ORIGIN OF BLACK VEINS IN ORDINARY CHONDRITES. D.D.Badjukov[1] ,G.Kurat[2], and F. Brandstaetter[2] , [1]Vernadsky Institute, Russian Academy of Sciences, Kosygin st., 19, Moscow, 117975, Russia, badyukov@geokhi.ru; [2]Naturhistorisches Museum, Postfach 417, A-1014, Vienna, Austria.

Introduction. Many chondrites contain black veins which were proposed to be a disequilibrium effect of shock metamorphism, caused by concentration of stress. High temperatures developed by this process which lead to local melting, whereas other areas exhibit only equilibrium shock effects [1,2]. A typical shock black vein is composed usually of melted silicate matrix with embedded metal and sulfide spheroids. Another shock effect is the blackening of chondrites due to mobilization of metal-troilite mixtures which have a low melting temperature - around 1000 °C- and fill tiny cracks [3]. This process requires relatively high equilibrium post-shock temperatures. Many chondrites have numerous black veins which are closely associate with black areas and which spread out into light-colored areas that suggests a formation in a single event.

On the other hand, there are some observations that are in contradiction with a shock origin of blackened chondrites and some varieties of black veins: some veins contain metal and sulfide particles of irregular shapes which do not support a molten state, there is an enrichment of black veins in organic compounds [4], black matter from the Fayeteville chondrite has He, Ne, and Ar contents 3-10 times higher than the light-colored portion [5], and there are possible differences in chemical compositions between the host and vein material[4,6]. It is clear that shock metamorphism alone cannot produce such features.

Observations: Motivated by these discrepancies we studied polished sections of the Gorlovka (H3-4), Kunashak (L6) and Pervomaisky (L6) chondrites using optical microscopy and SEM. According to the shock classification of [1] our estimations of shock stages for the meteorites selected are S4-5, S3, and S4, respectively. All studied samples display total or partial darkening and contain numerous black veins and pockets. There are two varieties of black veins in these chondrites that differ clearly by the morphology of metal and troilite inclusions.

The first variety is characterized by spherical and rounded shapes of the inclusions (Fig.1). The silicate part of these veins consists of a Fe- and Mg-rich, heterogeneous glass and tiny mineral grains. The Ni content of the metal droplets is very close to the Ni content of adjacent metal grains which is consistent with the origin of the veins by local melting.

In contrast, metal and troilite inclusions in the second variety of veins have irregular shapes (Fig.2). The silicate matrix consists of olivine, Ca-rich and Ca-poor pyroxene and orthopyroxene with an interstitial Na-containing glassy matter. This mineral composition is more or less uniform for different veins and seems to be depending on the mineral composition of the host. The Pervomaysky chondrite section demonstrates this fact. A black vein is located between a silica-enstatite aggregate and olivine-orthopyroxene groundmass of the meteorite. The vein contains relatively large clasts of enstatite and olivine embedded in a fine-grained matrix. The matrix consists of Ca-rich pyroxene, olivine, a Na-containing amorphous matter, whitlokite, sulfide and metal and hence cannot have been produced from the local material only. Metal particles in this variety of black veins for the Gorlovka and Kunashak chondrites have relative uniform compositions and lower Fe/Ni ratios then metal inclusions situated close to the veins (Fig.3). The Fe/Ni ratios for vein metal are lower than the ratios for the total metal in the respective host meteorites [7,8]. Ni contents of metal in the veins of the Pervomaysky chondrite are more variable, some metal grains are kamacite or Ni-rich taenite. This could be the result of some secondary process because many metal nuggets in a groundmass have mantles consisting of taenite (up to 55 wt% Ni) and Ni-poor kamacite (2.5 wt% Ni) embedded in a troilite matrix (Fig.4). We propose that the mantles were formed by sulfurization of metal [9] at very low temperature accompanied by re-precipitation of metal. The same process can take place also in black veins.

Discussion: The studied chondrite sections display two varieties of black veins that occur together. One of them carries direct textural and chemical evidences of local in situ melting. This suggests a formation by shock, maybe, like the formation of pseudotachylite veins in authigenic breccias of terrestrial impact craters. Textural and chemical peculiarities of the second variety of black veins shows a more complicated history of their origin. Simple annealing over extended periods of time cannot be the process of their formation because in that case shock-induced melt veins (the first variety) would not survive the thermal event. We propose the origin of the variety of veins due to fluid activities along cracks filled by a dusty material. These cracks can be produced by a shock event at a parent body (in terrestrial impact events this process leads to formation of breccias). At the same time, the shock can form real melt veins. Slight movements in the shocked volume perhaps in a release wave or by a crater flow can re-distribute the tiny dispersed material in the cracks and more or less average its chemical composition. It should be noted that the shocked mass has to have a very high gas permeability due to low gravitation. The shock event itself or some other process can provide the fluid activity. The fluid activity along the cracks can bring sulfide and metal in a mobile state and produce their re-precipitation as well as the precipitation of the Na-containing amorphous matter. The fluid activity could be a reason for blackening of chondrites due to mobile behavior of sulfide and metal. From this point of view some facts mentioned above [4-7] like high rare gas content, older ages of the vein matter, enrichment of veins in organic compounds (hydrocarbons-paraffins, N-containing compounds) can be explained.

