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# Mössbauer study of the Pavel and Gumoschnik meteorites, and some meteorwrongs

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Mössbauer spectroscopy is discussed as a tool for giving information on the origin of meteorites as well as classifying them into the groups of the iron, stone, and stony-iron meteorites. Mössbauer studies of two unidentified findings and two well documented stone meteorites: the Pavel one which fell on February 28, 1966 and the Gumoschnik which fell on April 28, 1904 demonstrate the possibility of the Mössbauer test for authentication of the meteorites.

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*Keywords*: Mössbauer spectroscopy, Meteorites, Meteorwrongs

## 1. Introduction

In the last few centuries five falls of meteorites have been registered on the territory of Bulgaria. Some of them are well documented [1, 2]. The authenticity of a meteorite is a very important question, which doubtlessly needs an answer, since often earth rocks or manufactured iron have been falsely considered to be of cosmic origin, the so-called **meteorwrongs** [3]. In all meteorites, kamacite and taenite (Fe-Ni alloys with different Ni contents), troilite (FeS), olivine (Mg, Fe)$_2$[SiO$_4$], pyroxene (Mg, Fe)[SiO$_3$] and Fe(III) mineralogical phases are identified. The Mössbauer parameters of these minerals are well known [4, 5]. Some minerals like troilite have extra-terrestrial origin only. Additionally, some iron-bearing compounds found in man-made iron samples such as cimentite (Fe$_3$C) have Mössbauer spectra absent in all meteorites discovered so far. In this contribution, Mössbauer spectroscopy is discussed as a tool for giving information on the origin of meteorites, as well as for classifying them into the groups of the iron, stone, and stony-iron meteorites. Mössbauer studies of two unidentified findings and two well documented stone meteorites: the Pavel one which fell on February 28, 1966 and the Gumoschnik - which fell on April 28, 1904 demonstrated the possibility of the Mössbauer test for authentication of the meteorites.

## 2. Experimental details

The Mössbauer spectra were obtained using a standard spectrometer working in a constant acceleration mode. The $^{57}$Co[Rh] radioactive source of about 30 mCi activity and for calibration a 25 μm α-Fe foil were used. To detect the Mössbauer quanta of 14.4 keV, a NaI(Tl) scintillation detector with a crystal of 0.1 mm thickness were used. The isomer shifts were referred to the α-Fe standard at room temperature. Iron concentrations and element composition were confirmed by Energy Dispersive X-ray Fluorescence (EDXRF) analysis using an electron probe micro analyzer JEOL Superprobe 733 with a Si(Li) detector Ortec 7986-P30.

## 3. Experimental results and discussions

Fig. 1. presents a Mössbauer spectrum of very high quality taken from the Pavel meteorite. The five major mineral components typical for meteorite samples kamacite, troilite, olivine, pyroxene and Fe(III)-bearing mineralogical phases are observed in the spectrum. The measured parameters are summarized in Table 1. Their numerical values are in very good agreement with those received from other meteorite samples.

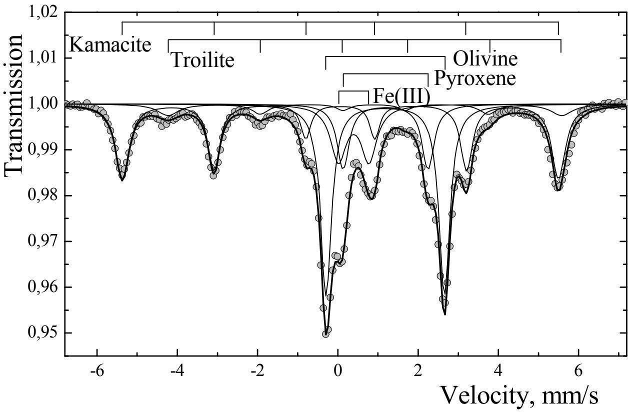

*Fig. 1. Mössbauer spectrum of very high quality obtained at room temperature from the Pavel meteorite.*

*Table 1. Mössbauer parameters of the major mineralogical components in the Pavel meteorite. Isomer shifts are referred to α-Fe at room temperature. The uncertainty is given in brackets.*

| Parameter \ Mineral | Isomer shift IS , mm/s | Qudrupole splitting $\Delta E_Q$ , mm/s | Hyperfine field $H_{hf}$ , T | Experimental line width $\Gamma_{exp}$ , mm/s |
|---|---|---|---|---|
| Kamacite | 0.06(3) | 0.00(3) | 33.3(2) | 0.3-0.4 |
| Troilite | 0.79(3) | -0.25(3) | 30.3(2) | 0.4-0.6 |
| Olivine | 1.18(3) | 2.95(3) | – | 0.33(3) |
| Pyroxene | 1.19(3) | 2.11(3) | – | 0.35(3) |
| Fe(III) | 0.39(3) | 0.76(3) | – | 0.45(3) |

Two new samples of the studied meteorites became available additionally. The Mössbauer spectra taken from these powder samples of the Pavel and the Gumoschnik meteorite are given in Fig. 2. The same major components are detected. The concentrations of the major components in the two different meteorite bodies are quite similar. Both meteorites belong to the group of the stone chondrite type [1, 6]. About 86 % of the meteorites that fall on Earth are stone chondrites, which are named in this way for the small, round particles they contain. These particles, or chondrules, are composed mostly of silicate minerals – olivine and pyroxene. About 8 % of the meteorites are achondrites which are of the stone type too but do not have a chondrite structure. About 5 % of the meteorites that fall are iron meteorites with intergrowths of iron-nickel alloys, such as kamacite and taenite. In the Mössbauer spectra, only one sextet of those minerals are observed [7, 8]. Stony-iron meteorites constitute the remaining 1 %. They are a mixture of iron-nickel alloy and silicate minerals - the so-called pallasite iron. Their Mössbauer spectra look different depending on which parts of the meteorite body the metal or the silicate one is measured.

