A LARGE DARK INCLUSION IN THE EFREMOFKA METEORITE. M. A. Ivanova[1], C. A. Lorenz[1], A. V. Korochantsev[1], M. A. Zaitsev[2], M. V. Gerasimov[2], [1]Vernadsky Institute of Geochemistry, Kosygin St, 19, Moscow 119991, meteorite2000@mail.ru; [2]Space Research Institute of RAS, Profsoyuznaya St. 84/32, Moscow, 117997, Russia.

Introduction: Dark inclusions (DI) are fine-grained lithic clasts ranging from 1 mm to a few cm. They have been reported in numerous carbonaceous chondrites, but are most prevalent in CV3 chondrites. They are considerably different from the host, and their origin is still a subject of debate. Two major models have been proposed: nebular and asteroidal. According to the nebular model, DIs are nebular condensates that experienced high – T metasomatic reaction with highly oxidized nebular gas [1]. In the asteroidal model, DIs are fragments of CV- like materials that experienced various degrees of hydrous alteration either before or after incorporation into an asteroidal parent body [2]. Furthermore, several authors have argued that dark inclusions might represent an extreme end-member in the alteration-dehydration sequence observed in CV chondrites, although alternative interpretations (e.g., CM origin) are also suggested [3-5]. Dark inclusions are very important in understanding aqueous alteration and thermal metamorphism processes that affected chondritic material prior to incorporation into host material. We have studied the petrography, mineralogy, and bulk chemistry of very big dark inclusion (named GRANDI), 3 x 5 cm in size, of elliptic shape in plane, from the Efremovka CV3 chondrite from the reduced subgroup [6]. We are planning to explore volatiles including organic compounds in this dark inclusion. Organic compounds (OC) together with other volatile components can be indicators of nebular sources and parent-body processing of carbonaceous chondrites [7].

Analytical procedure and samples: The Efremovka dark inclusion was recognized during sectioning of a sample of the meteorite obtained from the Russian Academy of Sciences. The thick section of DI and the Efremovka matrix were studied microscopically and by Semi-quantitative bulk EDX analysis using an FEI NOVA NanoSEM 600 scanning electron microscope at the Smithsonian Institution. Samples for pyrolitic gas chromatography-mass spectrometry (Pyr-GC-MS) were prepared for analysis of volatile and organic components by powdering of the bulk meteorite and GRANDI samples. Volatile components were extracted from the samples by two-stage pyrolysis at 460 and 900°C under the helium flow and analysed using a Chromatec Crystal 5000.2 gas chromatograph equipped with DSQ II quadrupole mass-spectrometer**.** Analytical data were interpreted using Xcalibur software (Thermo Scientific) and NIST 2005 and Willey Registry (8th ed.) mass-spectra libraries.

Results and Discussion. GRANDI is a typical – and the largest -- dark inclusion among those described in the Efremovka meteorite (Fig. 1a). It has a distinct boundary with the main Efremovka material and consists of well-shaped chondrules, their fragments, rare CAIs, and fine-grained matrix (Fig. 1 a,b,c). The mineral composition and matrix/object ratios are similar in the DI and the Efremovka meteorite. Many chondrules and CAI primary minerals are altered and represented by fayalitic olivine, chromite, Si-Al-rich material, Fe-diopside, chlorite-like material and probably phyllosilicates. The matrix of GRANDI is also represented by secondary mineral phases: fayalitic olivine, secondary Ca-rich minerals and phyllosilicates that probably dehydrated to various degrees. Chondrules and matrix of the GRANDI contain FeNi-metal and rare Ni-rich sulfides.

The bulk chemical compositions (Table 1) demonstrates important differences in some major elements between GRANDI, the bulk Efremovka host, chondrules from GRANDI and chondrules from the main Efremovka material. GRANDI material is enriched in Fe, Mn and Na and depleted in Ca, Al and S in comparison with the Efremovka bulk and chondrule compositions. Chondrules from GRANDI are also enriched in Fe and Mn and depleted in Ca, Al and S in comparison with those from Efremovka. This could indicate different sources of primary material of the GRANDI material and the Efremovka meteorite. Intriguingly, the Ca/Al ratio in GRANDI is super chondritic (1.28) in comparison with the chondritic Ca/Al ratio of the Efremovka host and chondrules from the Efremovka host and GRANDI. This could be explained by distribution of Ca during aqueous alteration in the parent asteroid of the GRANDI material before its incorporation in the Efremovka parent body during accretion. The Ca-rich rim around GRANDI also confirms this assumption.

