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Shock synthesis of geological minerals from impact cratering experiments

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Abstract

Shock synthesis of individual geological minerals has been investigated to discover the individual effects of differing levels of impact generated shock. We find that due to the structure of the minerals olivine and pyroxene, the minerals are altered at different peak shock pressures. This report gives the initial results from an on-going project which aims to investigate shock effects in many common geological minerals to help us further understand the composition of highly shock material we study today.

1. Introduction

Impact cratering has shaped the celestial bodies of the solar system to those we observe and study today. These events create sudden and short lived environment of high energy, temperature and shock pressure at the point of impact that the geological materials are often altered, melted or vaporized [1]. The shock effect can alter the composition and even the structure of the geological minerals as observed by [2 and 3]. By recreating these impact scenarios in a controlled laboratory environment, the effect of different shock pressures on various mineral compositions and textures, can be examined to aid in the understanding of the manner in which these high peak shocked pressure events have shaped the composition of the material that dominates our solar system today.

2. Method

Powdered and whole grains of common geological minerals found in chondrites, including orthopyroxene, clinopyroxene powders and olivine (peridot), were fired at speeds between 1 and 7 kms^{-1} (see table 1 for equivalent calculated shock pressures) into Al foil (1080) and Stainless Steel (304) using the Light gas gun (LGG) at the University of Kent [4]. The residues in the resulting craters were analyzed using Raman (532 nm), SEM and FEGSEM analysis and compared to the composition and structure of the un-shot minerals. Details of the shot undertaken so far are shown in Table 1. Values used for the calculation of the peak shock pressure using the planar impact approximation were taken from [5].

Table 1: Shots undertaken showing the impact speed and calculated peak shock pressure.

Mineral	Target	Impact Speed (km s^{-1})	Peak shock Pressure (GPa)
Peridot	Steel	2.0	29.6
		3.3	56.2
		5.3	108.3
Orthopyroxene	Al foil	3.1	28.7
		7.0	97.2
Clinopyroxene	Al Foil	4.7	85.3

3. Results

These initial results show that a significant change in the composition of the mineral can occur when experiencing different shock pressure depending on the structure of the mineral. In this report we focus on the results of the Raman analysis.

3.1 Orthopyroxene

The orthopyroxene used has a composition of $En_{86}Fs_{13}Wo_{1}$ and was supplied by Anton Kearsley. Post impact the residues show very few peaks when analysed by Raman and many are lost into the background, one peak show a broadening effect between 650 and 750 cm^{-1}. This feature is observed in the 3.1 km s^{-1} and 7.0 km s^{-1} impacts which suggest that shock effects change the Raman signal of Enstatite at a much lower pressure then olivine, at about 29.6 GPa. More analysis will be undertaken and shots at lower speeds to verify the shock pressure at which such change is observed.

3.2 Clinopyroxene

The clinopyroxene mineral was diopside with a composition of $Wo_{49}En_{48}Fs_3$ [6] from Jaipur, India supplied by M McCanta, University of Tennessee.
The one shot so far completed for the clinopyroxene was undertake at 4.7 km s^{-1}. When compared to the Raman spectrum from the un-shot material the major peaks have all significantly changed. Most had broadened covering many more wave numbers and the peak at 320 cm^{-1} appears to have been lost. This therefore shows that clinopyroxene also experience structural change as a result of high shock pressure but more experiments at a lower impact pressures are required.

3.3 Peridot

The composition of the peridot used was $Fo_{96.}$
For impact speed of 2.0, 3.3 and 5.3 km s^{-1} there was no significant change in the position of the main Raman peaks, donated as P1 and P2 (Table 2) meaning that a pressure of 108.3 GPa is required before large olivine mineral grains (here typically 3 mm peridot) show significant structural changes. This differs from the result of [2] which investigated much finer powdered (typically 1 – 10 µm) olivine material in similar impacts.
Though the P1 and P2 peaks remain un-altered, other small peaks at 961 cm $^{-1}$ are lost in all of the spectra of the post shot material.

Table 2: RAMAN wave number for the olivine P1 and P2 peaks of the impacted Peridot residue

Impact speed	P1 position	P2 position
2.0 km s^{-1}	823.66	855.68
3.3 km s^{-1}	823.86	855.87
5 .3 km s^{-1}	822.17	854.19
Un-shot	822.17	854.19

4. Discussion

The comparisons between the shocked and un-shocked minerals show that pyroxene minerals exhibit a different structural/composition change to that of olivine. The different mineral types appear to experience a major change in structure detected by Raman analysis which is likely linked to the structure of the minerals, such as the chain and orthorhombic structure of the pyroxene and olivine respectively.

Experiments using the gun always produced a large D and G Raman band which is a result of contamination from the carbon within the rifle powder used in the experiments, and so the D and G bands are ignored in this study.

This work is ongoing and will soon include other common minerals such as feldspar (albite and anorthite), quartz and pyrite as well as detailed FEGSEM and SEM analysis of all residues. By understanding how each mineral reacts at different shock pressures the experiments can move on to shock syntheses of whole rock facies to understand the shock interaction between the different minerals at grain boundaries and other mineral interfaces.

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References

[1] Stöffler, Dieter, and Falko Langenhorst. "Shock metamorphism of quartz in nature and experiment: I. Basic observation and theory." *Meteoritics & Planetary Science* 29, no. 2 (1994): 155-181.

[2] Harriss, Kathryn H., and Mark J. Burchell. "A study of the observed shift in the peak position of olivine Raman spectra as a result of shock induced by hypervelocity impacts." *Meteoritics & Planetary Science* 51, no. 7 (2016): 1289-1300.

[3] Burchell, Mark J., Nicholas J. Foster, Anton T. Kearsley, and J. A. Creighton. "Identification of mineral impactors in hypervelocity impact craters in aluminum by Raman spectroscopy of residues." *Meteoritics & Planetary Science* 43, no. 1-2 (2008): 135-142.

[4] Burchell, Mark J., Mike J. Cole, J. A. M. McDonnell, and John C. Zarnecki. "Hypervelocity impact studies using the 2 MV Van de Graaff accelerator and two-stage light gas gun of the University of Kent at Canterbury." Measurement Science and Technology 10, no. 1 (1999): 41.

[5] Ahrens, Thomas J., and Mary L. Johnson. *Shock wave data for minerals*. American Geophysical Union, (1994).

[6] McCanta, M. C., and M. D. Dyar. "Impact-related thermal effects on the redox state of Ca-pyroxene." *Meteoritics & Planetary Science* 52, no. 2 (2017): 320-332.