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The new cosmogenic structures on the Russia and Central Asia territories

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Abstract. This paper summarizes the experience gained as an addition to Catalog of the Earth's Impact Structures with the new craters discovered by the authors. 79 new potential astroblemes from 4 to 1600 km in diameter have been added. Our concept of the search for craters is being supplemented with new elements: the location of the volcanic formations on a board of giablemes; the triangular shape of some craters. The impact origin of one of triangular craters has been confirmed in this research.

Keywords: Morphostructural elements, cosmogenic structures, geophysical anomalies, impact catalogs.

1. Catalog of the Earth's Impact Structures

Currently, Catalog of the Earth's Impact Structures is one of the most complete ones among all the published ones and contains 3104 records [1]. The sources of the newest data added during the last three years and making up 1/5 of the Catalog were private reports of many independent researchers: Nikolai Filin, Alexei Smirnov, Yuri Grechanichenko, Vadim Ilchenko, Valery Yurkovets, Andrei Stepanenko, Yuri Kolesnichenko, Andrei Dolgoruky, Sergei Goncharenko, Andrei Gorshkov, Yu.A. Spiricheva, A.N. Petrova, Max Freydov, Victor Kuznetsov (Kazakhstan), Khusain Moldybekov (Kazakhstan), Krisztian Klajnik (Hungarian Astronomical Association), Terry Westerman (USA), Max Rocca (Argentina) etc.

The authors of the present paper obtained a significant part of the recently added data using (in addition to the classical features [2]) a specially developed technique for detecting large cosmogenic structures [3] (the table). This technique includes the following diagnostic procedures: geometric calculation of the center of the structure along the curvature of arcuate fragments of a crater bank; revealing the negative forms of a relief, a central hill and remaining fragments of the crater bank in stereoscopic maps of Radio Mobile program (in the 3D anaglyph stereo glasses [4]); finding additional signs characterizing the impact origin of the identified structures: sharp changes in riverbeds, the presence of sands, the outcrops of polymetallic ores [2], the presence of hydrocarbons deposits and other mineral resources of the hydrothermal origin [2] and, finally, a typical manifestation of geophysical anomalies demonstrated by the GIS-ENDDB system [3, 5].

The list of new 79 structures of catalog [1] supplemented by the authors

Name of structure	Land	Co	V	Lat	Long	D (km)
Achinsk-Uzhurskaya	Russia, S. Siberia	As	3	55.77	90.14	85
Akshatau Bolshoy	Kazakhstan	As	2	49.15	79.5	450
Altaysky big	Russia, S. Siberia	As	3	48.73	87.5	1200
Andijan (Fergana Valley)	Uzbekistan	As	2	40.72	71.96	60
Aral sea	Kazakhstan	As	2	44.68	58.26	450
Bigatch 2	Kazakhstan	As	2	48.32	81.96	17
Big Puchezh-Katunki	Russia, Povoljie	Eu	2	57.7	45.575	460
Bigatch 3	Kazakhstan	As	2	48.43	81.45	20
Bigatch 4	Kazakhstan	As	3	47.57	81.74	15
Bigatch 5	Kazakhstan	As	3	47.35	81.71	10
Boltysh 2	Ukraine	Eu	2	48.887	32.42378	7.5
Bushveld-1600	South Africa	Af	2	−19.2	28.5	1600
Bushveld-200	South Africa	Af	3	−24.89	29.66	200
Bushveld-400	South Africa	Af	2	−24.26	28.2	400
Chernobylsky 2	Ukraine, Sumy area	Eu	2	51.962024	34.067638	150
Farid and Olga	Russia	As	2	60.88562	100.2317	17
Farid and Olga 1	Russia	As	2	60.97381	99.95409	1
France	England / France	Eu	2	49.93	0.43	1020
Gruzinsky 2	Georgia	As	2	42.38	43.476	22
Gruzinsky 3	Georgia	As	2	42.409	42.845	18
Gruzinsky 4	Georgia	As	3	42.359	43.002	9
Gruzinsky 5	Georgia	As	3	41.971	44.976	20
Gruzinsky big	Georgia	As	3	42.19	43.475	66
Haifa	Near East	As	2	32.7	35.4	60
Hetian	China	As	2	36.34	80.008	42
Inza-Maysky	Russia	As	3	53.85	46.05	800
Irano-Afganskaya	Iran-Afganistan	As	2	34	59	4200
Konder 2	Russia, Khabar.kr.	As	3	58.37	133.1	22
Konder Big	Russia, Khabar.kr.	As	2	57.9	133.8	132
Kronstadt	Russia	Eu	2	60.02515	29.71255	50
Matrosov	Russia	Eu	2	56.6374	30.774	80
Mekhnatabad	Uzbekistan	As	3	40.8	71.4	17
Minsk 1	Belarus	Eu	2	55.3	26.18	500
Minsk 2	Belarus	Eu	2	56.3	27.5	200
Namangan	Uzbekistan / Kyrgyzstan	As	2	41.17	70.81	72
Novosibirsky large	Russia, W.Siberia	As	2	50.66	83.98	802
Obskoy	Russia, N.Siberia	As	2	53.96	84.88	432
Obskoy 1	Russia, N.Siberia	As	2	53.6	83.5	42
Obskoy 2	Russia, N.Siberia	As	2	53.69	82.73	60
Obskoy 3	Russia, N.Siberia	As	2	53.64	81.77	32
Obskoy 4	Russia, N.Siberia	As	2	53.92	81.31	20
Obskoy 5	Russia, N.Siberia	As	2	52.6	78.3	216
Pavlovsky	Russia, Voronezh area	Eu	2	50.3	41.2	550
Petra	East Mediterranean Sea	As	2	30	34	200
Pohjois-Savo	Finland	Eu	2	63.1635	26.694	200

