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Orthopyroxene Megacrysts in Toufassour Mesosiderite: Mineralogy and Origin

Lahcen Ouknine[1,2], Abderrahmane Ibhi[1,2], Fouad Khiri[1,2], Ahmed Ait Touchnt[2], Paola Manzari[3], Olga De Pascale[4] and Giorgio S. Senesi[4]
[1]Petrology, Metallogeny and Meteorites Team, Faculty of Sciences, Ibn Zohr University, Morocco.
[2]University Museum of Meteorites, Ibn Zohr University, Morocco.
[3]Agenzia Spaziale Italiana, Roma, Italy
[4]CNR - Istituto per la Scienza e Tecnologia dei Plasmi (ISTP) sede di Bari, Bari, Italy

Abstract

Many specimens of the Toufassour mesosiderite meteorite found in Tata (Morocco) in 2003 contain large (up to 1.5 cm) single crystals of orthopyroxene, the abundance of which appears to be greater than that found in other mesosiderites. The aim of this work was to study the mineralogy and origin of these megacrysts. The results obtained have shown that, in contrast to orthopyroxene phenocrysts, the megacrysts feature a chemical imbalance with preexisting phenocrysts (Opx, Cpx and Ol), which suggests that pyroxene megacrystals are not crystallized in the same silicate bath.

1. Introduction

Since 2003, about 300 Kg of mesosiderite fragments have been harvested in and around a small depression named “Toufassour impact crater” in the Toufassour region of Morocco and marketed [1]. Studies performed by two university laboratories, Laboratoire LPMM of the University Ibn Zohr (Morocco) and Laboratoire MAGIE of the University of Paris VI (France) have confirmed the meteoric origin of these mesosiderite fragments that are reported as "Toufassour" by the Meteoritical Society. These meteorties are characterized by the absence of a fusion crust and a slightly glossy surface, with metal nodules protruding randomly and large silicate inclusions visible as greenish spots (Fig. 1).

2. Methods

The modal proportions of the different phases were obtained by counting points on a number of thin sections. Spot mineralogical analyses were carried out using the automated electron microprobe (SX 50) of the University of Paris VI (France). The majority of the phases were analyzed at an acceleration voltage of 15 kV and a current of 4 nA with integration times of 20 seconds applied to all elements.

3. Results

The Toufassour mesosiderites are mainly composed of free and nodule metals and silicates. The Fe-Ni metals consist of irregular particles of kamacite with round or lamellar taenite, inclusions of shreberzite and rare troilite. The silicate minerals are plagioclases with a poikilitic texture, pyroxenes and olivine. Clinopyroxene crystals are smaller than those of orthopyroxene and olivine. The composition (% vol) of the silicates of this meteorite is: pyroxene, 51.6%; plagioclase, 33,.6%; silica 5,.89%; Ca-phosphate, 0,.48%; chromite and rare ilmenite, 0.36%; iron hydroxide, 1.76%; and troilite, (0.27%). The composition of the pyroxene grains ranges between En_{85} Fs_{13} Wo_{02} and En_{59} $Fs_{33}Wo_{05}$ (FeO/MnO= 22 to 26), olivine (Fa_{19}, FeO/MnO = 35), chromite [Cr/(Cr + Al)= 0.76], two plagioclases (Ab_{07} An_{93} and Ab_{82} An_{11} Or_{06}), augites (En_{54}, Fs_{07}, Wo_{39}). kamacite (Ni=6%), and merrillite with significant amounts of MgO [2, 3].

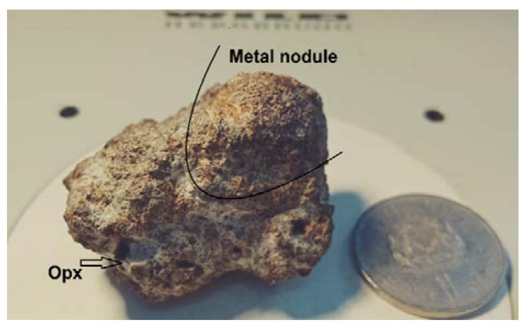

Fig. 1. Toufassour mesosiderite.

