A Meteoritic Component in Melt Rocks from the Boltysh Impact Structure, Ukraine: First Assessment.

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Introduction: The Boltysh crater is a complex impact structure, 24 km in diameter, situated in the central part of the Ukrainian Shield, centered at 48°45' N and 32°10' E in the basin of the Tyasmin river, a tributary of the Dnieper river. The subsequent description of the geology of the structure closely follows the description in Gurov et al. [1] (and references therein). The crater formed in the crystalline basement of the Ukrainian Shield, which at the time of impact was probably partly covered by a thin veneer of late Cretaceous fine grained siliciclastic and carbonate rocks. The basement rocks of the region are Proterozoic porphyroblastic granites, with ages of ca. 1550 Ma, and older biotite gneisses (ca. 1850 – 2220 Ma). Ejecta from Boltysh cover an area of at least 25,000 km^2.

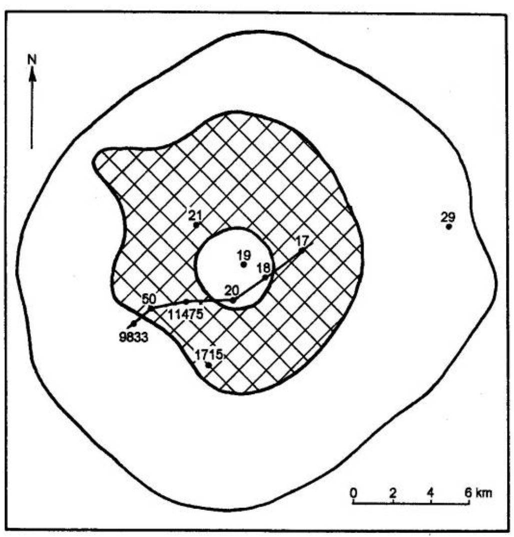

Fig. 1: Schematic outline of the Boltysh impact structure, showing the locations of some drill cores. Also, the position of cross-section shown in Fig. 2 is indicated. The estimated outcrop of the eroded original rim is shown by a darker shading. Core 50 was used in the present study.

Recently the crater and its post-impact deposits became covered with Quaternary sediments up to 30 m thick and now have very little surface expression. However, the deeper structure of the crater and the composition of crater filling sediments is known from drill cores and geophysical investigations undertaken in the 1960s and 1980s (Fig. 1).

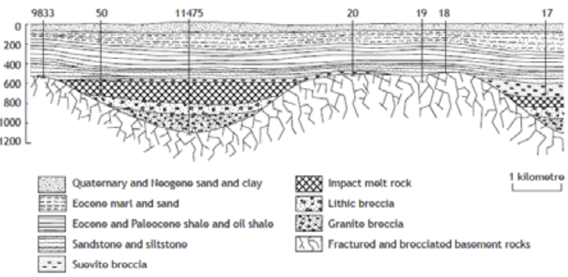

Fig. 2: Cross–section through the central part of the Boltysh structure (I–I), showing locations of boreholes and depths of sedimentary lithologies (from [1].

Boltysh is a complex impact structure, with a central uplift, and a maximum depth to the crater floor of about 1 km around the central high. The crater floor is defined by transition from fractured granites to allochthonous fine grained breccia and lies at a depth of 1065 m in borehole No. 11475 (Figs. 1, 2), not all of the other boreholes penetrated to this depth. The central uplift is elevated 60-80 m relative to the surface of the impact melt in borehole No. 50 and is covered by a thin veneer of suevite. The inner crater (about 12 km in diameter, Figs. 1, 2) is filled with impact melt rocks, suevites, and lithic breccias. The impact melt rocks form an annular sheet, 12 km in diameter and up to 220 m thick, surrounding the central uplift. The surface of the melt sheet seems to be sub-horizontal in the boreholes, providing evidence that the melt formed a "lake" in the deepest part of the crater immediately after the impact.

Two main types of impact melt rocks make up the melt sheet. The lower part comprises melt rocks with a glassy matrix that occur in the intervals 653 – 736 m in the core No. 50 and 657 – 791 m in core No. 11475. The upper part of the melt sheet is composed of microcrystalline impact melt rocks and a variably thick layer of suevite.

Impact melt rocks of the upper horizon are microporphyritic rocks with fine grained matrix containing microlites of feldspars and biotite, the latter forming pseudomorphs of pyroxene. The matrix is composed of fine-grained to cryptocrystalline aggregates of feldspars and quartz forming spherulitic and micropris-matic structures. The impact melt rocks contain abundant shocked quartz clasts. Xenoliths of highly shocked and selectively melted granites, up to 2 m in diameter, occur in the interval from 645 to 620 m in core No. 50.

