

STRUCTURAL STUDIES OF IRON METEORITE DRONINO. V. I. Grokhovsky¹, M. I. Oshtrakh¹, O. B. Milder², V. A. Semionkin², R. M. Kadushnikov³ and S. A. Glazkova¹. ¹Faculty of Physical Techniques and Divices for Quality Control and ²Faculty of Experimental Physics, Ural State Technical University – UPI, Ekaterinburg, 620002, Russian Federation (grokh47@mail.ru; oshtrakh@mail.utnet.ru), ³Smart Imaging Technologies, 1770 Saint James Place, Houston, TX 77056, USA.

Introduction: In 2003 a large iron meteorite shower called Dronino was found in Kasimovo region of Ryazan oblast in Russia. The Meteoritical Society's Meteorite Nomenclature Committee defined this meteorite as ungrouped ataxite [1]. Samples of meteorite Dronino were collected by the Meteoritic expedition of the Ural State Technical University – UPI in September 2003 at a depth of 1.5–2 m. The major part of meteorite fragments was oxidized, however, metal with massive sulphide inclusions was kept non-oxidized in large bulk samples. Samples of metal phase and sulphides were studied in this work using various techniques.

Materials and Methods: The meteorite Dronino sections of bulk non-oxidized fragments, metal and isolated sulphides prepared as a powder were studied. The sections were studied by a complex of metallographic techniques: microhardness, digital microscopy with image analysis platform SIMAGIS and electron probe microanalysis using scanning electron microscope Philips 30XL with EDS. The powder samples were studied by Mössbauer spectroscopy and X-ray diffraction. Mössbauer spectra were measured with the constant acceleration computerized high precision and high sensitive spectrometer SM2201 using 512 channels of analyser. The 0.5×10^9 Bq $^{57}\text{Co}(\text{Cr})$ source was used at room temperature. All spectra were measured at room temperature in transmission geometry with moving absorber. Mössbauer spectra were computer fitted with the least square procedure using Lorentzian line shape. Mössbauer parameters isomer shift (δ), quadrupole splitting (ΔE_Q), hyperfine field (H_{eff}) and subspectrum area (S) were determined. The values of isomer shift are given relative to $\alpha\text{-Fe}$ at 295 K. X-ray diffraction patterns were obtained using diffractometer DRON-3M with $\text{FeK}\alpha_1$ radiation.

Results and Discussion: The microscopic analysis demonstrated that metal part of meteorite Dronino is complicated plessite-like structure two examples of which are shown in Fig. 1. The content of Ni in two Fe(Ni) phases was determined by the electron probe microanalysis as ~7.0 wt. % and ~26.5 wt. %, respectively. A lower volume fraction of the high Ni phase was determined in the oriented bands by the quantitative image analysis. The average microhardness of metal part was about HV 300. This value was two

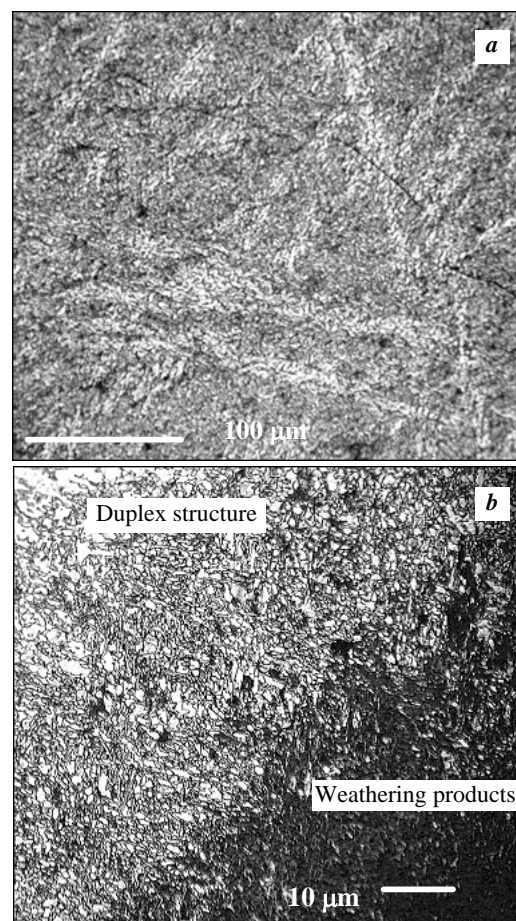


Fig. 1. Optical micrographs of typical regions of Dronino: *a* – oriented bands formed by mixture $\alpha\text{-Fe}(\text{Ni})$ and $\alpha_2\text{-Fe}(\text{Ni})$ phases; *b* – duplex $\alpha\text{-Fe}(\text{Ni})$ and $\alpha_2\text{-Fe}(\text{Ni})$ structure with weathering products which replaced kamacite at the area surrounded sulphide nodule.

times higher than that of equilibrium kamacite.

