The magnetic hysteresis characteristics of the meteorites Allende, Canyon Diablo, El Hammami, Ghubara, Gold Basin, Nantan and Sichote Alin

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Abstract: The magnetic hysteresis characteristics of the respective samples have allowed to class as the Carbonaceous Chondrite the Allende meteorite, as the ordinary chondrites the El Hammami, Ghubara and Gold Basin meteorites. But the meteorites Canyon Diablo, Nantan and Sichote Alin have been preferentially classed as the ataxites - Ni-rich iron meteorites, containing mainly taenite, instead of the originally classed as the iron meteorite-coarse octahedrite, IIICD type of iron meteorite and the iron-coarsest octahedrite IIB, respectively.

Key words: ordinary meteorites, ataxites - Ni-rich iron meteorites

1. Introduction

The interplanetary material including its magnetic properties plays an important role in the study of at least our solar system. These constituents are the messengers of the conditions within the interplanetary space and its

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magnetic field. There is also an evidence that magnetic interactions between permanently magnetized dust grains could have played an important role in the aggregation process, e.g. in the formation of planetesimals and cometesimals (*Nübold et al., 2002*). And therefore it is useful to pay an interest to whatever magnetic characteristics of the meteoritic material of all dimensions and masses, what is also the aim of this paper. In the previous works the important mineralogical, chemical, physical and some magnetic features were studied, to make a more comprehensive view about the 7 selected meteorites. *Kapišinský et al. (2004)* studied the magnetic susceptibility, the Curie temperatures, the anhysteretic remanent magnetization and the stability of this magnetization against the alternating field of the samples of meteorites Allende, Canyon Diablo, El Hammami, Ghubara, Gold Basin, Nantan and Sichote Alin. There has been presented a general review about these meteorites in the above cited work. Additionally were measured very important hysteresis characteristics, which we have presented in this work, to complete the knowledge about the above mentioned meteorites. The laboratory study of the extraterrestrial materials offers the opportunity to test the ideas and the advance the knowledge derived from years of the experience of the terrestrial synthetised magnetic compounds of natural rock materials. Very important problem in the study of the meteorites is the source of their remanent magnetization. So the knowledge about the hysteresis properties can contribute to the solution of such problem, except of its applying to more precise classification of the respective meteorites.

2. Experimental results

Magnetic hysteresis results were obtained with the vibrating sample magnetometer in the Magnetic laboratory of the National Institute of Polar Research, Tokyo, according to procedure proposed by Dr. Minoru Funaki. The results are presented in Figs 1, 2 and in the Tab. 1. The temperature change of 14–16°C was actual during the measurements of the samples.

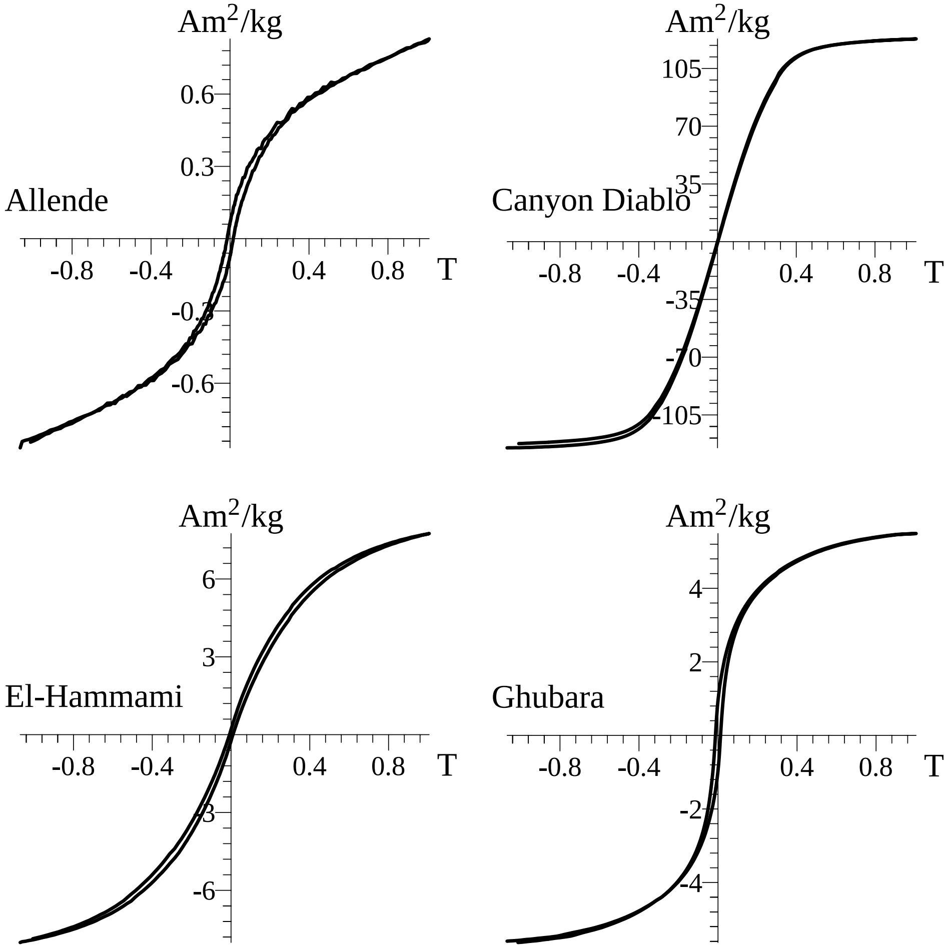

Fig. 1. Magnetic hysteresis loops for Allende, Canyon Diablo, El Hammami and Ghubara samples of meteorites. T – applied field in Tesla; y-axis – magnetization of the sample in Am^2kg (A-Ampere).