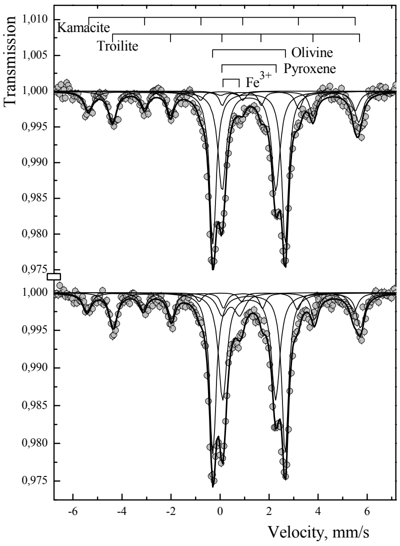

*Fig. 2. Mössbauer spectra obtained at room temperature from two new samples - the Pavel meteorite (top) and the Gumoschnik meteorite (bottom). Both are of the stone type and show similar spectra. All mineralogical components typical for meteorites are identified.*

Large metal cores, sometimes up to 500 kg in weight, are often wrongly identified as meteorites. One example is given in Fig. 3, where a very complicated Mössbauer spectrum obtained at room temperature from the surface oxide layer of the first analyzed finding is presented. Large quantities of magnetite, other iron oxides, and oxihydroxides are identified. Alpha iron and cimentite are also detected.

In Fig. 4. the Mössbauer spectrum obtained at room temperature from the metal core of the same finding is given. In this sampling, iron oxides are detected in small quantities. The major compo-nents are α-Fe and cimentite. The detection of large quantities of cimentite, $Fe_3C$, leads to the unambiguous conclusion that this finding is definitely not a meteorite. Probably it is a chip of man-made cast iron.

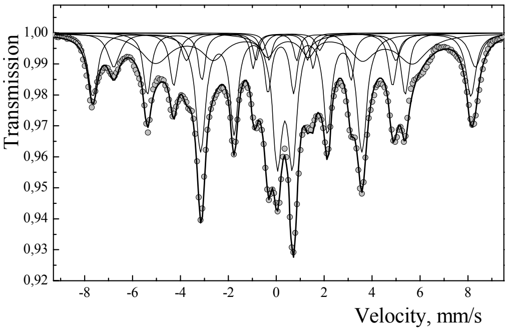

*Fig. 3. Mössbauer spectrum obtained at room temperature from the surface oxide layer of the first finding. Large quantities of magnetite, other iron oxides, and oxihydroxides are identified. Alpha iron and cimentite are also detected.*

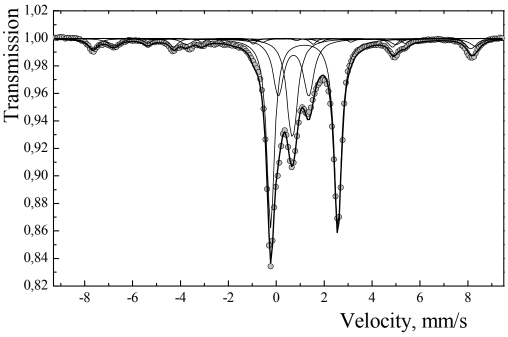

*Fig. 4. Mössbauer spectrum obtained at room temperature from the metal core of the first finding. In this sampling, iron oxides are detected in small quantities. The major components are α-Fe and cimentite.*

In Fig. 5. the Mössbauer spectrum obtained at room temperature from the second finding is presented. The minor components detected are magnetite, other iron oxides, and α-Fe. The weak lines observed on the left and right hand velocity part of the spectrum belong to them. The major components are iron in silicates, Fe(III) in glasses, and other Fe(III) minerals. They give rise to the strong lines in the central part of the spectrum. This Mössbauer spectrum is not typical of meteorite samples.

Many other non-Mössbauer evidences show that this finding is not a meteorite.

Probably it is a fragment of incombustible matter left after a charcoal fire, the so-called clinker, or probably some kind of slag.

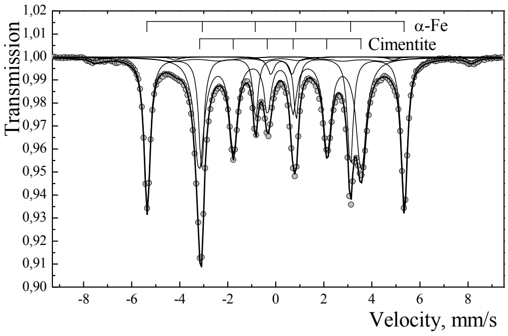

*Fig. 5. Mössbauer spectrum obtained at room temperature from the second finding. The minor components detected are magnetite, other iron oxides, and α-Fe. The major components are iron in silicates, iron(III) in glasses, and other iron(III) minerals.*

## 4. Conclusions

Mössbauer spectroscopy has been successfully used as a tool for getting information on the origin of meteorites as well as classifying them into the groups of the iron, stone, and stony-iron meteorites. Mössbauer studies of two unidentified findings and two well documented stone meteorites: the Pavel one which fell on February 28, 1966 and the Gumoschnik which fell on April 28, 1904 demonstrate the possibility of the Mössbauer test for authentication of the meteorites. The two unidentified samples studied are not meteorites. They are some man-made products.

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