Name of structure	Land	Co	V	Lat	Long	D (km)
Poltavsky 1	Ukraine, Poltava area	Eu	2	50.25855	33.10064	270
Poltavsky 2	Ukraine, Poltava area	Eu	2	50.41386	31.51818	140
Poltavsky 3	Ukraine, Poltava area	Eu	2	50.27205	34.03572	134
Pripyat Basin	Belarus	Eu	2	52.053352	30.11344	480
Pskovskaya	Russia	Eu	2	56.8838	28.3917	100
Puchezh-Katunki 2	Russia, Povoljie	Eu	2	57.05	43.02	200
Ramenskoye	Russia, Moscow area	Eu	2	55.6	38.4	100
Russian	Central Russia	Eu	2	58.0481	36.21338	424
Saint Petersburg	Russia	Eu	2	60.28	30.23	480
Samarkand	Uzbekistan	As	2	39.44	66.688	201
Samarsky-1	Russia, Volga basin	Eu	3	52.28	49.67	250
Samarsky-2	Russia, Volga basin	Eu	3	53.1	51.02	70
Samarsky-3	Russia, Volga basin	Eu	3	53.03	48.95	70
Schelkovsky	Russia, Moscow area	Eu	3	55.84	37.77	50
Smolensky East	Russia, Smolensk area	Eu	2	55.4	33.7	200
Smolensky West	Russia, Smolensk area	Eu	2	55.15	30.95	150
Sudan	Africa	Af	3	17.37	32.66	800
Suez	East Mediterranean Sea	As	2	28.94	31.87	120
Suzdalsky	Russia	Eu	2	55.12	40.88	300
Svetetsky big	Russia, Moscow area	Eu	3	55.67	39.73	44
Syktyvkar	Russia, Komi ASSR	Eu	2	62.41	51.65	180
Syria-African (Mediterranean)	East Mediterranean Sea	As	2	31.58524	25.34358	1900
Troitsko-Pechorsky	Russia, Komi ASSR	Eu	2	62.4	55.15	400
Ust-Kamenogorskaya	Kazakhstan	As	2	50	83.8	180
Varzik-Marble	Uzbekistan	As	1	41.2	71.2278	4
Verhne-Taimyrsky	Russia	As	2	73	96.3	50
Volgo-Donskaya	Russia, Don / Volga basin	Eu	2	50	45	1950
Voronezhsky	Russia	Eu	2	53.13	37.12	1240
White Nile	Africa	Af	3	13.74	33	500
Yamzhacha	Russia, Ne Ural	Eu	2	61.29	58.24	12
Yantar'	Russia	Eu	2	54.0345	17.84	580
Zapadno-Sibirskaya	Russia, N.Siberia	As	2	60	73	1728
Zuunhangai 1	Mongolia	As	2	49.16714	95.6698	18
Zuunhangai 2	Mongolia	As	2	49.3379	95.50967	8.5

