

DISENTANGLING CRATERING PROCESSES USING NON-TRADITIONAL ISOTOPE RATIOS ON CORE M0077A OF THE IODP-ICDP EXPEDITION 364 IN THE CHICXULUB IMPACT STRUCTURE

Déhais, Thomas; Kaskes, Pim; De Graaff, Sietze Jan; Chernonozhkin, Stepan; Debaille, Vinciane; Vanhaecke, Frank; Claeys, Philippe; Goderis, Steven

Published in:

Large Meteorite Impacts VI 2019 (LPI Contrib No. 2136)

Publication date:
2019

Document Version:
Final published version

[Link to publication](#)

Citation for published version (APA):

Déhais, T., Kaskes, P., De Graaff, S. J., Chernonozhkin, S., Debaille, V., Vanhaecke, F., ... Goderis, S. (2019). DISENTANGLING CRATERING PROCESSES USING NON-TRADITIONAL ISOTOPE RATIOS ON CORE M0077A OF THE IODP-ICDP EXPEDITION 364 IN THE CHICXULUB IMPACT STRUCTURE. In *Large Meteorite Impacts VI 2019 (LPI Contrib No. 2136): Abstract 5106* (Vol. 6, pp. 1-2). [5106] Houston, TX: Lunar and Planetary Institute.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

DISENTANGLING CRATERING PROCESSES USING NON-TRADITIONAL ISOTOPE RATIOS ON CORE M0077A OF THE IODP-ICDP EXPEDITION 364 IN THE CHICXULUB IMPACT STRUCTURE.

T. Déhais^{1,2}, P. Kaskes^{1,2}, S. J. de Graaff^{1,2}, S. M. Chernozhkin³, V. Debaille², F. Vanhaecke³, Ph. Claeys¹, and S. Goderis¹ ¹Analytical, Environmental and Geo-Chemistry, Vrije Universiteit Brussel, Brussels, Belgium (thomas.dehais@vub.be), ²Laboratoire G-Time, Université Libre de Bruxelles, Brussels, Belgium, ³Atomic & Mass Spectrometry, Ghent University, Ghent, Belgium.

Introduction: The Chicxulub impact structure, located on the Yucatán peninsula of Mexico, has been drilled by the IODP-ICDP Expedition 364 in 2016. A continuous sequence of the upper peak-ring has been retrieved from Site M0077A. This core is from top to bottom composed of ~110 m of Paleogene sediments, ~130 m of suevite and impact melt rocks, and ~590 m of crystalline and metamorphic basement lithologies [1]. The suevite complex deposition is the result of several processes, including the fall-back of material ejected by the impact, slump and avalanches on the peak-ring, and wash-back by tsunami waves within the crater [2]. Therefore, the suevite was likely exposed to different thermodynamic processes during its deposition, as was the case for the impact melt rocks. In addition, the whole core has been the subject of severe hydrothermal alteration, potentially overprinting any primary compositional and isotopic signatures [3].

This abstract examines the Fe, Zn, and Cu isotopic composition of 27 samples from various units within core M0077A, and combines these with major and trace element data and petrographic observations. The main objectives are to disentangle the different processes affecting the various units of the upper peak-ring, such as mixing of distinct target lithologies, tracing potential volatilization or condensation effects (as observed for sulfur [4]), and determining the degree of post-impact hydrothermal alteration.

The choice of the Fe, Zn, and Cu stable isotope systems here is motivated by the relative abundance of these elements in the samples, their distribution among different mineral phases, and their difference in volatility with a 50% condensation temperature of 1334K for Fe (medium refractory), 1037K for Cu (semi-volatile), and 726K for Zn (highly volatile) [5 ; 6]. Because of these different condensation temperatures, the isotopic ratios of these elements may exhibit variations inherited from distinct thermodynamic environments and time intervals during crater formation.