Comparison of Boltysh and Chicxulub Impact Structures: One of the main reasons for the present study is the (within error) identical age of the two impact structures [2], raising the possibility that Boltysh and Chicxlub might be coeval and that they might have formed by a dual impact, similar to, e.g., the Ries and Steinheim (even though the spatial separation of the two bodies would have been rather large). The first physical evidence pointing to a contribution of extra-terrestrial material at the K-T boundary were the anomalously high PGE abundances, as well the observation that the interelement ratios of the PGEs in K-T boundary clay samples are very similar to the values observed in chondritic meteorites. Further confirmation of an extraterrestrial component at the K-T boundary, and later in melt rocks from the Chicxulub crater, come from Os- and Cr-isotopic data. In particular, Cr-isotope evidence data for a meteoritic component was found that is in better agreement with a carbonaceous chondritic composition of the impactor, rather than an ordinary chondritic composition. More recently, this identification was refined to a CM2 carbonaceous chondrite (e.g., [3]).

Samples and Methods: Twenty-two samples of melt rock and breccia from core No. 50 were selected for major and trace element analysis. Of those, eight samples were selected for platinum group element (PGE) studies. The contents of the PGE and Au were analyzed by Ni sulphide fire assay followed by ICP-MS. Details of methodology are given in [4]. Osmium is partially lost during sample digestion and is not reported. The results are shown in Table 1.

Table 1: PGE and Au concentrations in Boltysh drill core samples (in ppb; blank corrected)

	Ir	Ru	Rh	Pt	Pd	Au
BOL-734	0.31	0.72	0.15	1.70	1.71	0.19
BOL-682.2	0.31	0.77	0.16	2.52	1.60	0.17
BOL-717	0.07	0.22	0.06	0.29	1.36	0.30
BOL-684	0.08	0.23	0.09	0.82	1.22	1.33
BOL-650	0.36	0.80	0.17	1.97	1.25	0.11
BOL-580	0.08	0.32	0.06	1.12	3.05	1.35
BOL-603	0.09	0.34	0.07	0.39	1.04	0.23
BOL-627.8	0.10	0.31	0.09	1.31	1.00	0.35
Blank-1	<0.03	0.16	<0.03	0.24	0.21	0.09
Blank-2	<0.03	0.13	<0.02	0.46	0.44	0.28

Results and Discussion: Five of the 8 samples contained concentrations of the more refractory PGE (Ir and Ru) in the range of values typically found for many terrestrial upper crustal rocks (e.g., [5]) but three samples of impact melt (BOL 650, 682.2 and 734) produced significantly higher Ir and Ru (and Rh) concentrations and flatter chondrite normalised patterns. If the five low-Ir and Ru samples contain entirely terrestrial PGE, then subtracting this as a background contribution suggests that the 3 high-Ir and Ru samples contain ~0.25 ppb and ~0.4 ppb non-terrestrial Ir and Ru respectively. This is consistent with a small chondritic component (0.05-0.1%) in these samples. The component measured thus far is too small and the range of PGE concentrations is too narrow to employ techniques that may further constrain the type of chondrite, such as determination of PGE ratios by regression analysis (e.g., [6, 7])

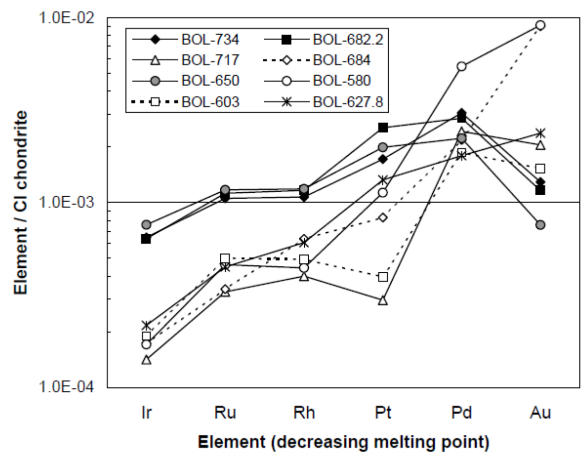

Fig. 3: Chondrite-normalized PGE and Au abundances in Boltysh drill core samples, showing that three of the samples contain a minor chondritic component.

Conclusions: Our study clearly indicates the presence of a meteoritic component in melt rocks from the Boltysh impact structure, Ukraine. Unfortunately, due to the low abundances in the analyzed samples, it is only possible to say that the data are consistent with a chondritzic impactor, but it is not yet possible to determine of the impasctor was of the same type as for the coeval Chicxulub impact structure.

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References: [1] Gurov et al., in “Biological Processes Associated with Impact Events”, Ed. Cockell et al., Springer, p. 335-358, 2006. [2] Kelley S. and Gurov E. (2002) *Meteoritics & Planet. Sci.*, 37, 1031-1043. [3] Trinquier et al. (2006) *Earth Planet. Sci. Lett.* 241, 780-788. [4] McDonald I and Viljoen K.S. (2006) *Appl. Earth Science (Trans. Inst. Min. Metall. B)*, 115, B81-93. [5] McDonald et al. (2007) *Meteoritics Planet. Sci.* 42, 743-753. [6] McDonald et al. (2001) *Geochim. Cosmochim. Acta* 65, 113-123. [7] Tagle, R., and Berlin, J. (2008) *Meteoritics & Planet. Sci.* 43, 541-559.