Another element is added to the technique proposed in multi-ring craters to determine more accurately which ring can be considered to be its external boundary. Thus, investigating the "Konder Big" crater ($D = 132$ km), it was noted that in the south-east part of its board there is a famous "Konder" crater ($D = 9$ km) [1, 5], which has morphological signs of the volcanic origin. The regularity of the location of volcanic formations on the crater board (well expressed in the gravitational field as an intense positive anomaly) was also noted for the following structures: the "France", $D = 1020$ km (where the anomaly indicating to the paleo-volcano is in az-

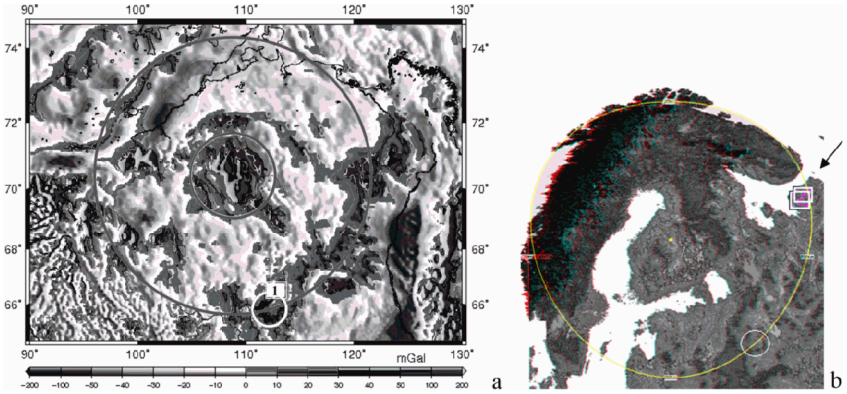

Figure 1. The potential giablemes and volcanogenic formations on their board: a) a volcanic body in the form of a settling structure (white circle) and a kimberlite pipe Udachnaya (rectangle 1) on the board of the giableme "Heta-Oleneksky nuclear" ($D = 842$ km), b) the volcanic body (white circle) and the kimberlite pipes Lomonosov and Griba (the rectangles indicated by the arrow) on the board of the giableme "Ancylus Lake" ($D = 1600$ km)

imuth 125–130° relative to the center of the crater and corresponds to the location of the high-mountainous Lake Geneva), "Yantar", $D = 580$ km (azimuth 125–130°), "Aral", $D = 450$ km (125–135°), "Inza-Maysky", $D = 800$ km ($\sim 135°$), as well as for the "Heta-Oleneksky nuclear" or "Bolshaya Kotuykanskaya" structure, $D = 842$ km ($\sim 165°$) and "Ancylus Lake", $D = 1600$ km ($\sim 150°$).

For the Northern Hemisphere it is noted that the higher the latitude of the location of the giableme, the closer the azimuth of the volcanic manifestation to 180°, and the closer it is to the Equator, the closer it is to 90°. According to this structural feature, the boundary of the multi-ring structure "Heta-Oleneksky nuclear" has been refined ($D = 842$ km instead of 1100 km) (Figure 1a), the "Irano-Afganskaya" ($D = 4458$ km instead of 4200 km) and "Ancylus Lake" ($D = 1600$ km instead of 1300 km) (Figure 1b). The correctness of these refinements is also confirmed by the fact that the Udachnaya kimberlite pipe is located on the new boundary of the "Heta-Oleneksky nuclear" (Figure 1a), and the kimberlite pipes of Lomonosov and Griba are on the new board of the "Ancylus Lake" giableme (Figure 1b).

2. The diagnostic signs of the newly added structure

As stated above, most of the listed structures are characterized by the morphological expression in the relief and are confirmed by geophysical features (in the gravitational or the thermal field). For them, it was noticed that the radius of the central hill of the giant astroblemes and the radius of their outer edge are in the ratio 1 : 3.