Sample Selection and Methods: All data were obtained by bulk analysis on homogenized powdered samples. The isotopic compositions of Fe, Zn, and Cu were determined using MC-ICP-MS, following established ion-exchange chromatographic procedures. Major and trace element compositions were obtained using ICP-OES and ICP-MS, with total sample dissolution based on alkaline fusion of homogenized sample

powders. Particular attention was paid to the transitional interval, including five samples between 616.58 to 617.33 meters below sea floor (mbsf), suevite unit, with twelve samples between 617.34 to 721.62 mbsf, and upper impact melt interval, characterizing three samples between 721.62 to 747.02 mbsf, as these parts of the core may have been affected more strongly by distinct thermodynamic conditions. The three samples from the upper impact melt sheet range from macroscopically homogeneous black clast-poor melt rock to dark green impact melt rock (with schlieren), containing angular black melt fragments [1]. In addition, several samples have been selected from the granitoid basement material, including two granites, two dolerite dikes, one metamorphic clast, and two lower impact melt rocks from between 747.02 to 1334.69 mbsf [7].

Results: The Fe concentrations are expressed as Fe₂O₃ based on a volatile-free basis to allow comparison between the different lithological units. These Fe₂O₃ concentrations range from ~1.5 to 14 wt% throughout core M0077A [Fig. 1], with the granites exhibiting the lowest values (~1.5 wt%). All impact melt rocks and most of the suevite samples display limited variation between ~4.5 to 7 wt%. Certain suevite samples (at 617.67, 618.67, 690.59, and 704.50 mbsf) and all samples from the transitional unit fall within the range of granites and impact melt rocks. A single suevite sample at 617.35 mbsf shows a higher value of ~8.5 wt%. The highest Fe₂O₃ concentrations within core M0077A are found for the dolerite and metamorphic samples (~10.8 to 14 wt%), which are in range of the upper continental crust value (UCC) of ~11.2 wt% [8]. The Zn concentrations for all samples vary between ~2 and 85 ppm. Suevite samples, granite, and metamorphic samples range from ~2 to 50 ppm. The Zn concentrations in the impact melt rock vary from ~25 to 75 ppm. The dolerite dikes record the highest concentrations up to ~85 ppm. Additional measurements for the samples of the transitional and suevite units are in progress.

All stable isotope ratios for Zn and Fe vary according to a mass-dependent relation. Consequently, the various stable isotope ratios for a single element show similar trends. Therefore, only the $\delta^{56/54}\text{Fe}$ and $\delta^{66/64}\text{Zn}$ results are discussed in this work [Fig. 1]. The Cu results have so far only been obtained for a fraction of the samples, and are the subject of additional analyses.

The $\delta^{56/54}\text{Fe}$ fall within a narrow range of -0.1 to 0.2‰ throughout core M0077A, similar or close to the values obtained for the BHVO-2 reference basalt (~0.11‰) and are in range of the values typically obtained for the upper continental crust [9]. More strongly fractionated values are measured in the transitional unit ($\delta^{56/54}\text{Fe}$ down to -0.95‰) and the top part of the suevite ($\delta^{56/54}\text{Fe}$ down to -0.34‰). Similarly, the Zn isotope ratios exhibit limited variation in the core ($\delta^{66/64}\text{Zn}$ between ~0.1 and 0.4‰), comparable to the value of ~0.3‰ obtained for BHVO-2 and in range of UCC values [10]. Compared to Fe, only few samples exhibit fractionated values. These samples are different from those displaying isotopic deviations for Fe. The black impact melt rock displays $\delta^{66/64}\text{Zn}$ of -0.5‰. This is distinct from the values of the green schlieren, which fall within the range of 0.34 to 0.42‰. A metamorphic clast at 1252.33 mbsf displays a positively fractionated $\delta^{66/64}\text{Zn}$ value of 0.9‰, which is also observed for a single sample from the transitional unit at 617.04 mbsf with $\delta^{66/64}\text{Zn}$ of 0.82‰. Four suevite samples from 649.94 to 675.91 mbsf display gradually increasing $\delta^{66/64}\text{Zn}$ from ~0.0 to 0.4‰ with decreasing core depth.

Discussion: For both Fe and Zn, the isotopic compositions of most samples are in range of UCC values. This is the case for all main units within the core M0077A, including the transitional unit, the upper peak-ring sequence (suevite and upper impact melt rocks), and the lower peak-ring sequence (granitoid basement and dikes, and lower impact melt rocks).

However, there is still some isotopic heterogeneity preserved within the core, likely driven by distinct lithological or mineralogical carriers. In the case of the transitional unit, the negative $\delta^{56/54}\text{Fe}$ values down to -1‰ corresponds to a pyrite interval at ~616.54 mbsf.

