3D Modeling of Suevite Massifs with UHPHT Glasses at the Kara Astrobleme and the Ust-Kara Area (Pay-Khoy, Kara seashore, Arctic, Russia)

Tatyana Shumilova, Sergey Isaenko, Alexandr Zubov

1 Institute of Geology, Komi Scientific Center of Ural Division of Russian Academy of Sciences, Russia; Pervomayskaya st 54, Syktyvkar, 167982, Russia

shumilova@geo.komisc.ru; tg_shumilova@mail.ru

Abstract. The unusual natural ultrahigh pressure high temperature (UHPHT) impact glasses have been discovered at the Southern part of the Kara astrobleme (Pay-Khoy, Russia) in 2015. The glasses form a complex of stockwork-like system of thin vein bodies set within suevite breccia at the right bank of the Kara river. The Kara glasses have many specific features pointing to UHPHT origin. For better understanding of the geological position of the UHPHT impact glasses we have provided additional field observation with the use of copter facility to observe the outcrops from the «air-bird high» and collecting data for 3D modeling. Here we present natural topological details for the more complete analysis of the discovered UHPHT complex at the Kara River (Pay-Khoy, Russia) and “bottom flow” suevites with UHPHT impact ribbon-like glasses on the Baydarata Bay shore (Kara Sea, Arctic, Russia).

1. Introduction
The geomorphology can give an important information about real size, structure and setting details of geological objects. For the topographic studies many cosmic and air-craft technologies with different sounding facilities used many decades. At present, the modern drones are in a focus of the present and future interest for numerous applications, but, till present it is on the beginning stage of their using [1-3]. Drones have essential advantages in contrast to large air-craft facilities by easy in exploitation, cheap, high detail and resolution analysis, mobility for study of geological objects, possibility of different kinds of instrumental zonding, marchrout works, mobile field analysis of the hard geological objects and accumulation of an important field documentation for 2D and 3D modeling. It is expected, that the drone facilities should be widely used in different industrial applications including numerous geological needs. In this work we demonstrate the amateur results produced by a small drone facility for documentation of the impactites outcrops in wild territories free of restrictions for the small drones flights.

In the focus of the present studies are the unusual natural ultrahigh pressure high temperature (UHPHT) impact glasses which for the first time have been discovered at the Southern part of the Kara astrobleme (Pay-Khoy, Russia) at the right bank of the Kara river in 2015 [4]. The UHPHT glasses are presented with stockwork-like system of thin veins within suevite breccia. The Kara glasses have many specific features pointing to their UHPHT origin that has been described in our several publications [4-7]. To understand the geological position of the UHPHT impact glasses we have provided field observations with the detail topographic photo – and video-documentation of the outcrops from the «air-bird high» with data collecting for 3D modeling. Here we present natural topological details of the...
discovered UHPHT glasses in impactite complexes at the Kara River (Pay-Khoy, Russia) and in “bottom flow” suevites on the Baydarata Bay shore (Kara Sea, Arctic, Russia).

2. Objects
The field observations have been provided in 2015, 2017 and 2019 on the right bank of the Kara river and on the sub-shore of the Baydarata Bay (Kara Sea, Arctic, Russia). It is accepted that the Kara astrobleme has about 65 km in diameter [8] which was formed by giant impact event about 70 Ma [9, 10] close to the Kara seashore. At present the Kara meteorite crater is set in the basin of the Kara river including its mouth (Figure 1), the crater is slightly seen from air and cosmic observations in the present eroding level but the impactites are very good recognized in natural nicely preserved outcrops in the rivers stream channels and canyons around the astrobleme rim [4, 8].

Figure 1. Position of the Kara meteorite crater: a – geographic overview position; b – the detailed position in the landscape. The present excepted rim of the Kara astrobleme (65 km diameter) is marked by solid yellow line; the proposed wider diameter (120 km) is marked by dotted yellow line. The studied regions are marked by red squares – 1 – Baydarata Bay Area (UKA); 2 – Kara southern sector.
The impactites natural outcrops get hundreds meters (up to first kilometers) in extention and up to tens of meters in visible thickness. The impactites are presented generally by suevitic breccia of layer-like thick bodies with rare presence of lens, dykes and layer-like bodies of impact melt rocks up to 8 m in visible thickness. At the same time very impressive impactites have been found on the seashore of the Baydarata Bay which some scientists assign to an independent twin crater of 25 km in diameter named by Ust’-Kara astrobleme [8]. In rare works the Ust’-Kara object is supposed to be a giant independent crater of 80 km in diameter [9]. More a less the others suppose that the impactites of the Ust’-Kara Area (UKA) and the Kara astrobleme belong to a single giant meteorite crater with a diameter up to 120 km centred in the Kara dome [9-12]. But, till present the real size and structure of the Kara impact event are not clear. At the present study stage we analyzed the impactites bodies with the mentioned UHPHT impact glasses which have complicated morphology and contacts between their host impactites varieties, so it is need to analyze their relations with high quality distance observations with video- and photo-documentation.

