AFTER-COAL IMPACT DIAMONDS AND DIAMOND FOSSILS IN THE GIANT KARA IMPACT CRATER. T. G. Shumilova[1], S.I.Isaenko[1], V. V. Ulyashev[1], S. S. Svetov[2], S.Yu.Chazhengina[2], V.V.Kis[3], [1]Institute of Geology FRC Komi SC UB RAS, Pervomayskaya st. 54., Syktyvkar, 167982, Russia; shumilova@geo.komisc.ru; s.i.isaenko@gmail.com; [2]Institute of Geology of the Karelian Research Centre of the Russian Academy of Sciences, Petrozavodsk, Pushkinskaya St.11; ssvetov@krc.karelia.ru; [3]Institute for Technical Physics and Materials Science, Centre for Energy Research, Hungarian Academy of Sciences, Budapest, Hungary, 1121 Budapest XII., Konkoly-Thege u. 29-33, Hungary, kis.viktoria@energia.mta.hu.

Introduction: It is widely known that impact diamonds can be formed by the solid-phase diffusion-less mechanism from graphite transition to diamond under shock pressure > 30 GPa [1-4]. Much less known impact diamond variety formed after coal substance was found in the 70-s by V.A.Yezerskiy [5] at the unique Kara astrobleme (Pay-Khoy, Russia). After more than 30 years since the discovery of the after-coal diamonds by application of a complex of modern high resolution techniques we have found that the type of diamonds have specific structural, elemental composition and properties [6].

Sampling and methods: The sampling of the diamondiferous suevites and clast-poor impact melt rocks was provided in 2015 and 2017 at the Kara impact crater (Pay-Khoy ridge, Russia). The afte-coal impact diamonds have been enriched from the host impactites by chemical dissolution at the Laboratory of Diamond Mineralogy of the IG FRC Komi SC UB RAS (Syktyvkar, Russia). The studies have been provided with a wide complex of high resolution methods including Raman spectroscopy in visible and ultra-violet light, scanning electron microscopy (SEM) with focused ion beam preparation (FIB), electron probe microanalysis (EPMA), elemental mapping, high resolution transmission electron microscopy (HRTEM), electron diffraction (ED); infrared spectroscopy (IR), LA-ICP-MS and organic $^{\delta 13}$C isotopic studies.

Results: Our study of after-coal diamonds and co-following carbon phases by the complex of the methods allowed recognize a new short-distance diffusion mechanism of the diamonds formation similar to supposed to experimentally produced impact diamonds from coal and bitumen proposed by N. I. Borimchuk et al. [7]. Also, we have divided at the Kara impact crater two different varieties of impact diamonds presented by really after-coal substance (sugar-like diamonds) and diamond pseudomorphs formed after organic relics (diamond fossils) (Figure 1). The both varieties are free of mechanical defects and deformation twinning, also named by lonsdaleite. The after-coal variety is characterized by uniform shaped particles having irregular morphology after carboniferous fragments of the host black shales of a target. They have unusual porous structure with well shaped diamond crystallites of 20-30 nm in size. At the same the diamond fossils nicely preserve the organics micromorphological details, have microcrystallites size just about 2-5 nm being ultrananocrystalline diamond material. The latter is a novel promising material intensively studied in material science [8].

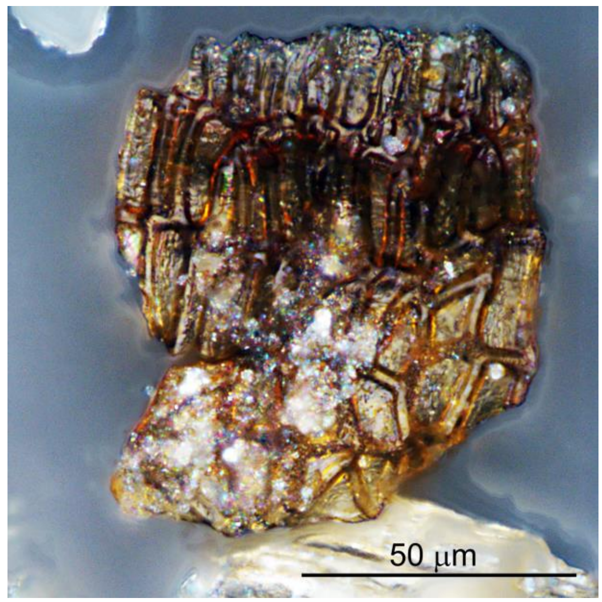

Figure 1. Optical image of diamond fossil enriched from a host melt clast within suevite of the giant Kara meteorite crater (Pay-Khoy, Russia), reflected light through a binocular microscope.

Following to LA-ICP-MS data the diamond fossils have REE-poor composition compare to the after-coal diamonds. The IR measurements point to preservation of cellulose and lignin components within the ultrananocrystalline diamond aggregates. The carbon isotopic composition of the Kara diamonds (-24.2 ÷ -28.0 ‰ ±0.1 ‰) points to organic carbon precursor came from host rocks such as black shales and sandstones of the Kara sedimentary target. At the same time, we cannot exclude that a part of the diamond fossils has been formed after alive wood fragments.

Conclusion: Following to the present studies it is found that the natural impact diamonds can be formed by different mechanisms stimulated by shock process – diffusion-free (after graphite) and short-distance diffusion (after coal and organics) mechanisms. The latter can be explained by different mechanical properties and elemental composition resulted in easily producing of plastic and liquid state of the carboniferous matter stimulating in some diffusion effects. The non-after-graphitic impact diamonds have very special structure and composition differ them from the well known after-graphite impact diamonds. By the moment we can conclude that the lonsdaleite presence (mechanical defect diamond twinning) cannot be the necessary proof of impact origin for the impact structures. Following to the much more widely spread sedimentary rocks, "*a priory*" containing some organic matter, we can preview an essentially wider distribution of after-organics diamonds and other carbon phases within impact craters. The preservation of structural elements of organic matter in the products of intensive impact metamorphism under giant impact events can help in impact nature proving for debated impact structures around the world, gives a new information for geological paleo-reconstructions and astrobiological studies, and for developing of the extraterrestrial life origin models.

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References:

[1] Stoffler D., Hamann C., Metzler K. (2017) *Meteoritics & Planetary Science,* 1–45, doi: 10.1111/maps.12912.

[2] Kenkmann T., Poelchau M. H., Wulf G. (2014) *Journal of Structural Geology*, 62, 156–182.

[3] Koeberl C. (2014) *In: Holland H.D. and Turekian K.K. (eds.) Treatise on Geochemistry, Second Edition, Oxford: Elsevier*, *2,* 73-118.

[4] Melosh H.J. (2003) *Impact Cratering: A Geologic Process. Oxford University Press, New York*. 245 p.

[5] Yezerskiy V. A. (1986) *Int. Geol. Review. 28:2, 221–228*.

[6] Shumilova T. G., Isaenko S. I., Ulyashev V. V., Kazakov V. A., Makeev B. A. (2018) *EJM, 30, 1,* 61–76.

[7] Borimchuk N. I., Zelyavskiy V. B., Kurdyumov A. V., Ostrovskaya N. F., Trefilov V. I., Yarosh V. V. (1991) *Doklady Akademii nauk, 321, 1,* 95–98 (in Russian).

[8] Williams O. A. (2006) *Semicond. Sci. Technol. 21,* R49–R56.