



Raman spectroscopy as a tool to identify high-pressure minerals, implications for the Mars2020 mission

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The formation of craters on the surface of Mars is primarily attributable to the impact of celestial bodies. This impact results in the generation of elevated temperatures and pressures, resulting in the formation of high-temperature and high-pressure minerals [1]. This is the case of the Jezero crater, landing site of the Mars 2020 mission's Perseverance rover. This rover is currently analyzing the crater rim of the mentioned crater, an area where high-pressure minerals may be present.

One of the techniques on board the rover is Raman spectroscopy, which is part of the SuperCam and SHERLOC instruments. This technique can determine the presence of high-pressure minerals by analyzing the shift of the Raman bands. In some cases, calibrating the Raman band position, the pressure to which certain compounds were subjected can be estimated. However, it should be noted that not all minerals behave in the same way in Raman spectroscopy when subjected to high-pressures. On the one hand, some minerals are transformed into other mineral phases because of high-pressure, usually their corresponding high-pressure polymorphs. On the other hand, other minerals exhibit a shift in the position of their Raman bands towards higher wavenumbers when exposed to high-pressures.

This study presents a compilation of minerals under high-pressure conditions that may likely be found on the Jezero crater rim and their behavior as observed through Raman spectroscopy.

Table 1 summarizes a selection of the minerals most likely to be encountered on Mars which, upon exposure to high-pressures, are known to undergo phase transformations. The table lists the high-pressure mineral name, the Raman band position of this mineral, the pressure and/or temperature at which it is formed and the original mineral from which the new mineral phase is formed.

Conversely, Table 2 displays the minerals that exhibit Raman shift towards higher wavenumbers when subjected to high-pressure conditions. The mineral names, the position of the Raman band at ambient conditions, the position of the Raman band at the maximum pressure studied in the literature and the value of this pressure, are included in the table.

Table 1. High-pressure minerals [2,3].

Table 2. Minerals whose Raman bands shift to higher wavenumbers with pressure [4,5,6].

It is important to note that certain compounds may also undergo Raman band movements due to cation exchange. This is the case of feldspar, siderite, calcite, magnesite and dolomite in Table 2. However, it may be considered that Raman band shifts can occur due to cation exchanges or enrichments. Therefore, detected Raman shifts must be always studied in parallel to elemental characterization and stoichiometric calculations to attribute an accurate origin to the observed wavelength movement. In the case of Perseverance rover, LIBS (laser-induced breakdown spectroscopy) MOC (major-element composition) values can be crucial for the Raman spectroscopy accurate result interpretation at the Crater Rim.

It is worthy to highlight that some of these minerals have been identified in Martian meteorites, such as maskelynite in the NorthWest Africa (NWA) 1195 meteorite [7], coesite in the NWA 8657 [8] or high-pressure calcite [9]. Given the prevalence of these minerals in samples with a Martian origin, there is a high probability of their occurrence in crater rims on the planet's surface.

References

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