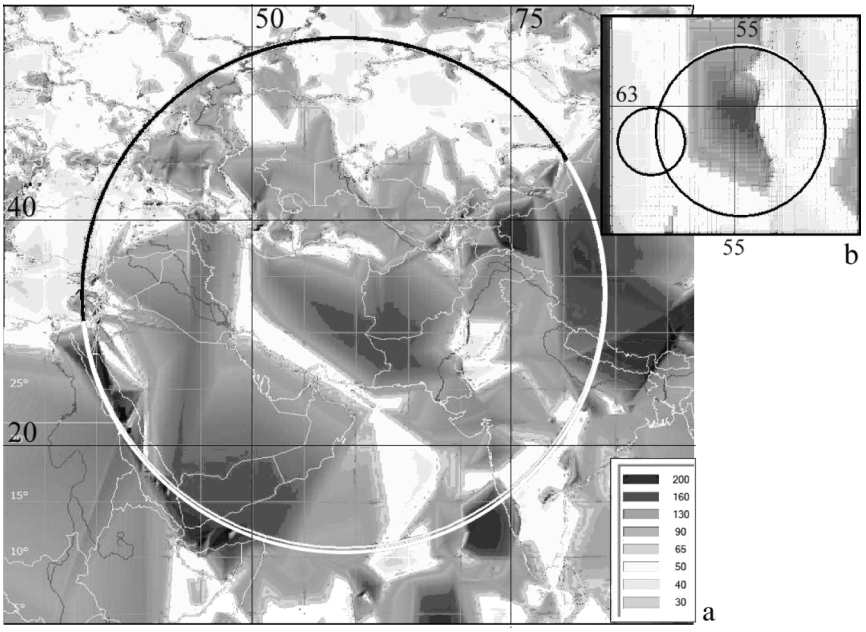

Figure 2. The potential impact structures "Irano-Afganskaya", $D = 4458$ km (a) and "Troitsko-Pechersky", $D = 400$ km (b) in a heat flow map

Let us note that the morphological signs expressed in the relief are applicable in the case of a good preservation of the crater, which practically does not happen, due to the presence of the gigantic area of such structures. The geophysical signs are of more reliable.

In particular, the largest of these structures the "Irano-Afganskaya" ($D = 4200$ km) is manifested in the thermal field as a giant semi-ring of elevated values (up to 200 mW/m^2) of the heat flow along the perimeter of the structure, the inner ring of the lower values ($D = 1800$–2300 km) and the central anomalous region of increased values (up to ~ 150 mW/m^2) corresponding to the Iranian upland ($D = 800$–1700 km) (Figure 2a). By a good expression in the thermal field (most often in the form of a butterfly-shaped positive anomaly or a shapeless one localized in the center of the structure), also, the structure "Altai large" ($D = 1200$ km), the "Aral" ($D = 450$ km), the "Volgo-Donskaya" ($D = 1950$ km), the "Altaysky big", "Namangan" ($D = 72$ km), "Troitsko-Pechersky" ($D = 400$ km), "Ust-Kamenogorskaya" ($D = 180$ km), "Haifa" ($D = 60$ km) (Figures 2, 3b) are characterized.

The following giablemes from the list under consideration are expressed in the gravitational field as a positive bank and a central peak, as well as, a submerged ring between them or as a multi-ring anomaly: "Sudan" ($D = 800$ km), "Heta-Oleneksky nuclear" ("Bolshaya Kotuykanskaya" structure) ($D = 842$ km), "Bushveld-1600" ($D = 1600$ km), the "Volgo-Donskaya"

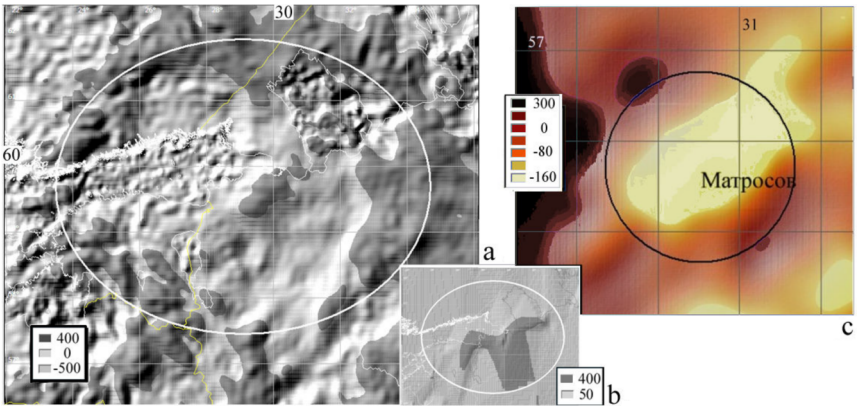

Figure 3. The characteristic gravitational anomalies (in mGal) of impact craters: "Saint Petersburg" giableme, $D = 480$ km (a), with its thermal field (b) in mW/m^2 and "Matrosov" crater of mach smaller size, $D = 80$ km (c)