Similar to other mesosiderites, orthopyroxenes are important components [4]. In particular, the phenocrystals occupy about 20% of the meteorite volume, and appear in different forms in the same sample, i.e. as stocky and stretched individuals. The presence of various forms of crystals in the same sample represents the different response of the crystals to deformation. The orthopyroxene megacrystals are large (500 µm to 1.5 cm) and identifiable with the naked eye. Some of them feature cracks perpendicular to their elongation, parallel to the joints of the folding strips. These breaks are limited to orthopyroxene crystals and do not continue in the matrix. They result from the brittle behavior of these crystals during decompression due to shocks occurring either during the detachment from the parent body or at the impact with the terrestrial ground. Structural formulae calculated on the basis of 6 oxygen atoms show that orthopyroxene phenocrystals are generally En_{70} Fs_{25} to En_{59} Fs_{30} hypersthene relatively rich in iron with an average FeO=19.4%. Orthopyroxene megacrystals are generally bronzites En_{86} Fs_{12} to En_{81} Fs_{18} low in iron (average FeO about 10.7%, and similar to orthopyroxenite diogenites, thus they are probably related to the HED group [5].

4. Discussion and Conclusions

The Xmg (Mg/Mg+Fe) differentiation ratio, used to estimate the evolution of the crystallization of ferromagnesian minerals, decreases as differentiation evolves in the fluid yielding orthopyroxenes. The diagram of the FeO/MnO ratio as a function of this ratio (Fig. 2) shows that there is no petrogenetic correlation between the megacrystals and phenocrystals of orthopyroxenes. In orthopyroxene (opx) and clinopyroxene (cpx), aluminum occupies both tetrahedral and octahedral sites, while chromium can only be in octahedral sites, thus the Al/Cr exchange is limited to octahedral sites. The diagram of $(2Cr/Cr+Al\text{-}Na)_{Cpx}$ as a function of $(2Cr/Cr+Al\text{-}Na)_{Opx}$ (Fig. 4) shows that mega-orthopyroxenes and clinopyroxenes are not correlated, which suggests that the two components do not have the same equilibrium constant for this exchange reaction.

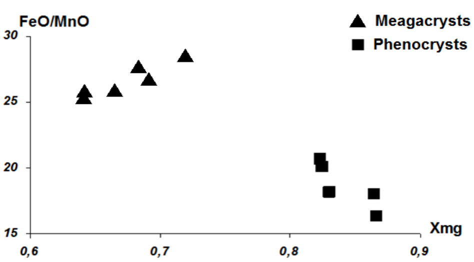

Fig. 2. FeO/MnO ratio as a function of Xmg in Toufassour orthopyroxenes.

The equilibrium constant $K_{Mg/Fe}^{Ol/Opx}$ based on the exchange reaction between the molecules of Fo and Fa in olivine (ol) and those of Fs and En in orthopyroxene, Matsui and Nishizawa [6] showed a coefficient between olivine and orthopyroxene phenocrysts is about 0.97, which indicates a balance between these two phases. On the contrary, the Mg/Fe partition coefficient between the phenocrystals of olivines and those of mega-orthopyroxenes shows a low value, i.e. about 0.70, indicating an imbalance between these two phases. These preliminary results let think about a possible origin of these megacrystals in diogenites that are ultramafic rocks dominated by orthopyroxenes featuring cumulative igneous textures [7]. Further investigations are ongoing to assess exactly the origin of these megacrystals.

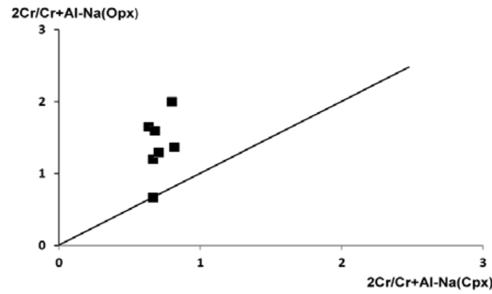

Fig. 3. (2Cr/Cr+Al-Na) in clinopyroxenes as a function of (2Cr/Cr+Al-Na) in Toufassour orthopyroxenes.

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