ORGANIC MASS SPECTRA OF SHOCKED MURCHISON METEORITE.
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To examine the behavior of organic matter in carbonaceous meteorites during impact, we have analyzed laboratory-shocked samples of the Murchison carbonaceous chondrite using thermal-desorption photoionization mass spectrometry (Surface Analysis by Laser Ionization, SALI) [1]. This method reveals the presence of indigenous aliphatic, aromatic, and organosulfur compounds and elemental sulfur in unshocked Murchison [2]. Very little impact-induced organic loss occurred at peak shock pressures up to 20 GPa. However, shock to 36 GPa peak shock pressure resulted in roughly 70 % loss of total organics. The residual organic matter desorbed at higher temperatures (T_{desorb} = 360-700°C) than for unshocked Murchison (T_{desorb} = 40-700°C). Detailed examination of the mass spectra indicates that impact-induced loss of organic compounds is not an isochemochemical process. Amines and elemental sulfur are the most labile, aliphatic and aromatic compounds have intermediate stabilities, and organosulfur and inorganic sulfides are the most stable. The shock process results in production (increased residue than in the starting material and thus we expect the mass spectrometry (Surface Analysis by Laser Ionization, SALI) fingerprints are absent from the spectra, indicating that efforts to avoid sample contamination were successful [2].

Figure 1 shows cumulative mass spectra (the sum of all spectra acquired over the temperature interval 25-800°C) of unshocked material and of Murchison shocked to 20 and 36 GPa. Complete listings of peak identities are in references [2] and [3]. In the 36 GPa sample, peaks at m/z of 160, 192, 224, and 256, identified as S₅, S₆, S₇, and S₈ resulting from sublimation of elemental S, are nearly absent. In addition, the ammonia peak (m/z = 17) associated with the decomposition of amines (amino acids) is reduced to background level. Noticeable in the 36 GPa spectrum are peaks at m/z = 98, 114, and 126 that are not present in the unshocked or 20 GPa spectra. We think that these peaks are not simple aliphatics (C₇H₁₄ = 98, C₈H₁₈ = 114, C₉H₁₈ = 126) because the peak intensities fail to follow a logarithmically decreasing trend with increasing carbon number. We also disfavor substituted thiophenes (C₃H₄S = 98, HOCH₂-C₄H₃S = 114, C₃H₇-C₄H₅S = 126) because of the relatively low intensity of a thiophene peak (C₄H₄S = 84, note the interference C₆H₁₂ = 84). Although we cannot identify them unambiguously, these peaks are clearly the result of chemical reactions occurring during the shock event.

Figure 2 shows thermal desorption spectra corresponding to m/z = 17 (NH₃), 64 (elemental sulfur and sulfides), and 114 and 126. In the shocked sample, thermal desorption occurs primarily at temperatures greater than 350°C. The increase in the intensities of the m/z = 114 and 126 peaks in the shocked sample is evident.

Figure 3 shows the thermal desorption spectrum of the C₃ to C₅ aliphatic compounds (sum of peaks with m/z = 42, 56, 70, 84, 44, 58, 72, and 86) and the thermal desorption spectrum of the ratio of the unsaturated aliphatics (alkenes, m/z = 42,56,70,84) to the saturated fraction (alkane, m/z = 44,58,72,86). The shocked Murchison releases aliphatics (from the breakdown of kerogen) at a higher temperature and over a narrower temperature range than does the unshocked material. The alkene/alkane ratio is lower in the shocked material. If we assume that the differences in this ratio are accounted for by loss to the gaseous phase (as opposed to chemical reactions resulting in new species remaining in the solid residuum) then we tentatively conclude that the C:H ratio is greater in the solid residuum than in the starting material.

Previous studies of Murchison suggested that impact-induced devolatilization was isochemical, that is, that little chemical fractionation occurs during impact [4]. Later more detailed studies of serpentine showed that some deuterium/hydrogen fractionation occurred during impact, with H being enriched in the vapor, D in the residue [5]. The results of this study indicate that chemical reaction and fractionation are an integral part of the impact process when complex materials such as carbonaceous chondrites are involved.

Figure 1 (Above). Cumulative (25-800°C) SALI-118 nm mass spectra of unshocked and shocked Murchison. Prominent mass peaks are labelled and mass assignments are discussed in the text.

Figure 2 (To right). Thermal desorption mass spectra for unshocked and shocked Murchison for m/z = 17 (NH₃), m/z = 64 (elemental sulfur T < 400°C, inorganic sulfides T > 400°C), and m/z = 114 and 126 (identity unknown).

Figure 3. Thermal desorption mass spectra for the sum of C₃ to C₆ aliphatics and for the ratio of C₃ to C₆ alkenes to alkanes. See text for discussion.