($D = 1950$ km), the "Konder Big" ($D = 132$ km), the "Novosibirsk large" ($D = 802$ km), the "Big Puchezh-Katunki" ($D = 460$ km) [3], "Puchezh-Katunki 2" ($D = 200$ km), "Saint Petersburg" ($D = 480$ km) (Figure 3a), "Troitsko-Pechersky" ($D = 400$), "Ust-Kamenogorskaya" ($D = 180$ km), "France" ($D = 1020$ km). The structures with a diameter of the first tens of kilometers are manifested in the gravitational field in the form of well-defined negative anomalies: the "Andijan" ($D = 60$ km), the "Boltysh" (with the refined diameter $D = 40$ km), the "Matrosov" ($D = 80$ km) (Figure 3c), "Haifa" ($D = 60$ km), and "Yamzhacha" ($D = 12$ km).

3. Triangular impact structures and the "Varzik-Marble" crater

It is interesting to note that when studying the landscape of various regions using stereographic maps, several cases were found where clear cut negative structures in the relief do not have a ring, but a triangular shape (Figure 4).

With a careful consideration, another regularity attracts attention. The triangles adjoin by one of their peaks to the maximum of the relief. It is possible that the impact onto the slope in the presence of a fragile sedimentary layer causes the formation of such structures as a result of the descent (displacement down the slope) of this layer.

One of the examples of such a formation is the "Varzik-Marble" crater ($D = 4$ km). The crater is located in the village of Karakurgan, the Chust district, the Namangan region (The Republic of Uzbekistan).

In addition to the triangular shape, the crater has a number of other unusual features. For example, to the left of the proposed impact center, there is a completely destroyed landscape (circle 1 in Figure 5a), but on

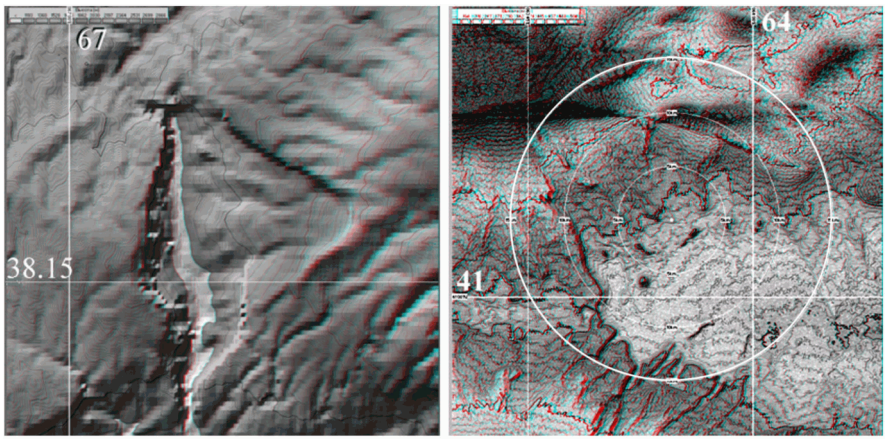

Figure 4. The examples of craters of the triangular shape obtained by the Radio Mobile program [4]