The DI sizes and their notable abundance in Efremovka indicate that they originated from some large source different from the host meteorite. We didn't observe any fractures or veins crossing the DI and the Efremovka material, nor any reaction zone between GRANDI and the Efremovka host material, which may indicate a lack of any chemical exchanges between material of the DI and the Efremovka matrix. Together with the compositional differences of DI and the host meteorite, especially the distribution of Ca, it probably indicate that DIs source was a separate parent body that was accreted and fragmented before the Efremovka parent body.

Preliminary results of the Pyr-GC-MS investigation showed that both the GRANDI and the Efremovka host material are similar by qualitative composition of volatile organic compounds. They are represented by aromatic hydrocarbons: benzene (main component), toluene, and traces of ethylbenzene, xylenes and naphthalene; sulphur-containing compounds: thiophene and traces of methylthiophene; and nitrogen-bearing compound - acetonitrile. Most of the organic compounds were evoluted at 460°C. At 900°C only small amount of benzene and toluene were released. Generally, both samples are poor in volatile organics and mainly composed of macromolecular nonvolatile components (refractory kerogen). A small amount of SO_2 was detected.

The last thermal metamorphism probably took place after consolidation of the DIs and the Efremovka material and continued during a time long enough to result in depletion of volatile organic compounds in both the DI and the Efremovka main material.

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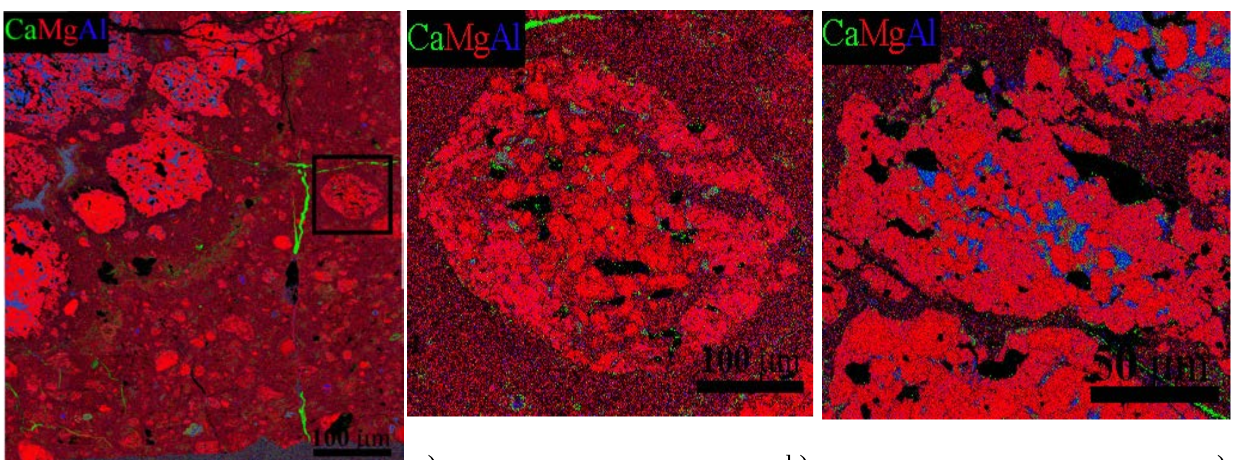

a) b) c)

Fig. 1. X-ray maps of the grand Dark Inclusion (GRANDI) from the Efremovka CV3 chondrite. a) contact area between the GRANDI and the Efremovka main material; b) chondrule from the GRANDI, c) chondrule from the Efremovka matrix.

Table 1. Bulk chemical compositions of GRANDI (DI), chondrule from GRANDI, chondrule from the main matrix of Efremovka and the Efremovka host material (normalized, wt%).

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	Cr_2O_3	MnC	FeO	NiO	C
DI	0.73	23.76	2.3	34.21	0.32	1.11	0.09	2.18	0.18	0.51	0.35	33.1	1.24	
Chondrule from DI	-	31	1.83	37.28	0.4	0.47	-	1.29	0.17	1.07	0.38	24.31	1.8	
Chondrule	-	32.39	3.28	42.99	-	3.76	-	2.25	0.12	0.53	0.17	13.74	0.95	
Efremovka bulk*	0.25	24.71	3.37	34.31	0.31	5.15	0.03	2.66	0.17	0.55	0.19	17.2	1.59	0.76

- Efremovka bulk composition from [8]