Thermal history of type-3 chondrites in the NASA antarctic collection

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Chondrites are the most primitive meteorites. However, they were all modified in some ways by post-accretion geological processes operating on their asteroidal parent bodies. Hence, to decipher the formation(s) and origin(s) of their components, we must first understand how chondritic materials were modified in their asteroidal parent bodies. The modifications induced by secondary processes should not be underestimated and have to be precisely estimated before any interpretation of chondrite properties in terms of cosmochemistry. In particular, all chondrites contain some organic components that were potentially chemically and physically modified through post-accretion processes. A thin understanding of the induced evolution is required to allow for pertinent comparisons with other primitive extraterrestrial materials, such as cometary grains, to finally address questions such as the origin of organics in the Solar System.

Type 3 chondrites experienced thermal metamorphism on their asteroidal parent body due to the radioactive decay of elements such as ^{26}Al. Temperatures higher than 300 °C were experienced on timescales of several thousands of years. Still, type 3 chondrites remain as unequilibrated rocks and common mineralogical thermometers cannot be applied. The polyaromatic carbonaceous matter is sensitive to thermal episodes (of long and short duration) experienced by the host meteorite. In particular, its structural order directly reflects the thermal history experienced on their parent bodies. The structural modification of the aromatic carbonaceous matter towards a higher order is irreversible, and independent of the mineralogy and degree of aqueous alteration. It is mainly controlled by the peak metamorphic temperature. Moreover, under the assumption of fairly similar organic precursors among chondrites of distinct groups, the structural order of polyaromatic organic matter allows for a direct comparison of their metamorphic grades. It is then possible to evaluate the metamorphic grade of the objects and to assign a petrologic type along a unique petrologic scale [1–4]. This technique has been successfully applied to type 3 Unequilibrated Ordinary Chondrites [1], carbonaceous CV chondrites [2], and CO chondrites [3]. The interpretation of the structural order of the polyaromatic carbonaceous matter in terms of thermal history is thus reliable. Raman spectroscopy enables the determination of the degree of structural order of the polyaromatic organic matter present in the matrix of chondrites. Both falls and finds, from Antarctica [4] and elsewhere, have been analyzed. It does not require a large amount of samples and is relatively easy to implement. Raman spectroscopy is particularly sensitive to the lowest petrologic types (3.0–3.2).

The present NASA collection of Antarctic meteorites represents an incredible source of precious samples for our community. The present work finely characterizes the thermal history of most of the type 3 chondrites (UOCs, CVs, and COs) from that collection. At the present time, the objectives are threefold: (*i*) determination of reliable petrologic types indispensable for our community; (*ii*) identification of the most primitive type 3 chondrites (petrologic type $\leq$ 3.1); and (*iii*) identification of potential "anomalous" samples having experienced a slightly different thermal history.

The JSC Meteorite Working Group generously allocated us with more than 150 chondrites (UOCs, CVs, and COs). The following points summarize the main results. (*i*) At the present time, the thermal histories of more than 100 samples have been characterized. (*ii*) The terrestrial weathering experienced by several chondrites ($\sim$25 chondrites) has been too pervasive for the method to be applied. For these meteorites, as signatures of oxide minerals dominate Raman spectra of the matrix, the organic matter might have been significantly altered through oxidation. (*iii*) Real discrepancies with the preliminary JSC petrologic type attributions were found for several chondrites with mostly underestimations of the metamorphic grades. (*iv*) The structural grade of the polyaromatic carbonaceous matter is fairly homogeneous in most of the considered chondrites with a few exceptions, interpreted in terms of shock events. (*v*) Recently, there were some promising advances (e.g. [5,6]) in terms of interpretation of the structural order of the polyaromatic carbonaceous matter as a geothermometer for terrestrial rocks of low maturity grades. The used spectral tracers will be considered and the thermometry potentially applied to infer new constraints on the metamorphic temperature experienced by these type 3 chondrites.

References: [1] Quirico et al. (2003) MAPS 38, 795. [2] Bonal (2006) PhD dissertation. University Grenoble I. [3] Bonal et al. (2006) GCA 70, 1849. [4] Bonal et al. (2007) GCA 71, 1605. [5] Lahfid et al. (2010) Terra Nova 22, 354. [6] Kouketsu et al. (2013) Island Arc 23, 33.