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MAKING (MORE) SENSE OF DESTRUCTION – A COMPREHENSIVE GEOCHEMICAL INVESTIGATION OF CHICXULUB IMPACTITES RECOVERED DURING IODP-ICDP EXPEDITION 364.

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Introduction: In 2016, the IODP-ICDP Expedition 364 drilled into the peak-ring structure of the Chicxulub impact crater, Yucatán, recovering the near continuous core M0077A, which includes ± 130 m of suevite and impact melt rocks, and ± 610 m of granitoid basement material [e.g., 1]. The basement material is intruded by both impact melt rocks and pre-impact magmatic dikes, with the latter ranging from voluminous dolerites to rare dacites and felsites. The pre-impact lithologies have been subjected to pre-impact tectonic deformation and hydrothermal alteration and syn-impact shock-metamorphism [2]. Moreover, the entire core has been subjected to post-impact tectonic deformation and hydrothermal alteration [1,2].

This study concerns the major and trace element composition of 101 samples from core M0077A to better constrain the geochemical variation (or lack thereof) of the suevite and of the two impact melt rock units, while also characterizing the basement lithologies. This approach aims to better understand impact melt formation through the direct study of both the product (impact melt rocks and suevites) and its initial components (the pre-impact lithologies).

Sample selection and methods: We subdivide the impact melt rock section into an upper unit, which was sampled between 721.45 – 759.02 m (representing core depth), and a lower unit, sampled between 997.65 – 1334.33 m. Sample selection focused on black, macroscopically homogeneous, clast-poor lithologies. Granitoid basement material was sampled at regular intervals throughout the core between 730.29 – 1334.33 m, with a focus on isolated clasts entrained in the impact melt rock as they might reflect granitoid material that has laterally moved throughout the crater. These clasts possibly sampled a larger variety of granitoid material, allowing for more general conclusions on target rock heterogeneity. An effort was made to sample each individual pre-impact dike identified throughout the core. For comparison to other impactite material, suevite was sampled at regular intervals between 628.90 – 721.59 m. In total 29 granites, 20 (unique) pre-impact dikes, 32 impact melt rocks, 14 suevites, and 6 non-granite clasts were sampled. All data reflects bulk analyses using ICP-OES and ICP-MS on homogenized

powdered samples employing alkaline fusion to acquire total sample solution.

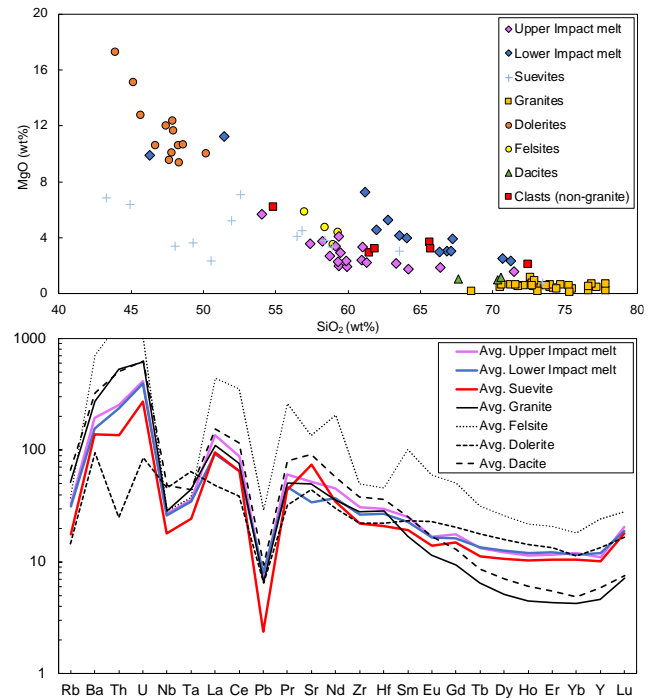


Figure 1. MgO vs SiO₂, with data recalculated on a volatile-free basis (top). CI Chondrite-normalized [3] trace element data of all reported lithologies (bottom).

Results: The granites are characterized by high SiO₂ (~70 - 78 wt%) and low MgO (< 1.5 wt%) contents (Fig. 1) and show an enriched light rare earth element signature when compared to CI chondritic composition, with most plotting above 10x CI, while heavy rare earths show values below 10x (Fig. 1). This results in strongly varying La/Yb ratios from 10 up to 50x CI (Fig. 2). Their composition is fairly homogeneous throughout the stratigraphy (Fig. 1), arguing for lateral consistency of the granites. The more mafic dolerites, with low SiO₂ (~43 - 50 wt%) and high MgO (~9 - 15 wt%) contents, display a flatter trace element pattern, between 10 and 100x CI (Fig. 1). With one exception, the La/Yb ratios are, comparatively low, not being higher than 5. The felsites and dacites are distinct from one another, with the felsites representing the more enriched lithology,

showing trace element values of around 100x CI up to 1000x and La/Yb ratios up to 30. While the dacites do show similarly high La/Yb ratios, their overall trace pattern is less enriched than the felsites (Fig. 1).

