REMOTE RAMAN DETECTION OF NATURAL ROCKS.

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Introduction: Standoff remote Raman technique is increasingly highlighted as a viable method for planetary surface chemical analysis. This technique requires no sample preparation, transfers minimal to no target sample damage, and can be used under daylight conditions; saving time and increasing the number of accessible targets. The University of Hawaii (UH) in collaboration with Los Alamos National Laboratory (LANL) and NASA Langley Resarch Center, has developed a Compact Remote Raman+LIBS+Fluorescence System (CRRLFS) that is capable of Raman, LIBS, and fluorescence measurements under daytime conditions from standoff distances. The instrument is shown in Figure 1. This work is in support of the Mars 2020 mission where UH is collaborating with LANL and French partners IRAP and CNES, to develop the SuperCam instrument that will be a part of the Mars 2020 rover. The instrument will perform remote chemical analysis of Mars surface rocks using Raman, LIBS, and time-resolved fluorescence spectroscopy. [1]

In the past we have demonstrated remote Raman detection capability for a variety of minerals. The CRRFLS has been able to successfully acquire high quality Raman spectra of various light and dark minerals, water, water-ice, CO_2 ice, organics, and inorganic chemicals at distances of up to 50 meters with a 10 sec integration time [2-6]. Here, we extend our detection capability to investigate natural rocks using remote Raman spectroscopy.

Several igneous and metamorphic rocks were surveyed using the CRRFLS to identify the mineral constituents for the rocks. The following results display the ability of a portable compact remote Raman+LIBS+Fluorescence system for detecting various mineral phases, in natural rocks at a distance of 5 meters.

Samples and Instrumentation: The CRRFLS contains a small 532 nm Q-switched frequency-doubled Nd:YAG laser source and an electronically gated custom mini-ICCD detector. The 20 Hz pulsed laser was used at 20 mJ per pulse. It employs a 2.5-inch collection telescope, a 532 nm notch filter, a 50 micron slit, and two stacked volume phase transmission gratings. The compact spectrograph is 10 cm long x 8.2 cm wide x 5.2 cm tall.

Raman spectra were acquired for 30 seconds (600 laser pulses) for pink marble (Tate, Georgia, USA), biotite gneiss (Uxbridge, Massachussetts, USA), nepheline syenite (Bankcroft, Ontario, Canada), and tonalite (San Diego County, California, USA). Samples were acquired from Ward's Collection of Classic North American Rocks 45-7250. [6]

Figure 1: Compact remote Raman+LIBS+Fluorescence system (CRRLFS) mounted on a movable pan/tilt scanner.

Results and Discussion: Figure 2 shows remote Raman spectra of pink marble ($CaCO_3$) from a 5 m distance at various integration times. The CRRFLS is capable of fast data acquisition as seen by the detection of Raman lines at 1, 10, and 30 s.

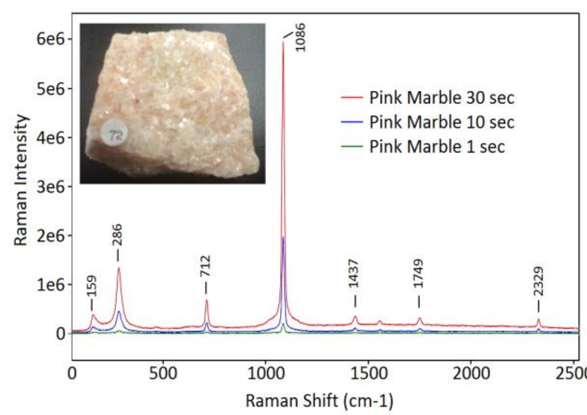

Figure 2: Pink marble remote Raman spectra at a 5 m distance over a 1, 2, and 30 s integration times.

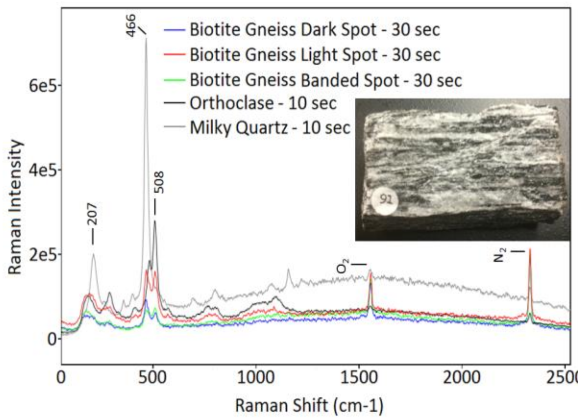

Figure 3: Biotite gneiss remote Raman spectra at a 5 m distance over a 30 s integration time.

