METEORITIC COMPONENT IN MELT ROCKS FROM THE BOLTYSH (UKRAINE) AND LONAR (INDIA) IMPACT STRUCTURES: FIRST ASSESSMENT. C. Koeberl[1,2], B. Mougel[3], and F. Moynier[3]. [1]Natural History Museum, Burgring 7, A-1010 Vienna, Austria (christian.koeberl@univie.ac.at), [2]Department of Lithospheric Research, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria, [3]Institut de Physique du Globe de Paris, Université Sorbonne Paris Cité, CNRS UMR 7154, Paris, France.

Introduction: Boltysh: The Boltysh crater is a 65 Ma complex impact structure (see [1] and references therein), 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 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.

Boltysh is a complex impact structure with a central uplift. The inner crater (about 12 km in diameter) 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.

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 microprismatic 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.

Introduction: Lonar: The Lonar crater (e.g., [2]) is a relatively small (rim to rim diameter 1830 m), almost circular, simple (bowl-shaped) impact crater centered at 19°58'N and 76°31'E, with an age of 0.57 Myr. The depression is excavated from the basalt flows of the Deccan Traps in the Buldana District of Maharashtra, India. The target rocks, which are basalts of the Deccan Traps, are quartz-normative tholeiites with a moderate degree of iron enrichment. In the Lonar area, about 600-700 m of Deccan basalt flows overlie a Precambrian basement. In the upper part of the sequence, the individual basalt flows range from about 10 to 30 m in thickness and different flows are usually separated by red bole (i.e., weathering horizons). On the inner slope of the crater walls, five such individual flows are exposed.

Impact ejecta have been documented not only inside the crater (in the crater fill), but also to a distance of about 1.3 km from the crater rim in the form of an ejecta blanket. Various shocked minerals (e.g., plagioclase with planar deformation features [PDFs]) and maskelynite were found in these ejecta.

Earlier Studies of Meteoritic Components: Boltysh: The platinum-group element (PGE) contents of several melt rock samples from core 50 at Boltysh were recently determined [3]. Some of these samples contained concentrations of the more refractory PGE (Ir and Ru) in the range of values typically found for many terrestrial upper crustal rocks, but three samples of impact melt produced significantly higher Ir and Ru (and Rh) concentrations and flatter chondrite normalized patterns. Subtracting the 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. However, this amount is too small to further constrain the type of meteorite that was involved.

Lonar: Two studies report the search for a meteoritic component. Based on Ni, Cr, and Co contents, Misra et al. [4] postulated an admixture of up to ~20% of a chondritic component in submillimeter-sized impact spherules found in the continuous ejecta blanket of the Lonar crater.

Another study [5] determined the osmium isotope characteristics of rocks from the Lonar crater. Most impactites have distinctly lower $^{187}Re/^{188}Os$ and $^{187}Os/^{188}Os$ ratios compared to the target rocks and exhibit up to two orders of magnitude higher abundances of Ir, Os, and Ru. Also, the impactites show near-chondritic interelement ratios of the highly siderophile elements. This was interpreted to represent an addition of up to 0.03% of a chondritic component to most impact glasses and impact melt rocks. The magnitude of the admixture is significantly lower than the reported 12–20 wt% of extraterrestrial component for Lonar impact spherules, reflecting the typical difference in the distribution of projectile component between impact glass spherules and bulk impactites.

Samples and Methods: We analyzed three samples of Boltysh melt rocks and three Lonar impactites. Mass spectrometry was used for the determination of the chromium isotopic composition of the rocks measured in this study. All chemical separations and isotopic measurements were performed at the Institut de Physique du Globe de Paris, France. $^{53}Cr/^{52}Cr$ and $^{54}Cr/^{52}Cr$ isotope ratios were measured by multi-collection (9 cups) Thermal-Ionization Mass-Spectrometry (TIMS) Fisher Scientific Triton. Details of our Cr isotopic measurement methodology were published by [6].

Results: Chromium isotopic data are reported in Table 1 in ε-units, which is the relative deviation in parts per 10,000 of $^{53}Cr/^{52}Cr$ ($\varepsilon^{53}Cr$) and $^{54}Cr/^{52}Cr$ ($\varepsilon^{54}Cr$) from the terrestrial Cr standard NIST SRM 3112a. Two Boltysh melt rocks (BOLT-721 and BOLT_717) have Cr isotopic compositions that are clearly outside of the terrestrial range with negative $\varepsilon^{54}Cr$ and $\varepsilon^{53}Cr$ (see Fig. 1). On the other hand, one sample (BOLT_627.8) has a terrestrial isotopic composition. Two Lonar impactites (LQ15 and especially LO-72) have clear non-terrestrial Cr isotopic composition with positive $\varepsilon^{54}Cr$ and $\varepsilon^{53}Cr$, while one sample (LQ-60D) has a terrestrial-like composition.