3. Evaluation of data and basic characteristics of the meteorites

Allende: It was originally characterized as the Carbonaceous chondrite type CV3 (*Kapišinský et al. 2004; Heide and Wlotzka, 1995*). The relatively large H_c and H_{rc} values have shown that NRM of the meteorite is

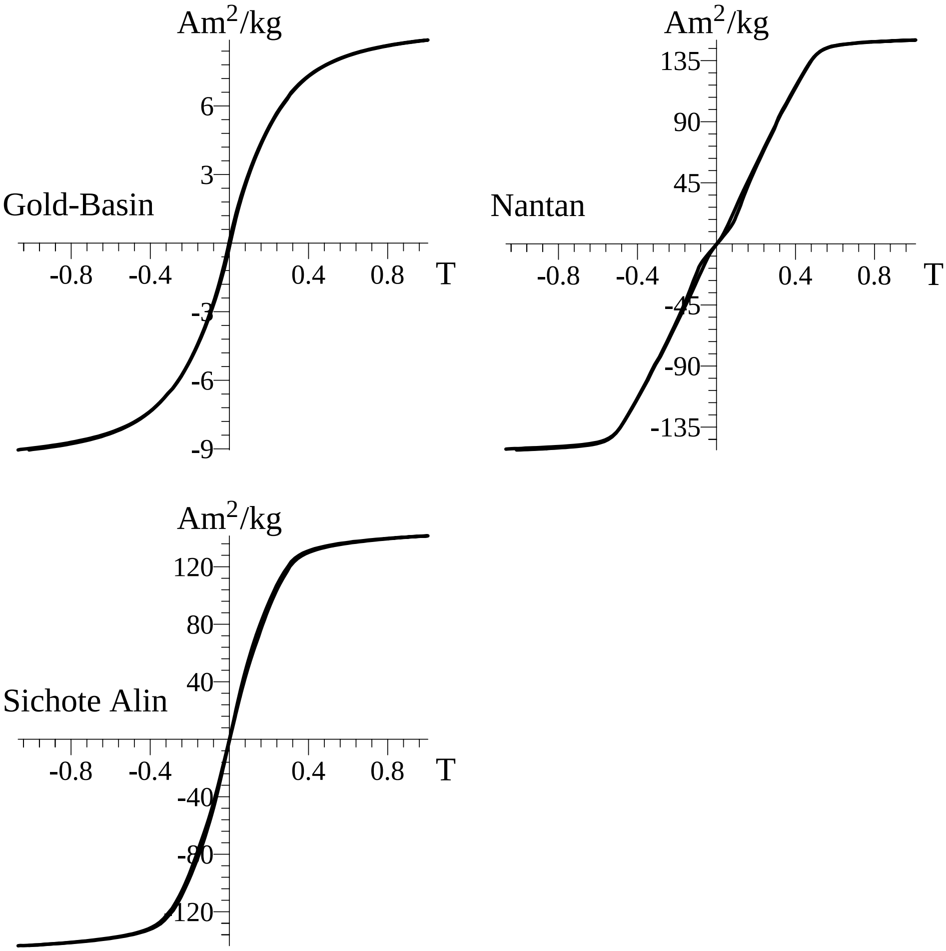

Fig. 2. Magnetic hysteresis loops for Gold Basin, Nantan and Sichote Alin samples of meteorites. T – applied field in Tesla, y-axis – magnetization of the sample in Am^2kg (A-Ampere).

stable against alternating magnetization (AF). These new data have supported the original idea.

Canyon Diablo: The iron meteorite, of the structural class - coarse octahedrite with the more complex chemism. For original classification see previous paper (*Kapišinský et al. 2004; Heide and Wlotzka, 1995* and *website 1).* Usually pure phase of iron meteorite (octahedrite) posseses relatively

Tab. 1. The magnetic hysteresis loop characteristics of the meteorites

Name of sample	I_s [Am^2/kg]	I_r [Am^2/kg]	H_c [mT]	H_{rc} [mT]	Remarks
Allende	0.383	0.0586	16.5	55.0	C.Chondrite
Canyon Diablo	117	0.415	1.0	-	Iron
El Hammami	5.19	0.217	8.6	125.4	Chondrite
Ghubara	4.69	0.915	16.0	16.0	Chondrite
Gold Basin	7.201	0.124	3.2	24.9	Chondrite
Nantan	141	0.155	0.9	-	Chondrite
Sichote Alin	132	0.520	0.9	-	Iron

Explanations: I_s–saturation magnetization; I_r–saturation remanent magnetization; H_c–coercive force; H_{rc}–remanent coercive force; mT–milli Tesla; C–Carbonaceous; Am–Ampere-meter.

high values of I_s about 200 Am^2/kg. But the real value of I_s of this sample is very low. The low I_s may be due to inclusions of the silicates, weathering derivates or weighting waste. The H_c value is low, what has predict the low stability of remanence. If the I_s value is correct, this piece of meteorite may by classified as the ataxite - Ni-rich iron meteorite, which contains mainly taenite.