Mössbauer spectra of meteorite Dronino are shown in Fig. 2. The results of the spectra fitting are given in Table 1. Mössbauer spectrum of metal phase consists of two sextets parameters of which can be related to $\alpha\text{-Fe}(\text{Ni})$ (kamacite) – component 1 and to $\alpha_2\text{-Fe}(\text{Ni})$ – component 2. Comparison of Dronino metal phase Mössbauer parameters with those of some other iron meteorites demonstrated various differences [2]. For instance, magnetic hyperfine field for the $\alpha\text{-Fe}(\text{Ni})$ phase in Dronino was found increased in comparison

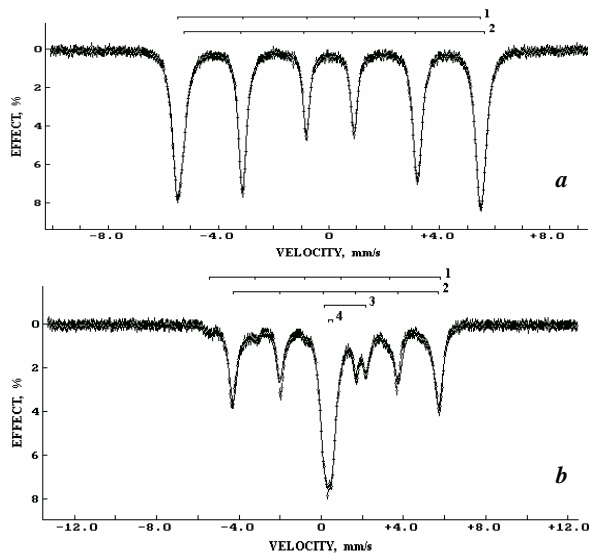


Fig. 2. Mössbauer spectra of meteorite Dronino: metal phase (a) and sulphides (b). 1–4 indicate spectral components resulting from the better fit (see Table 1). T=295 K.

Table 1. Mössbauer parameters of meteorite Dronino.

Sample	No ^a	δ , mm/s	ΔE_Q , mm/s	H_{eff} , kOe	S, %
Metal	1	0.021	-0.078	339.6	80
	2	0.066	-0.218	337.3	20
Sulphide	1	0.114	0.131	348.6	6
	2	0.773	-0.162	309.0	50
	3	1.135	2.037	—	15
	4	0.435	0.229	—	29

^aNumbers of components in Fig. 2.
Experimental errors for δ and ΔE_Q were ± 0.038 mm/s (metal) and ± 0.050 mm/s (sulphide), experimental errors for H_{eff} were ± 1.2 kOe (metal) and ± 1.6 kOe (sulphide).

with those in meteorites Chinga, Sikhote-Alin and Bilibino. This fact was related to the presence of ~0.7 at. % of Co in Dronino kamacite. Mössbauer spectrum of Dronino sulphides consists of 4 components which represent 2 sextets and 2 doublets. A minor sextet 1 has Mössbauer parameters which can be related to Fe–Ni alloy with a higher magnetic field than in kamacite. It is possible that Ni concentration in this alloy was higher than in usual kamacite. The largest part of iron (component 2) was in the form of FeS. Mössbauer parameters of this component were the same as those for troilite found in ordinary chondrites [3]. The component 3 has Mössbauer parameters which characterized the high spin ferrous compound. The component

4 has Mössbauer parameters which characterized the high spin ferric compound with very small quadrupole splitting. Comparison with Mössbauer parameters of well known ferric compounds permitted us to suppose that this compound may be related to the Co containing petlandite.

X–ray diffraction study of the metal part powder of meteorite Dronino showed the presence of broadened lines of the α -Fe(Ni) phase. On the other hand, there were no lines of teanite phase. We supposed that broadening of the α -Fe(Ni) phase lines may be a result of the presence of the α_2 -Fe(Ni) phase that correlates with Mössbauer data. In this case the α_2 -Fe(Ni) phase contained high Ni concentration and this phase may be considered as martensite. An analysis of the X–ray diffraction pattern of sulphide powder showed that the major part of the powder contained troilite with small amounts of pentlandite (Fe, Ni)₉S₈, pyrite (Fe, Ni)S₂, chromite FeCr₂O₄, kamacite α -Fe(Ni) and teanite γ -Fe(Ni). However, there were no full agreement of these data with Mössbauer results.

An analysis of the results obtained permitted us to suppose that meteorite Dronino was strongly effected with heat (shock). The initial octahedral metal structure with thin Widmanshtetten plates was changed as a result of the reheating to the α - γ region of the Fe–Ni equilibrium phase diagram. Further cooling led to formation of the α_2 -Fe(Ni) phase due to martensitic transformation γ -Fe(Ni) \rightarrow α_2 -Fe(Ni). Similar structure was obtained by laboratory heating of meteorite La Primitiva till 720 °C [4]. The complicated mineral composition of sulphide nodules and their environment is a result of the long period of terrestrial weathering mainly.

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