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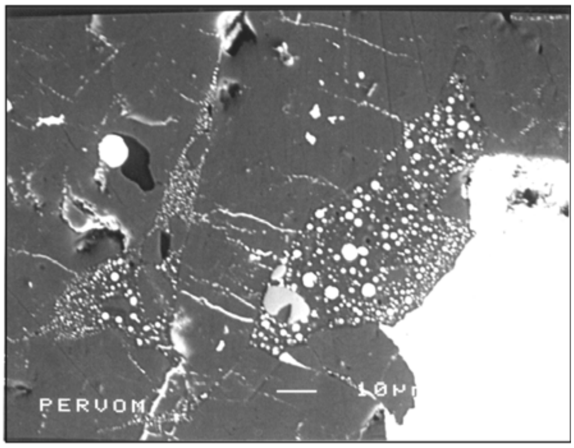

Fig.1. Shock-induced black veins and a melt pocket in the Pervomaysky chondrite (BSE image). Metal (white) and sulfide (light gray) droplets are dispersed in a glassy matrix (dark gray). Surrouding matter is olivine (dark gray) and metal (white). Scale bar = 10 µm.

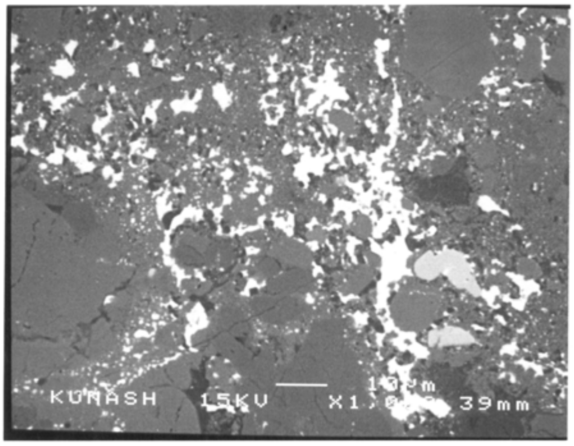

Fig.2. The Kunashak chondrite (BSE image). Black veins with irregular particles of metal (white) and troilite (gray) intergrown with olivine and orthopyroxene. Scale bar = 10 µm

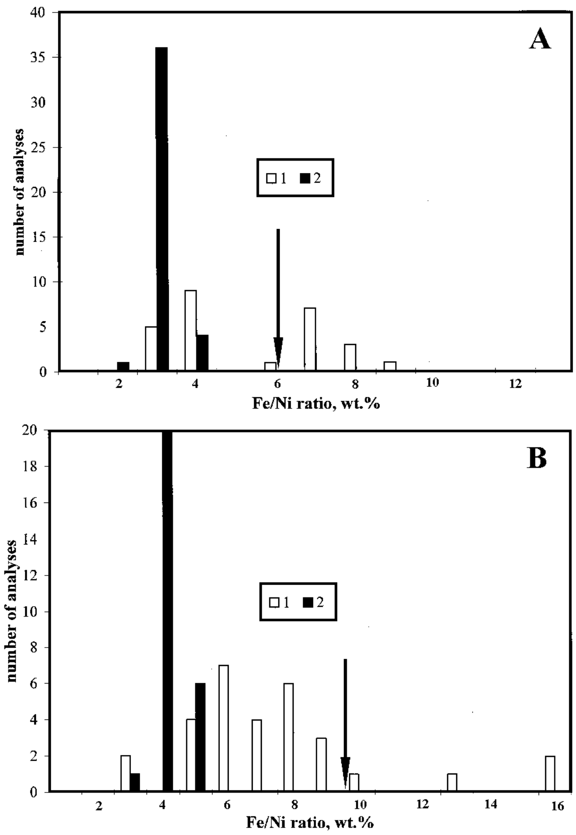

Fig.3. Distributions of Fe/Ni ratios in groundmass metal (1) and in metal particles in shock veins of the second variety of black veins from the Gorlovka (A) and Kunashak (B) chondrites. Arrows indicate mean Fe/Ni metal ratios for the meteorite [8,9].

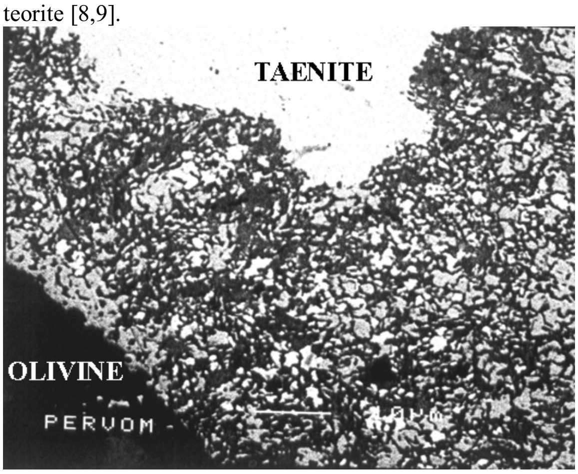

Fig. 4. BSE image of a taenite grain in Pervomaysky showing an outer rim. The rim consists of troilite (dark grey) with embedded fine low-Ni kamacite (light grey) an Ni-rich metal (white) grains. Scale bar = 10 µm