DRONINO: AN ANCIENT IRON METEORITE SHOWER IN RUSSIA. V. I. Grokhovsky[1], V. F. Ustyugov[1], D. D. Badyukov[2], and M. A. Nazarov[2], [1]Ural State Technical University – UPI, Mira 19, Ekaterinburg, 620002, Russia (grokh47@mail.ru), [2]Vernadsky Institute of Geochemistry and Analytical Chemistry, Kosygin St., 19, Moscow, 119991, Russia.

Introduction: Dronino is a huge iron meteorite shower recovered recently in Russia. The iron is a low Ni ataxite containing sulfide nodules. Based on trace element chemistry Dronino is classified as an ungrouped iron. Textural characteristics of the meteorite point out a reheating event and a following very fast cooling.

Occurrence: The first piece of a rusted iron was found by Oleg Gus'kov, a Moscow resident, near the Dronino village (54°44.8′ N; 41°25.3′ E) of the Ryasan' district in July 2000. This village is about 350 km east-south of Moscow. The first examination of the area discovered the debris of a meteorite shower. In summer 2003, scientific expeditions and meteorite hunters collected more than 600 fragments totaling about 3000 kg. The fragments occur at a depth of 0.2-2 m within an eleptic area of 0.75x1.5 km (Fig. 1). The distribution of the fragments suggests that the meteorite formed a crater of about 30 m in diameter. This crater is not reflected in the present-day topography of the site. The majority of the fragments have masses of 0.1 – 15 kg (Fig. 2). The smallest and the largest ones are 6 g and 250 kg, respectively.

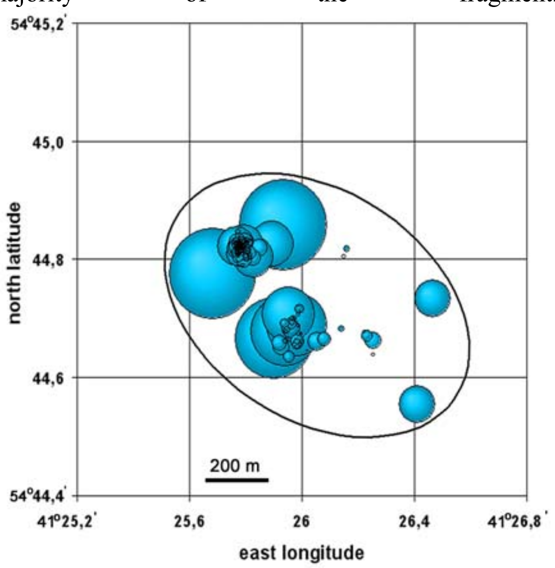

Fig.1. The Dronino meteorite strewn field. Diameters of circles are proportional to masses of fragments. Proposed direction of the meteorite trajectory is from SE to NW.

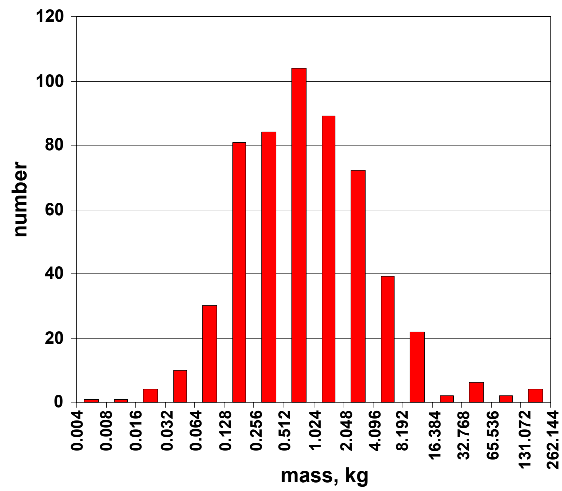

Fig. 2. The mass-distribution of Dronino fragments.

Dronino fragments are rusted and covered Fe hydroxides of a few cantimeters in thick. Pieces located close to the surface are more fresh whereas deep-seated masses occur in fluvioglacial sands and heavily weathered. It is possible that some fragments were redeposited during aggriculture works.

Texture and mineralogy: Etched sections of Dronino show a fine-grained ataxitic duplex texture consisting of two phases (Fig. 3). One phase contains 7.0 ±0.5 wt% Ni and 0.75 wt% Co. Another phase has 26.3±0.5 wt% Ni and 0.35 wt% Co. The bands are of 0.05-0.1 mm width and have different reflectance in reflected light. Microhardness of this plessite-like structure is about HV 300. It is twice more hard than eqilibriated kamacite. Mossbauer spectroscopy and X-ray diffraction studies of the metal part of the Dronino meteorite [1] show the presence of kamacite α Fe(Ni) and martensite α_2Fe(Ni) phases only. There are rare large kamacite grains (20-80 μm in size) of an irregular shape, which are scattered in the matrix. Sulfide nodules of a few mm in size comprise 10 vol.% of the meteorite. The nodules are rounded and often elongated. Occasionally small worm-like sulfide inclusions are present.

