Meteorite Heating During Atmospheric Entry

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Introduction: The extent of meteorite heating during atmospheric entry has to be considered when studying properties that are highly temperature sensitive. This is the case for instance of paleomagnetic studies: even mild heating (≥150°C) can impart a partial thermoremanent magnetization to the meteorite (because cooling occurs in the geomagnetic field), interfering and potentially obliterating the original paleomagnetic signal. Another example is the study of incipient parent body thermal metamorphism in primitive chondrites. Modeling and thermoluminescence data show that strong heating (≥400°C) is restricted to only about 1 mm below the fusion crust [1]. However, it is not well known how deeper mild heating (200-400°C) can affect the meteorite. In view of the recent renewal of meteorite paleomagnetism and the never-ending quest for the most pristine chondritic materials, we address here the question of how much the heat wave can penetrate a meteorite during atmospheric entry.

Results: We studied two meteorites that have suffered no or very weak thermal metamorphism on their parent body (Murchison CM2, and EET 90628 LL3.0). These two meteorite groups were chosen to span a wide range of porosity (17.1% in Murchison, 6.0% in EET 90628 [2]). Porosity is indeed a parameter that may strongly affect the penetration of the heat wave. We studied two fusion crusted sample of these meteorites. A sample of Murchison bearing a fusion crust created artificially in a wind tunnel experiment [3] was also studied. The penetration of the heat wave below the fusion crust was evaluated using two properties that are highly sensitive even to mild temperatures: remanent magnetization and degree of maturity of the polyaromatic organic matter.

We acquired Raman spectra in matrix-rich areas at increasing distances from the fusion crust (in both punctual and mapping modes) and monitored the evolution of the spectral parameters of interest compared to the same parameters measured away from the fusion crust [e.g., 4].

Paleomagnetism will be used as an independent proxy for the heat wave penetration in Murchison. Indeed, when heated during atmospheric entry, Murchison will have acquired a partial thermal remanent magnetization (pTRM) in the geomagnetic field (about 57 µT at the location of Murchison fall). This pTRM can easily be distinguished from the original extraterrestrial magnetization of Murchison that was acquired in much weaker field of about 1 µT [5]. Using progressive thermal demagnetization, we can estimate the maximum unblocking temperature of this pTRM, which corresponds to the peak temperature during atmospheric entry. Based on the Raman spectroscopy results, we prepared samples at different distances from the fusion crust and estimate the peak temperature they have reached. The spatial resolution is lower than for Raman spectroscopy, but this technique can provide quantitative temperature estimates whereas the Raman technique provides only relative temperatures.

Discussion and conclusions: The Raman maps reveal a clear effect of the heat wave over several hundreds of micrometers below the fusion crust in both meteorites. The paleomagnetic results will constrain deeper and milder heat wave penetration. These results will allow evaluating the "safe zone" where highly temperature sensitive properties can be studied. This is especially relevant when studying small meteorites with a small volume to surface ratio.

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