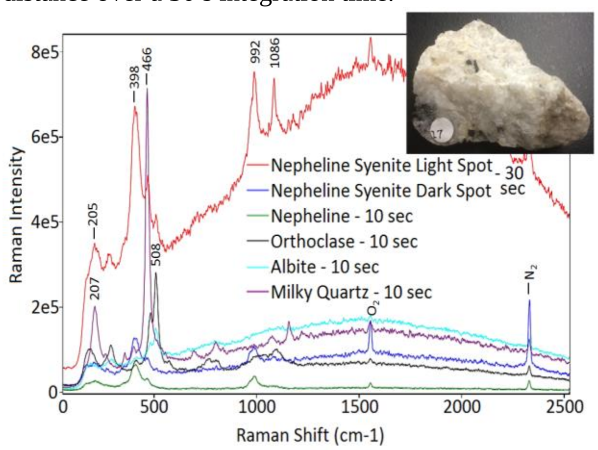

Figure 4: Nepheline Syenite remote Raman spectra at a 5 m distance over a 30 s integration time. Nepheline peaks are visible at 992 and 1086 cm^{-1}. The peak at 1086 cm^{-1} may also be attributed to accessory calcite components.

Figure 3 shows remote Raman spectra of light, dark, and both light and dark (intermediate) areas in biotite gneiss ($K(Mg, Fe_2^{+3})(Al, Fe^{3+})Si_3O_{10}(OH, F)_2$). The laser spot diameter of 5 mm was used for measurements. Fig. 3 also shows the refences remote Raman spectra of pure orthoclase and quartz minerals.

Figure 4 shows remote Raman spectra of nepheline syenite ($(Na,K)AlSiO_4$) at both light and dark spots, along with the remote Raman spectra of nepheline, orthoclase, albite and quartz. The sample shows high levels of fast organic/bio-fluorescence background. Individual pure nepheline, orthoclase, milky quartz, and albite spectra combined, make up the nepheline syanite spectrum. The dark spot analyzed only contains nepheline, while the light spot analyzed contains nepheline, orthoclase, milky quartz, and albite.

Figure 5 depicts remote Raman spectra of tonalite, NaCl, CaO, MgO, SiO_2, (quartz diorite with a quartz content >20% of the rock) at a 5 m standoff distance. Moderate levels of fast organic/bio-fluorescence background are visible. The tonalite spectrum matches up with the plagioclase, orthoclase, and quartz mineral components.

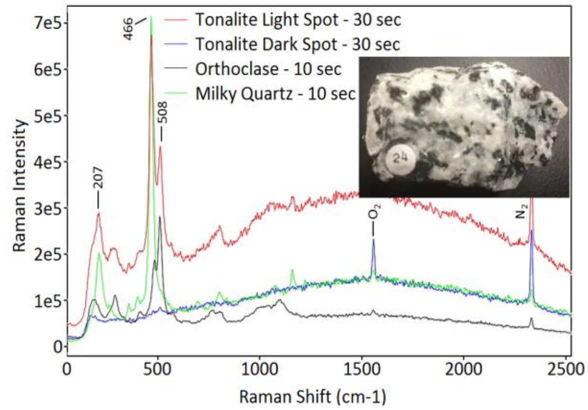

Figure 5: Tonalite remote Raman spectra at a 5 m distance over a 30 s integration time.

Conclusion: We have demonstrated the capabilities of the Compact Remote Raman+LIBS+Fluorescence System (CRRLFS) at a standoff distance of 5 m to analyze natural rocks in daylight conditions and with high fluorescence backgrounds, without sample collection or preparation. Biotite gneiss is a high grade metamorphic rock with banded dark biotite mica and lighter feldspar and quartz. Nepheline syenite is an igneous intrusive rock composed primarily of nepheline and alkali feldspar. Nepheline reacts with quartz to produce alkali feldspars such as orthoclase. Tonalite (quartz diorite) is an igneous intrusive rock containing quartz, biotite, and plagioclase, and orthoclase feldspars. Pink marble is primarily composed of calcite. The remote Raman analysis is consistent with the compositions of the rocks.

Future investigations involve analysis of progressive solid solution mixing models with natural rocks.

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