El Hammami: It has been originally classified as the stone, olivine - bronzite chondrite (H5) type class H5/6 (see also *websites 2a, 2b*). As we have inferred from the value of I_s, it may be the ordinary chondrite. The small H_c and large H_{rc} values may be explained by a very low amount of high coercive mineral - such as tetrataenite in the large amount of low coercive minerals.

Ghubara: It has been classified as the (L5) chondrite (see also *website 3*). The values of I_s have supported the original predictions that it is the ordinary chondrite. The H_c value has corresponded to the real value, but the H_{rc} is supposed to be incorrect.

Gold Basin: was previously classified as the ordinary olivine - hypersthene (L4) chondrite (see also *website 4*). This meteorite is the ordinary chondrite inferring from the I_s value. The H_c and H_{rc} values have verified the low stability of the remanent magnetization of this chondrite.

Nantan: has originally belonged to IIICD type of iron meteorite (see also *website 5*). Similarly like the Canyon Diablo it posseses little lower value of the I_s, as could be expected. The H_c curve of the sample has indicated the discontinuities at about 0.1 mT and 0.5 mT what have pointed out that there are the two kinds of coercivity within the sample. The low values of H_c have verified the low stability of remanence. With respect to the low value of the I_s, the meteorite may be classified as the ataxite - Ni-rich iron meteorite, which contains mainly taenite.

Sichote Alin: It was classified as the iron, the coarsest octahedrite IIB (see also *websites 6a, 6b*). Usually pure phase of iron meteorite (octahedrite) posseses relatively high values of I_s about 200 Am^2/kg, but the real value of I_s of this sample is a little bit low. The low value of the H_c has predicted also the low stability of remanence of the sample. With respect to the low value of the I_s, the Sichote Alin meteorite may be classified as the ataxite - Ni-rich iron meteorite, which contains mainly taenite.

4. Discussion and conclusions

The magnetic hysteresis loop characteristics of the 7 above named meteorite samples were studied. These magnetic characteristics have allowed to improve the original classification of the iron chondrites. They may be classified into the ataxites - Ni-rich iron meteorites, containing mainly taenite. This has concerned of the meteorites Canyon Diablo, Nantan and Sichote Alin. The mentioned magnetic characteristics have supported the original classification of the ordinary chondrites Allende, El Hammami, Ghubara and Gold Basin. Commonly, the I_s values in the iron meteorites are high enough and higher with the relation to ordinary chondrites. The H_c of the iron meteorites (octahedrites) are relatively lower to those of the ordinary chondrites. Previously obtained results about the stability of both types of the meteorites have not concluded the problem about the origin of the remanent magnetization (RM) of these meteorites. Many experiments on different meteorites realized by other authors show that ordinary chondrites had stable natural RM. Comparisons of the NRM and the laboratory induced RM have shown that neither the natural, nor laboratory-induced moments have been entirely thermoremanent (TRM) in the conventional sense. There has been involved a chemical process, since the remanence appears to be induced at the γ to α phase transition of kamacite during cooling of the chondrites *Stacey and Banerjee (1974)*. *Orlický et al.(2000)* have studied the Fermo (H) chondrite. The taenite was considered to be the main carrier of the RM of this chondrite. These authors have deduced from the results that according to the laboratory experiments nearly 50 % of the kamacite survived after thermal treatment to 780° C, cca 50 % was destroyed and part of it was successively transformed into the taenite during cooling. We have inferred from the results that in the laboratory the tested chondrites were undergone to quite different conditions with respect to those, which were actual in the extraterrestrial environments. *Hvoždara et al. (2003)* enlarged the considerations of a possible assessment of an origin of RM of the Fermo H-chondrite about the study of diffusion of heat from the surface of the meteorite into its interior. The mathematical model for penetration of temperature inside a spherical meteoroid heated from its surface has shown that there exists some time interval in which the sphere in almost of half of its radius was heated to the temperature above or close to the Curie temperature of the taenite ($T_C \approx$ 560-600° C). This means that when the meteoroid becomes so hot (560-600° C) any eventual extraterrestrial magnetization cannot survive and completely dissapears. A new, probably of the TRM origin was induced by the geomagnetic field during fall of the meteorite on the Earth's surface. We can propose that so far no final idea has been accepted to decide about the origin of the RM of the meteorites.

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