DIRECT GAS ANALYSIS EXPERIMENT OF IMPACT-VAPORIZED CARBONACEOUS CHONDRITES.
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Introduction: The Cretaceous–Paleogene (K–Pg) mass extinction event, which occurred at 65.5 Ma and was one of the most important events in the history of life on the Earth, was triggered by a meteorite impact [e.g., 1, 2]. However, the killing mechanism of the mass extinction are still controversy. Impact-induced sulfur-bearing gasses is a candidate that caused a strong environmental perturbation [e.g., 3]. The thick sulfate-rich sediment found at the impact site would have vaporized and released into the atmosphere as sulfur oxides. The sulfur-bearing gasses would have converted to sulfuric acid aerosols in the stratosphere and caused sunlight blockage and/or sulfuric acid rain.

The chemical composition of the impact-induced sulfur-bearing gasses is a key to understand the mechanism and influence of its environmental perturbation [4]. One of a most important hypothesis of the environmental perturbation of the K-Pg event is sunlight blockage and impact-induced winter caused by sulfuric acid aerosol [e.g., 5]. However, Ohno et al.[6] show that SO_3 was the dominant species in sulfate-composition impact vapor clouds. If the released sulfur-bearing gasses are dominated by SO_3, the estimated residence time of the released sulfur in the atmosphere is very short and intense acid rain would have acidified oceanic surface layer significantly [7]. SO_3 release also indicates that the sunlight blockage and cooling caused by sulfuric acid aerosol would not have worked as killing mechanism efficiently because of its very short duration time [7].

Nevertheless, the sedimental sulfate is not the only source of the sulfur-bearing gasses released by the impact. Previous studies suggest that a carbonaceous chondritic impactor is consistent with the geochemical evidences [e.g., 8]. The estimated mass of sulfur-bearing gasses released from the carbonaceous chondritic impactor is not negligible. Although it is smaller than that released from the sedimental sulfate [e.g..9], the amount of sulfur-bearing gasses released from the carbonaceous chondritic impactor would have been large enough to cause strong climate forcing [9]. The results of thermodynamic calculation of chondrite-composition impact vapor suggest that sulfur-bearing gasses in carbonaceous chondritic impact vapor are dominated by reducing species such as H_2S and/or SO_2, not SO_3 [10,11]. If a large amount of reducing sulfur-bearing gasses was released into the atmosphere, it would have been oxidized and formed sulfuric acid aerosols gradually. In this case sunlight blockage would have caused strong and long-term climate forcing. Thus, investigation of the molecular composition of sulfur-bearing gasses in carbonaceous chondritic impact vapor clouds is important to understand the environmental perturbation caused by the Chicxulub impact.

Recently, an experimental method of direct impact-induced vapor analysis using a high-power laser gun in Osaka University and a quadrupole mass spectrometer (QMS) had been established [12, 13]. Preliminary results of the application of the method to sulfur-bearing gasses in impact vapor of Murchison meteorite was reported by Ohno et al. [14]. In this study, we analyze the sulfur-bearing gasses in carbonaceous chondritic impact vapor using Allende and Murchison meteorite and discuss about its implication to the K-Pg event.

Experimental method: Figure 1 shows the experimental setup of this study. We accelerate Ta flyer foil using a large powered and high speed laser gun (GEKKO XII-HIPER facility of Institute of Laser Engineering of Osaka University. Detail of the facility and the method of flyer acceleration is described by Kadono et al. [12] and detail of the experimental system of gas analysis is described by Ohno et al. [6].). The flyer and the target sample are set in a large vacuum chamber and on a low pressure condition ($<10^{-3}$ mbar). A 200 μm-thick gold spacer is set between the flyer and the Murchison meteorite target. We irradiated a laser pulse (1054nm, 10-20 ns, ~1 kJ) on a 50 μm-thick plastic ablator, which is set in front of a 30 μm-thick tantalum flyer. The ablator is vaporized by the laser pulse and the generated high temperature vapor accelerates the flyer. The flyer impacts on a slice of Allende meteorite (CV3) target or Murchison meteorite (CM2) target.

