 (CE-5) mission which delivered the first lunar samples to the Earth since the 1970s, lunar exploration has come into a brand-new era. In the past decades, more and more precise and accurate analytical methodologies and techniques have been applied on planetary materials. Since 1990s, numbers of new developments have been made in the field of laser Raman spectroscopy (LRS) by innovations in hardwares [1,2] and algorithms [3-5]. Appling Raman spectroscopy on unknown materials of interest in geology and planetary researches, the mineral species and chemistries can be obtained according to their specific Raman spectra.

In this study, Raman spectroscopy was utilized to characterize lunar meteorite NWA (Northwest Africa) 10480 found in 2015 (Fig. 1). By collect and analyze the Raman spectra, the modal mineralogy and mineral composition in the meteorite were derived. The efforts in this study offer a potential reference to the *in-situ* exploration on the Moon in the foreseeable future.

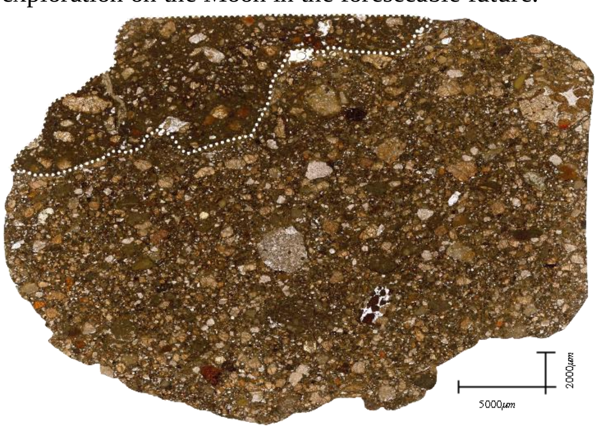

Fig. 1 Photomicrograph of thin section of NWA 10480 under plane polarized light. The brighter grains are feldspathic clasts.

Petrographic Features: Briefly, NWA 10480 is a polymict breccia composed of lithic and mineral clasts set in a fine-grained matrix. Lithic clasts are dominantly gabbroic, basaltic, and impact melt. Mineral clasts include olivine, plagioclase, and pyroxene with exsolution lamellate. Accessories are pigeonite, Ti-chromite, ilmenite, and silica. Shock melt veins and pockets are observed.

Raman measurement: LRS measurements were performed with Renishaw inVia® Raman Microscopes. Point-counting laser Raman analyses [6] were done with an equally spaced (~1000μm apart) 20×30 sampling grid to identify minerals and estimate modal mineralogy. Points showing spectra of mineral mixtures are simply treated as equally contributed from endmembers.

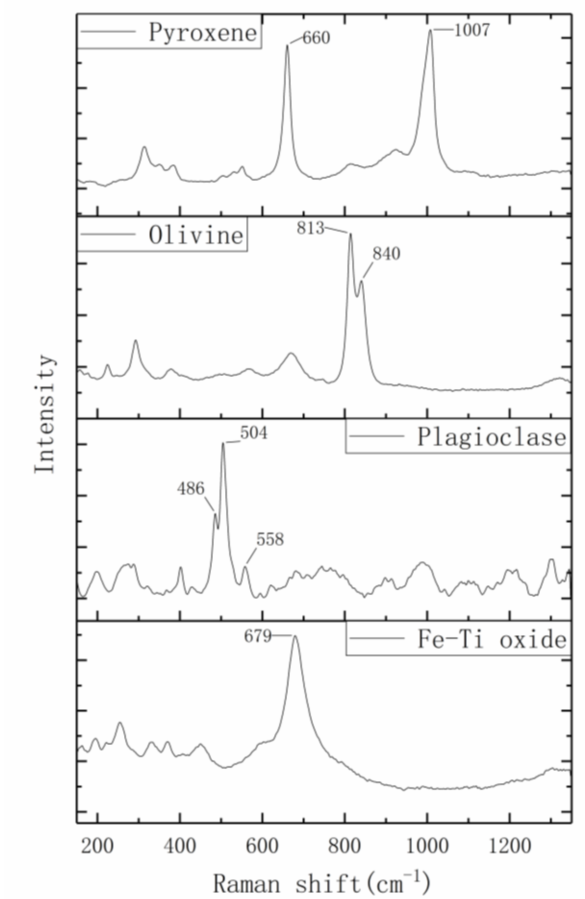

Fig. 2 Typical Raman spectra of major minerals in NWA 10480.

