OSMIUM ISOTOPE CONSTRAINTS ON THE PROPORTION OF BOLIDE COMPONENT IN CHICXULUB IMPACT MELTS.

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Introduction: There have been numerous previous attempts to identify the projectile that produced the Chicxulub impact crater. Kyte [1] reported a fragment of rock in K/T boundary sediments that had been deposited in the Pacific Ocean. The textures and chemistry of the fragment suggested it was an altered fragment of carbonaceous chondrite material. Kyte interpreted it to be from the Chicxulub projectile, which he noted would be consistent with computer simulations of the impact that suggested approximately 10% of the projectile may have survived as solid debris [2]. Shukolyukov and Lugmair [3] analyzed the chromium isotopes of altered K/T boundary clays and reported an extraterrestrial signature with an isotopic composition similar to carbonaceous chondrites. Both types of existing data suggest the projectile had carbonaceous chondrite affinities. It is still unclear, however, if this material is remnants of a carbonaceous asteroid or a comet, the latter of which is believed to have rocky components that are similar to carbonaceous chondrites based on studies of IDPs. These data are based on analyses of material associated with impact ejecta deposited far from the Chicxulub crater.

Impact melts within craters also often contain traces of the asteroid or comet that produced the craters. Consequently, impact melts like those recovered in the Yaxcopoil-1 (YAX-1) borehole may provide additional clues about the projectile's composition, and the proportion of material transferred to the impactites from the bolide. The trace elements best used to identify a projectile are siderophile elements, because these types of elements are depleted in the crust of a differentiated planet like the Earth, yet enriched in primitive meteorites. Studies of siderophile elements from other impact sites have shown that the proportion of a melt derived from the projectile can range from fractions of a percent (the norm) to a few percent.

The purpose of this Os isotopic study is to constrain the proportion of the bolide component in the impactites as a function of position (e.g. depth) within the impact structure. This can now be accomplished via examination of the recent drill cores into the impactites. Osmium is a good choice for geochemically identifying a meteoritic component because, like Ir, it was undoubtedly highly-enriched in the bolide relative to crustal impact rocks. More importantly, the Os isotopic composition of the crustal rocks impacted by the bolide were likely very different from that of the bolide. The $^{187}Os/^{188}Os$ ratios of most primitive meteorites average about 0.13, whereas continental crustal rocks, although highly variable, average about 1.0. Thus, the $^{187}Os/^{188}Os$ of the breccias should be a very sensitive indicator of the meteoritic component.

In the case of impact melts from within the Chicxulub crater, some siderophile element and Re-Os isotopic data already exist (e.g. [4-6]). Koeberl et al. [5], for example, reported $^{187}Os/^{188}Os$ equal to 0.113 $\pm$ 0.003 in a sample of melt from the Chicxulub-1 borehole. The siderophile element concentrations and other data indicate this value is a meteoritic signature rather than a mantle signature.

Samples: Recent drilling has produced the samples of impact melt breccias examined here. All samples examined here are from the YAX-1 borehole [7]. Two main types of impact breccias have been studied. The first type is a green altered impact meltrock found in the lower portion of the impact sequence. The texture of the rock is microcrystalline and is composed of pyroxene, plagioclase, and alkali feldspars. Its composition is consistent with continental margin rocks. It is generally massive with some flow structure. The rock was brecciated and altered after solidfication and contains small amounts of both shocked and unshocked clasts of the impacted lithologies. These lithologies include lithic quartzite, and isolated feldspar crystals. The compositions of these rocks are similar to those seen in meltrocks sampled by the Yucatan-6 borehole [8-9]. Our study includes samples YAX-1_861.4, YAX-1_863.51, and YAX-1_876.46, which represent both the top and lower portion of the green impact meltrock. The middle sample in the sequence has the least amount of (mineralogical) alteration [10].

The second type of melt breccia under study is a brown altered impact meltrock. It also has a microcrystalline texture and both shocked and unshocked clasts of the target material. Even though this rock type has been altered, remnant schleiren, metaquartzite, and micritic calcite have been identified. Sample YAX-1_841.32 is representative of this type of rock. It was recovered from a polymict breccia in the middle of the impact sequence.