The chemical compositions of the impact-induced vapor plumes were measured directly using a quadrupole mass spectrometer (QMS). We use an hollow aluminum sphere and a SUS inhalation tube in order to avoid dispersion of the released gas to the vacuum chamber and to improve the S/N ratio of the QMS analysis.

Results: Figure 2 shows an example of time series data of the QMS measurements. We observed significant amount of SO_2, OCS, CS_2 and H_2S gas released by the foil impact. The blank level, the QMS currents before the impact, is much lower than the QMS current values of the impact-induced SO_2, OCS, CS_2 and H_2S gas. H_2S was the most abundant species and no small amount of SO_2, OCS and CS_2 were also observed in all the shots of this study. On the other hand, QMS signals derived from SO_3 were not detected in any shots of this study although the sensitivity of this experimental method is high enough to analyze the impact-induced SO_3 quantatively [6].

Our experimental results suggest that impact-induced sulfur-bearing gasses in carbonaceous chondritic impact vapor would be dominated by H_2S, SO_2, OCS and/or CS_2. These species would have been converted to sulfuric acid aerosols gradually and caused long-term global cooling during the K-Pg event. Our experimental results also suggest that SO_3, which is the dominant sulfur-bearing species in the sulfate-composition impact vapor [6], is a very minor species in carbonaceous chondritic impact vapor. It implies that sulfur released from K-Pg carbonaceous chondritic impactor would not have contributed global acid rain.

References:

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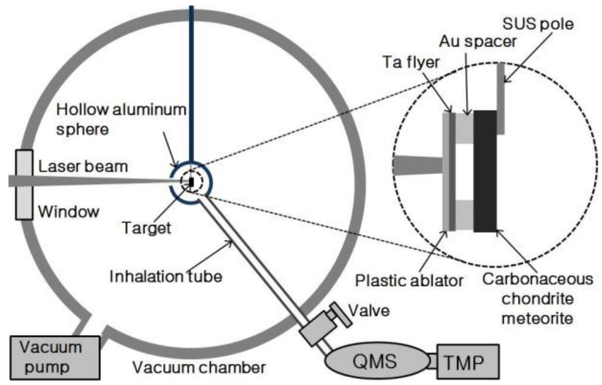

Figure 1: A schematic diagram of the experimental system. Detail is described by Ohno et al. [6].

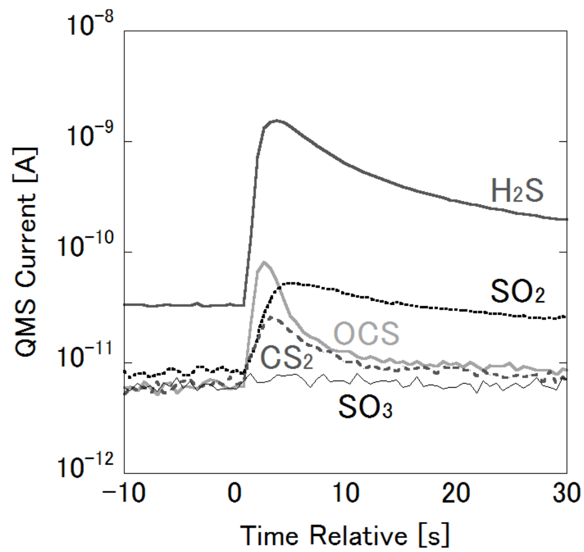

Figure 2: An example of the time-series data of the QMS measurements. The QMS currents of H_2S (mass number 34, dark gray solid line), SO_2 (mass number 64, black dotted line), OCS (mass number 60, gray solid line), CS_2 (mass number 76, dark gray dotted line), and SO_3 (mass number 80, black thin line) are plotted against the time. The QMS currents of H_2S, SO_2, OCS, and CS_2 increased significantly at the timing of the impact. No significant signals of SO_3 were detected.