



# Study of non-equivalent Fe positions in some extraterrestrial minerals using Mössbauer spectroscopy with a high velocity resolution

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## Abstract

Study of extraterrestrial minerals with non-equivalent Fe positions such as the M1 and M2 sites in olivine and pyroxenes in ordinary chondrites, the M1 and M2 sites in olivines from pallasites and the M1, M2 and M3 sites in iron nickel phosphides from iron meteorites was performed using Mössbauer spectroscopy with a high velocity resolution. Obtained differences were analyzed in order to characterize these minerals.

## 1. Introduction

A number of extraterrestrial iron bearing minerals have crystallographically non-equivalent sites for iron. Olivine ( $\text{Mg, Fe}_2\text{SiO}_4$ ) and pyroxene ( $\text{Mg, FeSiO}_3$ ) contain two different six-fold octahedral sites for  $\text{Fe}^{2+}$  and  $\text{Mg}^{2+}$  denoted as M1 and M2. These sites in olivine and pyroxene are occupied by  $\text{Fe}^{2+}$  and  $\text{Mg}^{2+}$  ions in different ways. The Fe–Mg distribution between two sites is of interest due to its possible application for minerals cooling history determination during meteorites formation. Iron nickel phosphides ( $\text{Fe, Ni}_3\text{P}$ ) were found in iron meteorites in two forms: schreibersite and rhabdite. The crystal structure of schreibersite and rhabdite was similar with three crystallographic sites for metal atoms denoted as M1, M2 and M3. These sites were occupied by Fe and Ni atoms in different way for schreibersite and rhabdite extracted from various meteorites. To study these extraterrestrial minerals we used Mössbauer spectroscopy with a high velocity resolution. This technique demonstrated new possibilities in the study of various iron bearing minerals in meteorites [1, 2]. Therefore, in the present work we discuss results of the study of olivine and pyroxene in bulk ordinary chondrites, olivine extracted from pallasites and iron nickel

phosphides extracted from iron meteorite.

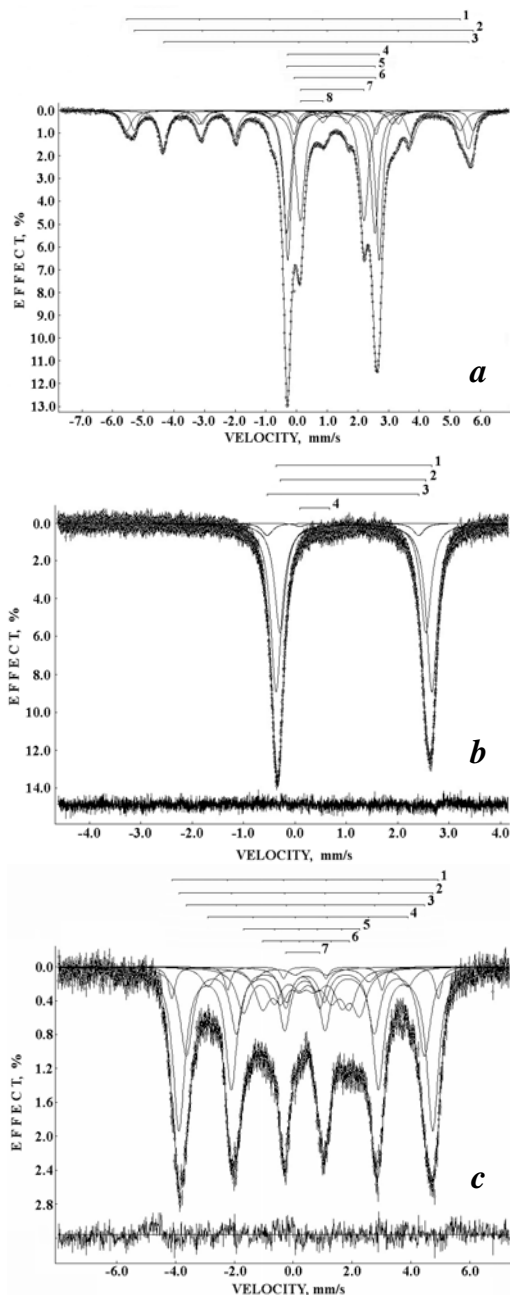
## 2. Materials and Methods

Samples of Saratov L4, Mount Tazerzait L5, Tsarev L5, Farmington L5, Mbale L5/6, Kunashak L6, Zubkovsky L6, Ochansk H4, Richardton H5, Vengerovo H5, Zvonkov H6 were prepared as powders for Mössbauer measurements with effective thickness of about 10 mg  $\text{Fe}/\text{cm}^2$ . Samples of olivine extracted from Omolon PMG and Seymchan PMG were prepared as powders with effective thickness of about 6 mg  $\text{Fe}/\text{cm}^2$ . Samples of schreibersite and rhabdites extracted from Sikhotealin IIAB iron meteorite mechanically and electrochemically, respectively, were prepared with effective thickness of about 5–6 mg  $\text{Fe}/\text{cm}^2$ .

Mössbauer spectra were measured using Mössbauer spectrometric complex with a high velocity resolution described elsewhere [3]. Spectra were measured in 4096 channels and then presented in 1024 channels for chondrite and iron nickel phosphide samples and in 4096 channels for pallasites. All spectra were measured at 295 K, pallasites spectra were also measured at 90 K while phosphides spectra were additionally measured at 220, 150 and 90 K.

## 3. Results and Discussion

Some of Mössbauer spectra are shown in Fig. 1. Mössbauer spectra of ordinary chondrites were better fitted one or two sextets related to Fe–Ni–Co alloys (1, 2), one sextet related to troilite FeS (3), two quadrupole doublets related to the M1 and M2 sites in olivine (4, 5), two quadrupole doublets related to the M1 and M2 sites in pyroxene (6, 7) and one quadrupole doublet related to  $\text{Fe}^{3+}$  compound (8). Mössbauer spectra of extracted olivine from two pallasites at 295 and 90 K were better fitted using



**Figure 1:** Mössbauer spectra of Farmington L5 at 295 K (*a*), olivine from Omolon at 295 K (*b*) and rhabdite from Sikhote-Alin at 90 K (*c*). Indicated components are the results of the best fit.

three quadrupole doublets which were related to the M1 and M2 sites (1, 2) and additional minor high spin ferrous compound with parameters slightly different from both components related to the M1 and M2 sites. In the case of olivine from Omolon

meteorite addition component 4 related to  $\text{Fe}^{3+}$  compound at 295 K. In the case of iron nickel phosphides from Sikhote-Alin iron meteorite different behavior of Mössbauer spectra were observed. Nevertheless, these spectra were fitted using a model of six sextets two pairs of which were related to the M1 (1, 2), M2 (3, 4) and M3 (5, 6) sites. Using relative areas of components related to the each non-equivalent position and chemical analysis of studied minerals the distribution of Fe and Mg or Ni in these sites were evaluated in addition to hyperfine parameters. As for hyperfine parameters, it was found small variations of parameters related to similar minerals obtained from different meteorites. This fact may be a result of small structural variations in these minerals.

## 4. Summary and Conclusions

Study of various minerals from extraterrestrial materials with crystallographically non-equivalent Fe positions using Mössbauer spectroscopy with a high velocity resolution revealed spectral components related to  $^{57}\text{Fe}$  in these sites. It was found small variations of hyperfine parameters related to small structural variations in the same minerals from different meteorites. Evaluation of Fe distribution in these sites for different minerals was made on the basis of relative areas of spectral components and results of chemical analysis. These data may be used for thermal history evaluation in silicates.

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## References

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