Analytical Methods: Samples were spiked for isotope dilution analysis and digested in Carius tubes in reverse *aqua regia* at 230°C. Subsequent separation/purification was accomplished via solvent extraction (Os) and anion exchange chromatography (Re). Osmium analysis was accomplished via negative thermal ionization mass spectrometry using the University of Maryland *Bobcat I* mass spectrometer. Rhenium was analyzed using the University of Maryland *Nu Plasma* multi-collector ICP-MS. Analysis was done using a triple electron multiplier arrangement for simultaneous measurement of masses 185, 187 and 190 (for ^{187}Os correction). Blanks for Re and Os averaged 13 pg, and 1.0 pg, respectively. The $^{187}Os/^{188}Os$ of the blank averaged 0.17. All ratio measurements were better than $\pm$ 0.5%. Most samples have quite low concentrations. Analytical uncertainties are variable, with the greatest uncertainty resulting from high blank/sample ratios. Our initial two measurements were of sample aliquants of approximately 0.1 g (YAX-1_861.4; YAX-1_876.46). Due to low concentrations of Re and Os, uncertainties in Os concentration and isotopic composition are approximately $\pm$10%. Rhenium quantities were at blank levels and are not reported. More material was digested for subsequent samples and blank/sample ratios decreased accordingly. Uncertainties for these samples are approximately ±1 for isotopic composition and ±1-6% and ±5-30% for Os and Re concentrations, respectively.

The $^{187}Re/^{188}Os$ ratios for all samples are relatively low, so corrections for 65 Ma of ^{187}Os ingrowth are relatively minor.

Results: Rhenium and Os concentrations in the green meltrocks are typical of continental crustal rocks. The brown impact meltrock has significantly higher concentrations of both Re and Os than the green meltrock. The brown meltrock also has the lowest initial $^{187}Os/^{188}Os$ of 0.32. Of the rocks analyzed for which there are Re data, all have initial ratios >0.3, well above the expected isotopic composition of the bolide.

Discussion: The results suggest that the impact breccias from the depths sampled include only moderate to minor Os from the bolide. No samples examined are dominated by a meteoritic signature. This is consistent with both the low abundances of Os in the rocks, the suprachondritic Re/Os ratios, and the suprachondritic initial $^{187}Os/^{188}Os$ ratios. Until further data are accumulated regarding the concentrations and isotopic compositions of the impacted lithologies, absolute constraints on the proportion of the impactor can only be crudely estimated. Assuming an average $^{187}Os/^{188}Os$ ratio of 1.0 for the target rocks, consistent with the isotopic composition of modern seawater [11], the bolide component could constitute as much as 40% of the Os in the green meltrocks (less than 1% of the total mass of the rock). More likely the isotopic compositions of the target rocks were substantially lower and the percentage of bolide Os is likely <10%. The lower initial ratio of the brown breccia and higher Os concentration may suggest either a higher percentage of the bolide component, or a substantially different mix of target lithologies. Effects of subsequent alteration cannot yet be estimated, but the similarity in isotopic systematics between the closely spaced YAX-1_861.4 and 863.51 samples (combined they define a 65 Ma isochron) suggests minimal open-system behavior.

We will continue to examine drill core samples to establish the distribution of bolide Os in the impact structure. As noted, one previous study [5] has reported a generally chondritic initial $^{187}Os/^{188}Os$ for Chicxulub melt breccias, so there is the possibility that we will identify. If we find a sample that is evidently dominated by the meteoritic component we will also analyze it for the abundances of other highly siderophile elements with the hope of fingerprinting the provenance of the bolide involved [e.g. 12].

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Table 1. Rhenium and Os concentrations, and Os isotopic compositions for Chicxulub meltrocks. Initial $^{187}Os/^{188}Os$ ratios are calculated for 65 Ma using a λ for ^{187}Re of $1.666 \times 10^{-11} a^{-1}$ [13]. $\gamma_{Os(T)}$ is calculated as per [14].

Sample	Weight (g)	Re (ng/g)	Os (ng/g)	$^{187}Os/^{188}Os$	$^{187}Re/^{188}Os$	$^{187}Os/^{188}Os_I$	$\gamma_{Os(T)}$
YAX-1_841.32	0.40	0.149	0.0984	0.3316	7.469	0.320	153
YAX-1_861.4	0.73	0.081	0.0307	0.6063	13.57	0.573	353
YAX-1_861.4 (55,4)	0.11	nd	0.0285	0.5246			
YAX-1_863.51	0.72	0.036	0.0226	0.5932	8.114	0.561	343
YAX-1_876.46 (64,3)	0.12	nd	0.0175	0.3289			