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Impact induced devolatilisation of hydrated minerals

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Abstract

Initial results from hypervelocity impact experiments show goethite and gypsum will undergo devolatilisation on impact, which can then be detected using a Raman spectrometer. However, the resulting devolatilisation of minerals does not represent the peak temperatures experienced upon impact. These results also indicate that pressure may play a role in the formation of crater residue materials.

1. Introduction

Raman spectroscopy is beginning to be seen as a valuable tool for quick classification of planetary surface mineralogy [1]. This is evident with the incorporation of a Raman spectrometer onboard ESA's *ExoMars* rover [2]. In addition [3] has shown this technique could also be used for the characterisation of minerals on asteroid surfaces.

Impact experiments conducted by [4-6] have shown hypervelocity impacts can release the volatile components of minerals. The devolatilisation of minerals may have played a vital role in the development and evolution of terrestrial bodies [7, 8]. [9] has shown Raman spectroscopy has the ability to detect the loss of volatile components. It might be possible to use the Raman spectra produced as a result of impacts as a gauge of temperature.

2. Experiments

Laboratory impact experiments were carried out using the University of Kent's light gas gun (LGG) [10]. Two minerals, Goethite and Gypsum (in the form of plaster of Paris), were made into projectiles and targets, and impacted onto Aluminium Alloy plates or impacted with stainless steels spheres respectively, at varying velocities. The LabRam-HR Raman spectrometer, based at the University of Kent, was used to analyse residues and craters generated by these impacts.

3. Results

3.1 Goethite

Analysis of crater residues from impacts at velocities between 1.36 and 5.13 km s^{-1} (Figure 1) showed a loss of OH at velocities above 1.36 km s^{-1} to form Hematite. The spectra taken from craters formed at 2.14 km s^{-1} and above exhibit broad peaks. This indicates the temperatures reached upon impact were not above 400 °C, seen when compared to Raman spectra taken when heating goethite under static conditions, which display narrow peaks at high temperatures. However, the peak temperature produced upon impact may be greater than that shown by impact residues, but requires modelling to determine exact peak impact temperatures.

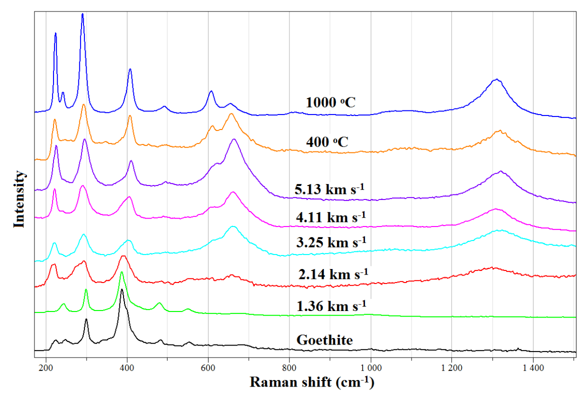

Figure 1: Raman spectra of impact residues and from heating goethite to 400 and 1000 °C under static conditions. Intensity is an arbitrary value due to spectra being offset for clarity.

Raman spectra taken from a crater formed by an impact into a goethite target shows there is little change in spectra. However, there is a slight shift in peak position at 385 cm^{-1}, which indicates a loss of OH.

3.2 Plaster of Paris

Impact residues from both hydrous and semi-hydrous phases of plaster of Paris (PoP) have shown the devolatilisation of this material. Impacts of hydrous PoP results in the loss of H_2O, indicated by the removal of H_2O bond peaks and the shift of $CaSO_4$ peaks. Semi-hydrous PoP appears to result in the complete decomposition of the material, producing CaO which bonds with CO_2 from the atmosphere to form $CaCO_3$ and subsequently detected upon analysis.

A sample of hydrous PoP was heated to a temperature of 1400 °C (in 50 °C increments) in air using the Raman spectrometer's variable temperature stage. Heating PoP showed there was a loss of the hydration between 100 and 150 °C, indicated by the loss of the H_2O peaks at 3401 and 3495 cm^{-1}. EDX analysis of the remaining material after heating showed a detectable loss of sulphur between the heated sample and a control sample. However, the Raman spectra taken of heated PoP sample does not resemble the spectra from impact residue made from the particles of the semi-hydrous phase or $CaCO_3$. This indicates that pressure may have played a role in the formation of the $CaCO_3$ residue.

4. Conclusions

Preliminary results from hypervelocity impact experiments have shown it is possible to use Raman spectroscopy to determine temperature ranges of impacts, particularly in relation to the loss of H_2O or OH. Although, the temperatures experienced may not represent the peak temperatures reached on impact, as they may have only lasted nanoseconds at the scales of these laboratory experiments. Pressure may also play an important role in the formation of some residue material. However, more experimental data is required to confirm these initial findings. Hydrocode modelling is currently underway to determine peak pressure and temperatures experienced on impact.

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