Table 1: Chromium isotopic composition of samples from the Lonar and Boltysh craters compared to average compositions of meteorites. n= number of replicates. 2s.e=2sd/√n

Samples	n	$\varepsilon^{53}Cr$	2 s.e	$\varepsilon^{54}Cr$	2 s.e
Lonar					
LQ15	4	0.08	0.06	0.22	0.09
LO-60D	2	-0.03	0.05	-0.13	0.06
LO-72	7	0.19	0.03	0.48	0.06
Boltysh					
BOLT_721	5	-0.05	0.04	-0.17	0.07
BOLT_717	7	-0.13	0.02	-0.31	0.06
BOLT_627.8	5	0.03	0.03	0.06	0.07

Discussion: Previous work has allowed the detection of the presence of minor meteoritic components in impactites from both craters, Boltysh [3] and Lonar [4]. Due to the very minor amounts of meteoritic contamination it was so far not possible, using PGE abundances or Os isotopic data, to determine the type of impactor. Our Cr isotopic analyses provide evidence for the chrondrite types that are involved in each case.

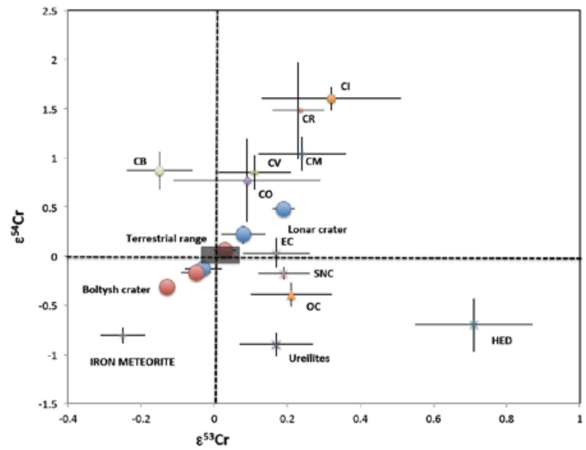

Fig. 1. Diagram showing the Cr isotopic compositions of the Boltysh and Lonar samples and various meteorite groups.

Our data confirm that some Lonar and Boltysh crater samples contain extra-terrestrial components. The strength of the Cr isotopic approach is that in addition to detecting the presence of meteoritic components it could also allow the determination of the nature of the impactor. In the case of Boltysh, negative $\varepsilon^{53}Cr$ signatures are rare among meteoritic materials, and restricted to CB chondrites and iron meteorites when they are not affected by large cosmogenic effects (Fig. 1). However the combination of negative $\varepsilon^{53}Cr$ and $\varepsilon^{54}Cr$ observed in Boltysh samples is only characteristic of iron meteorites (i.e., St Aubin meteorite, Fig. 1). Another possibility would be a volatile-depleted ordinary chondrite (so far not measured). Therefore, these data clearly show that the impactor at the origin of the Boltysh crater was not a carbonaceous chondrite as it is the case for the K-Pg impactor at Chicxulub.

The case of the Lonar crater is different. The two samples with positive $\varepsilon^{54}Cr$ (and $\varepsilon^{53}Cr$) most likely suggest the presence of a carbonaceous chondrite component in Lonar rocks (Fig. 1). The third sample falls onto the same trend but shows a slightly negative composition, within errors within the range of terrestrial material, and, therefore, may not represent evidence for a meteoritic component in this sample.

Acknowledgements: We thank E. Gurov for the Boltysh samples.

References: [1] E. Gurov et al., in “Biological Processes Associated with Impact Events”, Ed. Cockell et al., Springer, p. 335-358, 2006. [2] S. Osae et al. (2005) MAPS 40, 1473-1492. [3] McDonald I., Koeberl C., and Gurov E. (2009) Lunar and Planetary Science 40, abstract #1252. [4] S. Misra et al. (2009) MAPS 44, 1001–1018. [5] T. Schulz et al. (2016) MAPS 51, 1323–1339. [6] B. Mougel et al. (2017) EPSL 460, 105-111.