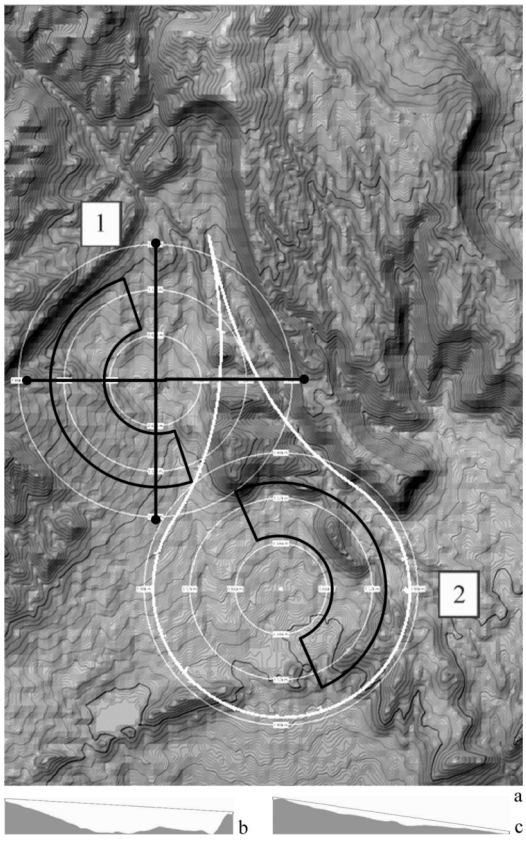

Figure 5. Elements of the triangular crater "Varzik", identified by the Radio Mobile software [4]: a) in the stereo-relief there are shown: the displaced left board of the crater (1) and the displaced right board (2) in the form of an elongated drop-shaped figure; b) and c) cross-sections of the crater 1: the symmetry in the west-east cross-section (b) and the asymmetry in north-south cross-section (c)

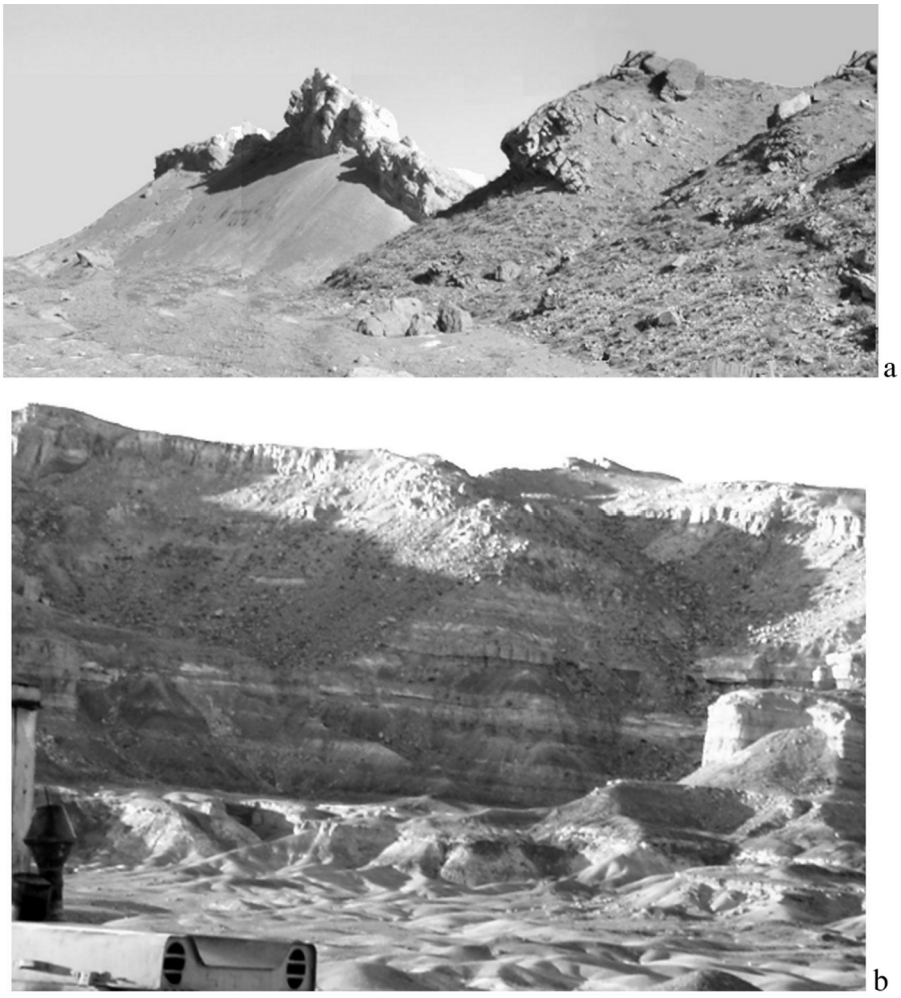

Figure 6. Photographs of crater boards 1 and 2 from Figure 5: a) the melted ridge of crater 1 near the mountain formations not exposed to the impact, b) crater board 2 with a height > 100 meters, the melted ground of the bottom of the crater is visible

the right — there are hills that have been insignificantly destroyed (the drop-shaped contour in Figure 5a). This asymmetry is also expressed in the cross-sections of the relief (Figures 5b, 5c).