3. Methods
For the study we used a drone Mavic Pro (SZ DJI Technology Co., Ltd) equipped with a Cinema 4K resolution camera and 3-axial gimbal stabilizer allowed to get high quality photo- and video-documentation – 4096 × 2160 pixels, with the frequency of 24 frames/s. The field video record has been evaluated with the program PIX4DMapper. The 3D model allows to watch the overview of the UHPHT massifs and to recognize tiny details of their position with the target sedimentary rocks.

For the 3D modeling we used a demo version of the program PIX4D Mapper PIX4Ddiscovery (https://www.pix4d.com). The license cannot be used for commercial purposes but can be used for scientific research aims. The program allows to work with photos and video-files. To create a new 3D model project it is need to input a movie-file or photo set for automatic processing for a model of the analyzing object. For example to the video-life 3D model on the figure 3 we used 110 high resolution images cut from a movie of 26 seconds duration from the natural field record. After automatic program processing with Pix4Ddiscovery by Pix4D the produced 3D model can be scaled in 3D and allows to get any of directions view of the object.

Also, we have used the free program SasPlanet 190708 (http://www.sasgis.org) with initial codes under the license GNU GPLv3. The program allows to process view points, treks and marchrouts produced directly in the field trips with an option to inset and combine the work information with free topological maps and other coordinated materials, schemes and so on. In our case for the setting of our field work material we used a package of the Google maps.

4. Results and discussion
In the focus of our study here we present the unusual suevitic occurrences with vein and ribbon-like UHPHT impact melt glasses penetrating suevitic breccia.

4.1. Kara suevites with stockwork-like UHPHT complex
Kara suevites with stockwork-like UHPHT complex have been discovered on the both banks of the Kara River 0.5-2 km to the south from the Togorey stream mouth [4, 5, 7]. Here we provide the short description of the massif on the right bank (Figure 2). In this complex the UHPHT glasses form stockwork-like system of thin veins intruding suevite massif [7]. The glasses have violet, grey and rare black color, multi-level melt differentiation including liquation and crystallization with melt-crystallized coesite [4-7]. At the outcrop the UHPHT complex is presented with the massif of 80 m in extention and up to 20 m in high in the general part having tooth-like morphology (Figure 2a).
The general massif is accompanied with several small columns of the first meters in high. For our field study the most difficult task was to analyze the real relations between the suevitic massif and the sedimentary target rocks by the reason of hard rock conditions for claiming, observation and sampling. For the most detail information, we provided special drone study with different sides observation for photo and video-documentation. The set of the produced high quality documentation allowed to provide 3D modeling with possibility to analyze the contact from different observation positions (Figure 2a, b). Following to the 3D model the contact of the UHPHT complex with the sedimentary rocks well corresponds to the sedimentary strata laying of the target rocks (Figure 2b). The produced 3D model of the studied massif well corresponds to our proposed model of the Kara astrobleme rim structure [7].

Figure 2. Images of the suevitic massif with the stockwork-like UHPHT impact melt glasses with coesite in different orientations sliced from the 3D model: a – frontal top image; b – top-slanting view with well recognized contact between suevitic massif and the black shales of the target.

4.2. Ust’-Kara Area suevites
Impactites at the Ust’-Kara Area (UKA) are presented generally by suevite breccia sheet-like bodies which are well distinguished on the ocean shore of the Baydarata Bay to the west from the Kara river mouth. According to our present study [13] the bottom layer of the suevitic bodies is rich in UHPHT glasses with coesite similar to the Kara vein impact glasses. By our «air-bird high» observations followed by 3D modeling we first time have found the specific stream-like morphology of the suevitic masses (Figure 3). According to the topographic features and the streams directions we propose that the suevitic masses were rather formed during movement in the general direction from the center of the Kara astrobleme.

4.3. “Bottom flow” from the 3D model
Following to our received data we see general similarity in topologic position and morphological features of the impactites with UHPHT impact melt glasses in the frame of the our proposed model [7] with their formation in “bottom flow” facies [13]. The UHPHT glasses belong to the bottom parts of the
suevitic layers both in the Kara impactites and the Ust’-Kara Area. At the present erosion level the flow-like morphology is better seen for the UKA object on the Baydarata Bay shore.

Analyzing the “bottom flow model” we combined the Kara astrobleme regional topology with the contour of the Martian Yuty Crater and its fluidized ejecta [14]. The Martian Yuty flow impactites are spread far from the crater rim and evidently present stream morphology. According to the morphology and geology composition it is possible to propose that the UKA impactites might belong to the bottom flow of the single giant Kara impact event.

Figure 3. Image of the UKA suevitic layer with flow-like morphology, sliced from the 3D model collected from 110 slides of the 26 s field video documentation. Ust’-Kara area, east part from the Kara River mouth, the Baydarata Bay shore (Kara Sea, Arctic, Russia).

5. Conclusions
The results support the preliminary interpretation of the nature of the UHPHT complex and allowed to conclude about the specific origin of the impactites presented with the proposed bottom facies of the suevitic breccia containing UHPHT impact melt glasses. The provided study demonstrate high informative use of the drone facility and allow to get the detail information which is impossible for any other methods of the topographic observations.

Figure 4. The combined image of the Kara astrobleme (yellow color) with a “mask” (projection of the relief) of the Martian Yuty Crater (red color), where the dome and the first rim for both are in the corresponding position. The present UKA (1) and Kara (2) field work areas are marked by the red squares.
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