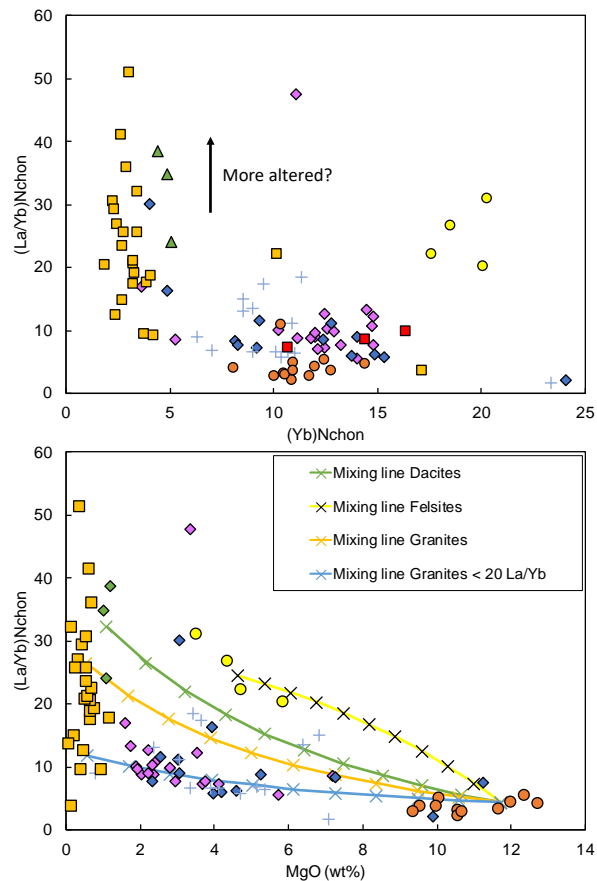


Figure 2. CI Chondrite-normalized [3] La/Yb plotted versus Yb (top) and MgO (bottom). MgO is recalculated on a volatile-free basis. Mixing lines are calculated between averaged dolerites and averaged (possible) endmembers. Symbol use as in Fig. 1.

Impact melt formation: Geochemical variations in the impact melt rocks highlight the complex nature of the impactites as a whole. This is documented in the higher Al_2O_3 (up to 18 wt%) and CaO (up to 20 wt%), and generally lower Fe_2O_3 and MgO (around 5 and 2 wt%, respectively) contents of the upper relative to the lower impact melt rocks ([4]; Fig. 1). However, the trace element compositions of both the upper and lower impact melt rocks are quite similar (Fig. 1). Interestingly, they are also comparable to those in the suevite ([4], Fig. 1,2). Slight variations, such as Sr and Ca enrichment in the suevite, likely reflect the contribution of carbonate material (i.e., as clasts and/or matrix). These variations notwithstanding, these observations suggest large scale homogenization of the Chicxulub impactite material.

Even though most trace element contents appear highly comparable, specific trace element ratios allow for better disentanglement of the impact melt components. Figure 2 shows mixing lines calculated between the dolerites and all pre-impact material. Mixing of averaged granites, felsites, and dacites with averaged dolerites, is not able to resolve the low La/Yb ratios observed in the impact melt [Fig. 2]. Only mixing between averaged granites that have < 20 La/Yb is able to explain the low ratios observed in the impact melt rocks [Fig. 2].

These observations imply one of the following scenarios: (1) The impact melt rocks represent the residue of a differentiated impact melt, recorded by the high Yb compared to La (Fig. 2); (2) An unconstrained target rock component significantly contributed to the melt that drove up Yb (to conversely decrease the La/Yb). Such contribution may derive from the non-granitic, crystalline and/or metamorphic clasts that have been documented to occur in the Chicxulub impact melt rocks ([1, 5], Figs. 1,2); (3) Alternatively, granites with La/Yb ratios of less than 20 represent less altered material, suggesting the majority of the granites to be significantly altered. Pervasive alteration has affected the Chicxulub core with Ca-Na and K-metasomatism [2] potentially compromising whole rock compositions of fluid-mobile elements (including La, Na, K). Consequently, variations in such elements might reflect alteration rather than primary magmatic signals. The observation that La/Yb ratios of the granites display variations by a factor of ~ 5 at similar Yb compositions (Fig. 2) strongly suggests that La has been remobilized, with only granites exhibiting $La/Yb < 20$ preserving primary signatures. This is also supported by La/Yb ratios plotted versus immobile elements Ti and Zr, wherein La/Yb is decoupled from variations in both elements.

Conclusions: As the characterized Chicxulub impact melt does not show evidence of crystal accumulation and various pre-impact components (dacites, felsites, and clasts) are significantly enriched in both La and Yb relative to the granites, the geochemical compositions of the impact melt rocks likely reflect mixing of mostly granitic target rock and dolerites, following an $\sim 80\% - 20\%$ contribution. Variations within the impact melt rock likely reflect local heterogeneities related to clast entrainment.

References: [1] Gulick S. P. S. et al. (2017) Exp. 364 Prelim. Rep., IODP, 38 pp. [2] Kring D. A. et al. (2017) *LPS XLVIII*, Abstract #1212. [3] Sun S-s. and McDonough W. F. (1989) *Geol. Soc., London Geol. SP.* 42, 313–345. [4] de Graaff S. J. et al. (2018) *AGU 2018*. [5] Kring D. A. (2005) *Chemie der Erde*, 65, 1–46.