It is also unusual that one relief ridge is melted, and the other one is not (the area of the rectangle with number 1 in Figure 5a), although the distance between them is only 300-400 meters (Figure 6a). The soil of the slopes within the described structure is brightly rusty, locally melted (for example, at the bottom of crater 2: Figure 6b), or covered with piles of stones that are black from one or both sides due to reflow (see Figure 6a).

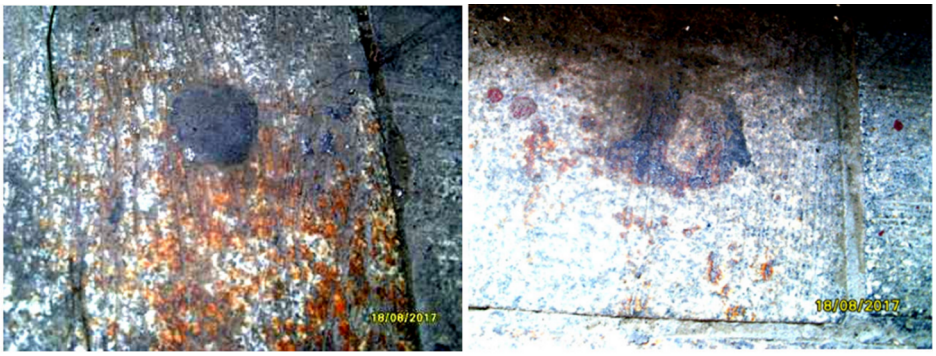

Figure 7. The marble facing plates of one of the underground passages of the Varzik town with an inclusion of an iron body

It is not accidentally that before the start of marble mining in these places, the nearest village to the described mountain was called Kora-Kurgon (Black Kurgan).

The place is famous for its valuable marble and travertine. A layer of the marble with a capacity of 60–80 meters is at the surface; its extraction has been producted since ancient times. In the town of Varzik, located 5 km from the epicenter of the impact structure, the facing plates of the ancient underground passages of this town made of this marble. In one of such passages, one of the authors has discovered a marble plate with inclusions of an iron body of the palm size (Figure 7).

Thus, the signs of the impact origin of this crater are sufficient, but there are many questions related to its unusual triangular shape. The assumption of descent of the sedimentary layer of thickness of 100 m or greater caused by the impact onto the slope explains the unusual characteristics of this crater: the asymmetry of the shape, the presence of angles (the triangular shape), the presence of mountain formations without signs of impact near the melted crest.

As a result of the impact, the marble roof could come off the sole, along the surface with a slope of up to 45° to the horizon (see Figure 5c), descend south-westward for 4,700 meters and stop, leaning against a wall of rocks (see Figure 5a). Such a mobility could be facilitated by the erosive influence on the sole of the river (its channel can be seen at the apex of the triangle on Figure 5a). As a result of this displacement, the melted comb, the edge of the original crater, found itself nearby the intact ridge of the rock barrier.

Thus, crater 1 of a triangular shape is the left part of the original crater, and crater 2 is a possible trace of the subsequent displacement of the right board of the crater along the slope to the south-east (see Figure 5a).

Conclusion

This paper summarizes the experience gained in the last three years as an addition to the Catalog [1] with the new structures discovered by the authors using the technique described earlier [3]. On this basis, 79 new potential astroblemes from 4 km to 1600 km in diameter have been added to the Catalog. At the same time, our concept of the search for craters is being supplemented with new elements. In particular, it is proposed to clarify the crater boards according to the location of the volcanic formations accompanying many giablemes. In addition, in the relief, we have revealed the new morphological type of the impact structures: craters of a triangular shape. The impact origin of one of these craters ("Varzik-Marble") has been confirmed in this research by some morphostructural and mineralogical observations.

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