Results and Discussion: ~650 Raman spectra were collected in this study. By comparing Raman spectra of NWA 10480 with spectral library built in previous studies, major minerals are identified. Typical Raman spectra of olivine, plagioclase, pyroxene and Fe-Ti oxide are shown in Fig. 2. Mineralogy research shows that olivine, plagioclase and pyroxene are solid solution and were made up of minerals with different cations. For example, olivine has 2 end-members which is fayalite, the Fe^{2+} end-member, and forsterite, the Mg^{2+} end-member.

Most feldspar on the Moon represent as plagioclase, in other words, there is very few alkali ions in the feldspar mineral on the Moon. This phenomenon is reflected in the Raman spectrum as the plagioclase's peak at ~504 cm^{-1} rarely shifts. The same peak in Raman spectra of alkali (K^+ ,Na^+ feldspar) lies in ~508-513 cm^{-1}. [3]

Modal mineralogy. The result of estimated modal mineralogy is shown in Fig. 3. NWA 10480 consists of 49 vol.% pyroxene, 20 vol.% plagioclase, 15 vol.% olivine, and 3 vol.% Fe-Ti oxides. Other phases (e.g., epoxy resin) not originating from the Moon have been excluded from modal abundance calculations.

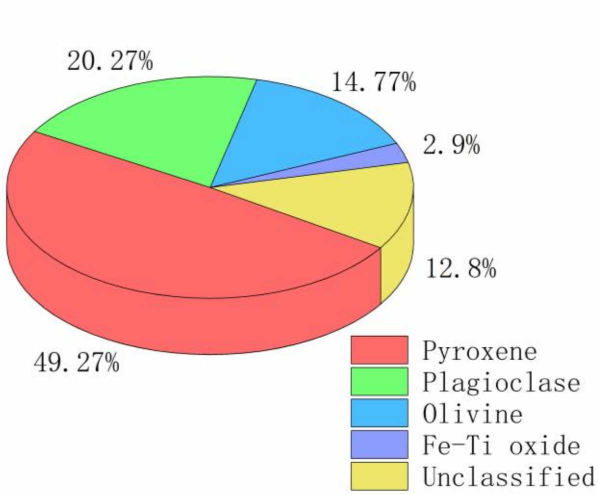

Fig. 3 Modal mineralogy of NWA 10480 estimated based on Raman point-counting.

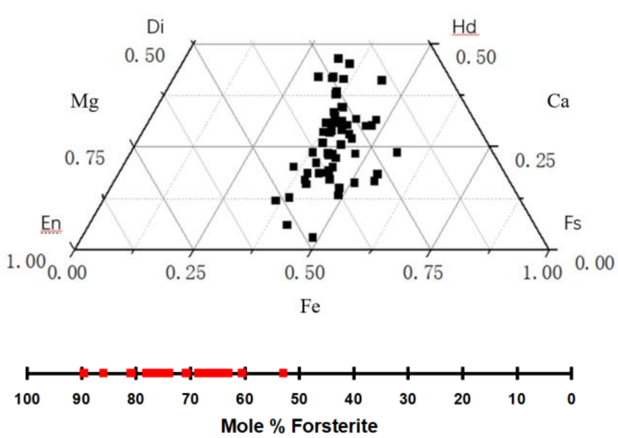

Fig. 4 Olivine and pyroxene compositions observed in NWA 10480.

Mineral composition. By using quantification methods developed in [4] and [5], compositions of olivine and pyroxene are derived based on their characteristic Raman peaks. The results are shown in Fig. 4. For pyroxene, we can find from the quadrilateral that most of them are augite and pigeonite. The overall pyroxene chemistry variation is $En_{10-50}Fs_{30-60}\ Wo_{0-50}$. We can learn from the chart that the Fo values of olivine is between ~53- 90. [7] After the inversion of Fo# in the *in-situ* detection, the possible origin of the olivine and pyroxene can be summarized in combination with the environmental morphology, and the geological process experienced can be inferred.

Conclusions and Future work: This study demonstrates a method that can estimate cation's abundance of mafic minerals via LRS in planetary mineralogy. This reveals a possibility in future *in-situ* spectroscopy, will be beneficial to mineral characterization and *in-situ* resource utilization. In the future research, varies of analytical methods like electron-microprobe (EMP) will be applied to determine the mineral compositions with higher accuracy.

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