Microbially reduced pyrite formed in normal marine conditions is known to exhibit fractionated values with respect to the host sediment [11]. This may indicate a different formation history for the pyrite at very top of the impactite section relative to that found elsewhere in the core.

The negatively fractionated isotopic Zn value of the black melt sample at 738.03 mbsf relative to two samples with green schlieren (showing ~50% and ~100% schlieren) with normal $\delta^{66/64}\text{Zn}$ suggest a hydrothermal overprint. The positively fractionated suevite sample at 617.04 mbsf may indicate a large metamorphic contribution to this particular sample.

Conclusions: Possible hints of volatilization or condensation in the M0077A core of the Chicxulub impact event appear to be overprinted by post-impact hydrothermal alteration. Nevertheless, the stable isotope signatures of Fe, Zn, and Cu may still contribute unique information related to the emplacement of the various impactite units. The Fe and Zn isotope ratios uniquely detect the admixture of distinct target lithologies within particular units. Further isotopic analyses on 10 additional samples selected throughout core M0077A will allow a complete overview and will further develop these initial results.

References: [1] Morgan J. et al. (2017) *Proceedings of the International Ocean Discovery Program*, 364. [2] Ormö J. et al. (2018) *LPS XLIX*, Abstr. #1221. [3] Kring D. A. et al. (2017) *LPS XLVIII*, Abstr. #1212. [4] Kaskes P. et al. (2019) *LMI VI*, Abstr. [5] Lodders K. (2003) *ApJ*, 591, 1220-1247. [6] Allègre C. et al. (2001) *EPSL*, 185, 49–69. [7] de Graaff S. J. et al. (2019) *LMI VI*, Abstr. [8] Rudnick R. L. and Gao S. (2004) *The Crust, 3, Treatise on Geochemistry*. [9] Heimann A. et al. (2008) *GCA*, 72, 4379-4396. [10] Pons M.-L. et al. (2013) *Geobiology*, 11, 201-214. [11] Craddock P. R. and Dauphas N. (2011) *EPSL*, 303, 121-132.

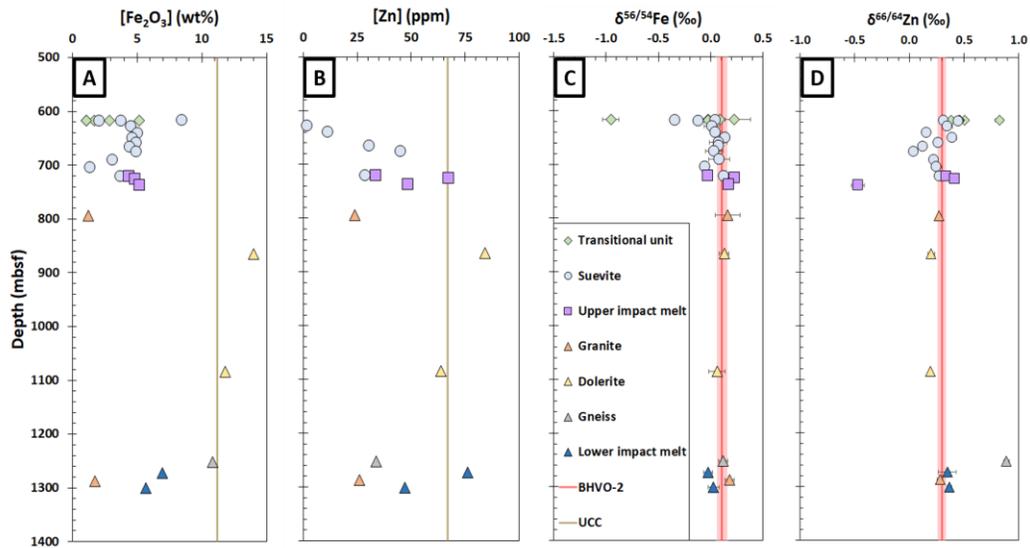


Figure 1. (A) $[\text{Fe}_2\text{O}_3]$ on a volatile-free basis, (B) $[\text{Zn}]$, (C) $\delta^{56/54}\text{Fe}$, and (D) $\delta^{66/64}\text{Zn}$ vs depth (2 σ uncertainty).