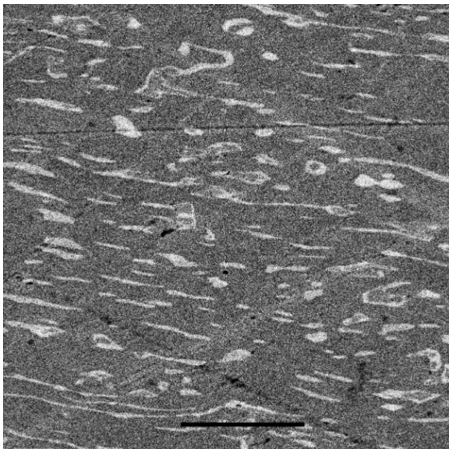

Fig. 3. BSE image of Dronino metal. Kamacite is dark grey, martensite is light grey. Scale bar is 25 μm

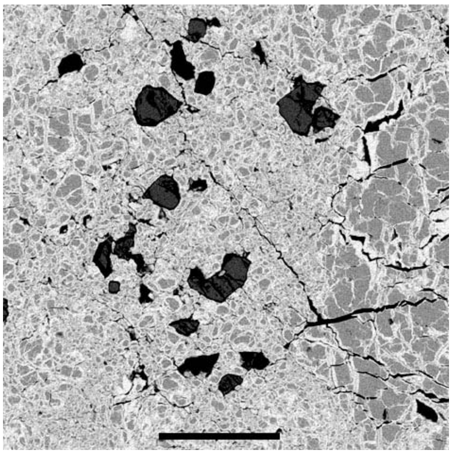

Fig. 4. BSE image of an interior of a sulfide nodule. Troilite is gray, Fe-Ni-S matter is light grey, chromite is dark grey. Scale bar is 70 μm.

The sulfide nodules consist of troilite that is commonly replaced (partially or totally) by a Fe, Ni, S-rich material due to terrestrial alteration. The matter replaces troilite along cracks and grain boundaries (Fig. 4). It has metal/S atom ratios varying from 1 to 6. Ni contents vary from 3.5 to 80 wt% and Co contents vary from a detection limit to 4.2 wt%. There is a strong anti-correlation between Ni and S contents. It is not clear yet either the secondary matter is a sulfide monomineral aggregate or it is composed of different phases. Some troilite nodules contain rare tiny metal grains with 52-53 wt% Ni. All sulfide nodules are surrounded by Fe hydroxides, which replace metal. Accessories of Dronino are chromite and Fe phosphate (graftonite?). Chromite occurs coomonly as small euhedral crystals in sulfide nodules. There are also minute chromite inclusions in Fe phosphate. Chromite contains MnO (0.2-0.4 wt%), TiO_2 (0.2 wt%), and V_2O_3 (0.2-0.5 wt%). No phosphides were found in Dronino and P content in the metal is not detectable with EMP

Chemistry: A bulk Dronino sample analyzed by INAA in UCLA [2] contains: Ni 98.1, Co 5.54 (mg/g), Cr 37, Cu 32, Ga <0.3, As 3.52, W 0.38, Ir 1.68, Au 0.284 (ppm). The average of EMP analyses of the metal is 10.8 wt% Ni. The higher Ni concentration relative to the INAA data can be explained by the presence of troilite in the bulk sample.

Discussion. The Dronino meteorite is most close to IVA irons in Ni, Ir and the low P but the low Au and Ga contents distinguish the Dronino element pattern from that of all known iron meteorite groups and, hence, characterize Dronino as an ungrouped iron. Worm-like sulfide inclusions suggest large plastic deformation at high temperatures when troilite was in a liquid state. The Fe-FeS eutectic temperature is 988^{o}C, but a Ni presence decreases it. This eutectic melt could be resulted from shock-induced melting at the kamacite – sulphide boundaries The duplex structure could be formed by reheating of intital octahedral texture to the (α+γ) region of the phase diagram. Small precipitations of isothermal taenite [3] formed first underwent then the martensitic transformation under the fast cooling that followed. The orientation, morphology, and the fraction of the α_2 – phase reflect the position of the intial octahedral bands. A similar structure was obtained during the heat treatment lab experiments with the Canyon Diablo meteorite [3].

The time of the Dronino fall can be constrained based on an absence of historical records of the event. The village of Dronino is located 20 km from the town of Kasimov, founded in 1152. If a meteorite of such mass had fallen during historic times, it would likely have been observed by the local population in Kasimov and farther away in the other old towns of Ryazan, Murom and Vladimir, and should have been documented in the local chronicles. However, no written reports of such an event have yet been found. So it appears likely that the Dronino meteorite fell earlier than the 12th century in an area that was at that time largely unpopulated.

References: [1] Grokhovsky V.I. et. al (2005) *LPSC XXXVI*. [2]Meteoritical Bulletin #88 (2004) *MAPS,* 39. [3] Brentnall W.D., Axon H.J. (1962) *J.Iron Steel Inst.* 200, 947-949.