

THERMAL HISTORY OF SÃO JOÃO NEPOMUCENO (IVA) IRON METEORITE INFERRED FROM GANGULY'S COOLING RATE MODEL AND ^{57}Fe MÖSSBAUER SPECTROSCOPY DATA

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In spite of the extensive work performed on the IVA irons there is still no consensus about their origin and thermal history [1]. Their particular chemistry and range in metallographic cooling rates are difficult to explain under conventional models. Although IVA irons are extremely depleted in volatile siderophile elements (e.g., Ga, Ge) [1], the chemical trends within this group are consistent with an origin in a single metallic body that fractionally crystallized. Nonetheless, their large spread of metallographic cooling rates correlating inversely with Ni content argues against an origin in a mantled asteroidal core [2]. If this would be the case, uniform cooling rates should be expected. Furthermore, metal-silicate mixing of the IVA group remains a complex issue. Following previous works [3], here the intracrystalline Fe-Mg distribution in orthopyroxenes, as measured by means of ^{57}Fe Mössbauer spectroscopy and associated to Ganguly's cooling rate numerical method [4], are used to infer the thermal history of São João Nepomuceno (SJM) meteorite, aiming to enlarge the understanding of the origin of IVA iron meteorite group.

All SJM samples used in this study belong to the Museu Nacional/UFRJ in Rio de Janeiro. The separation of silicate inclusions of the SJM meteorite from its metallic matrix was done in several thin slices, as described in [5]. The separated grains were inspected under an electron microscope for verification of their chemical composition. Two polished thick sections from SJM were prepared and, under an optical microscope, opx crystals were selected for chemical analysis. Major element chemical compositions were obtained with an ARL-SEM-Q (WDS) electron microprobe at ICATE-Argentina, as shown in [5]. Estimated precision for major and minor elements is better than 3 % and for Na about 10 %. Natural and synthetic standards were used for calibration and an online ZAF correction was applied to the data. Room temperature ^{57}Fe Mössbauer spectroscopy, in standard transmission geometry using a 25 mCi $^{57}\text{Co}/\text{Rh}$ radioactive source in sinusoidal mode, was performed at CBPF and at ICT. Spectra were recorded for 24 h in a 512 channels spectrometer and the calibration was taken at RT with α -Fe foil. The error in source velocity is less than 1 %. The NORMOS code was used for Mössbauer spectra analyses [6]. All isomer shifts reported in this work are given relative to α -Fe at RT.

In terms of the end-members of pyroxene solid-solution, the studied samples corresponds to: $\text{En}_{85}\text{Fs}_{14}\text{Wo}_1$. The derived opx unit formula calculated on the basis of six oxygen atoms is given by: $(\text{Fe}^{2+}_{0.273}\text{Mg}_{1.678}\text{Mn}_{0.016}\text{Ca}_{0.021}\text{Ti}_{0.001}\text{Cr}_{0.018})(\text{Si}_{1.982}\text{Al}_{0.012})\text{O}_6$. The ^{57}Fe Mössbauer spectra of opx samples, at temperatures ranging from 25 to 300 K, are characterized by two overlapping doublets attributed to Fe^{2+} at two nonequivalent sites (M1 and M2). The absence of any Fe^{3+} doublets and magnetically ordered iron oxides suggests that terrestrial weathering did not take place in these samples. Consequently, the absence of secondary phases related to oxidation processes means that the minerals in SJM represent a non-altered assemblage, at least from the latest thermal event that could have affected this meteorite. The occupancies of Fe^{2+} at M1 and M2 sites, $Fe(M1)$ and $Fe(M2)$, respectively, are obtained by multiplying the Fe^{2+} fractions (i.e. average Mössbauer area) at M1 (10%) and M2 (90%), by the total amount of Fe^{2+} (0.273) given by electron microprobe results. Thus, $Fe(M1) = 0.10 \cdot 0.273 = 0.027$ and $Fe(M2) = 0.90 \cdot 0.273 = 0.246$. Assuming complete order of Cr and Ti atoms at M1 site and Mn and Ca atoms at M2 site [7], Mg distribution over M1 and M2 sites can be calculated as follow: $Mg(M1) = 1 - (Fe(M1) + N_{\text{Cr}} + N_{\text{Ti}}) = 0.954$ and $Mg(M2) = N_{\text{Mg}} - Mg(M1) = 0.724$, where N_{Cr} , N_{Ti} , N_{Mg} are the numbers of Cr, Ti and Mg atoms per formula unit. Hence, the distribution coefficient [7] for the studied sample is $K_D = 0.083$. Using the geothermometric calibration of Wang et al. [7], we found $T = 494$ °C for the closure temperature of the order-disorder reaction in the opx from SJM meteorite. Based on Ganguly's numerical method the cooling rate for the opx from SJM meteorite is found to be $\sim 8.2 \times 10^3$ °C/My. At this point, before any interpretation, one question arises: Is this cooling rate value, obtained in the framework of Ganguly's method, reliable?

References

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