Hydrothermal activity on the CV parent body: new perspectives from the unique CV-like TAM5.29 micrometeorite

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Introduction: Unmelted micrometeorites (MMs) from anhydrous CC groups are relatively rare, in contrast ,up to the 50% cosmic spherules have oxygen isotopic compositions related to the CO/CV/CK population [1]. Among MM collections only two particles have been recognized as CV-like [2-3], although neither were the subject of a detailed investigation and their classification as CV-like revealed some issues. Here we provide a detailed characterisation of the first well-documented unambiguous CV-like MM, expanding knowledge in the compositional range of MMs as well as investigating the thermal metamorphism and hydrothermal history of the CV parent body-(ies). Furthermore, given that MMs originate from the asteroid belt [4] and cometary sources [5], the study of this sample can be a useful support to recent and upcoming space missions to C-type asteroids and comets

Methods: We collected Raman, EBSD and EMPA analyses at the University of Padova. FE-SEM-EDS analyses were made at the University of Pisa and µXRD at the Natural History Museum in London. Reflectance spectra were take with FT-IR at the IAPS-INAF laboratories in Rome.

Petrography: TAM5.29 is dominated by an Fe-rich matrix composed of orientated fayalitic olivines ($Fa_{42.5}$ to $Fa_{92.3}$). Inclusions of andradite surrounded by diopside-jarosite mantles are also present as well as minor fibrous phyllosilicates – chondrules are absent. Micron-sized spinels co-occur with metal-oxides dispersed within the matrix. Pyroxenes – within the inclusions - have variable compositions ($Fs_{1.8\text{-}60}$ $Wo_{0.7\text{-}48}$), meanwhile, portions of the olivine groundmass have been altered resulting in a mixture of fine-grained hydrated Mg-Fe-sulphur-rich minerals, that we identify as iddingsite. The particle bulk composition is similar to that of CCs and unmelted micrometeorites. However, TAM5.29 demonstrates enrichment in Fe and depletion in Mg compared to the CCs. The Al content of TAM5.29 is similar to that of CVs, however, Ca and Ti are depleted compared to CVs. Strong enrichment in K in TAM5.29 is also detected compared to both CVs and other UMM. Raman analyses identified ubiquitous carbon and the presence of OH, S-H and C-H functional groups. Another important observation is a linear feature that cross-cuts the fayalitic groundmass showing a displacement of primary features. This feature is composed of a nanocrystalline or glassy matrix and hosting anhedral rounded olivine crystallites and minor Fe-Ni oxides. We interpret the linear feature as a shock melt vein, evidence of impact processing.

Discussion: TAM5.29 mineralogy lies in between the CV_{oxA} and CV_{oxB} being rich in andradite, magnetite and FeNiS, like CV_{oxA}, but also containing hydrated minerals as seen in the CV_{oxB} group. CV_{oxB} also contains almost pure fayalite, which is rare in TAM5.29. TAM5.29 mineralogy is dominated by thermal metamorphism products formed at ~275-250°C within the presence of Fe-alkali-halogens-rich fluids [6] and under highly oxidizing conditions resulting in significant Fe enrichment. This may represent a newly described alteration environment on the CV parent body: higher oxidizing conditions, heterogeneous thermal metamorphism (different degrees of alteration within TAM5.29 micrometeorite were detected) and a different secondary alteration history enabled by a particular impact history. This is the proof of an even more heterogeneous CV parent body(-ies) thus adding a unique sample to the known CV lithologies. We suggest a multistage formation of TAM5.29: 1) metasomatism at ~275-250°C with Fe-alkali-halogens-rich fluids occurred on the parent body. 2) The particle was involved in an impact that terminated the metamorphic event resulting in a unequilibrated composition with cryptocrystalline and amorphous phases and generating a preferred orientation of olivine. 3) Formation of iddingsite at lower temperatures (<100°C), possibly from fluid released by hydrated minerals during the impact. Furthermore IR reflectance spectra of TAM5.29 is very similar to the spectra of C-type asteroids (e.g. Ceres, 52 Europa) thereby acting as analogue samples, giving possible insights into their composition and geological evolution.

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