Uranium isotope evidence for extensive seafloor anoxia after the end-Triassic mass extinction

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Introduction

- End-Triassic extinction (ETE) is one of the „Big Five" extinctions
- Central Atlantic Magmatic Province (CAMP) volcanism led to ecosystem collapse
- Proximal cause of the extinction is debated

Objectives

- Generating a new uranium isotope dataset across the Triassic-Jurassic boundary
- Earth system modelling to understand the role of anoxia in triggering the extinction and delaying the subsequent biotic recovery

$\delta^{238}U$ system

- Paleoredox proxy measured in limestone
- $\delta^{238}U$ is uniform in the ocean – information on the global seafloor redox condition (not the local basin)
- Reconstruction of proportion of seafloor under anoxic conditions and its temporal changes

Study area

- Csővár basin, Hungary
- Continuous section across the Triassic-Jurassic boundary (TJB)
- Uniform lithology
- Well studied section (bio- and cyclostratigraphy)

Preservation of global $\delta^{238}U$ signal

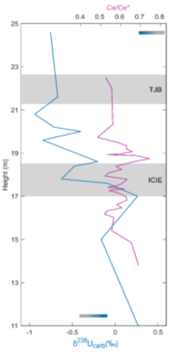

Fig. 2. Uranium isotope and Ce/Ce* data from the TJB interval of the Csővár section.

- Ce anomaly indicates oxygenated conditions in the Csővár basin and the preservation of global U signal

- In both the Csővár section and the Lombardian sections (Jost et al. 2017) a negative uranium isotope anomaly was detected below the TJB indicating a global $\delta^{238}U$ signal

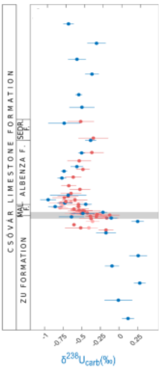

Fig. 3. Uranium isotope data of the Csővár section (blue) and the Val Adrara-Italcementi sections (red, Jost et al. 2017).

Results and discussion

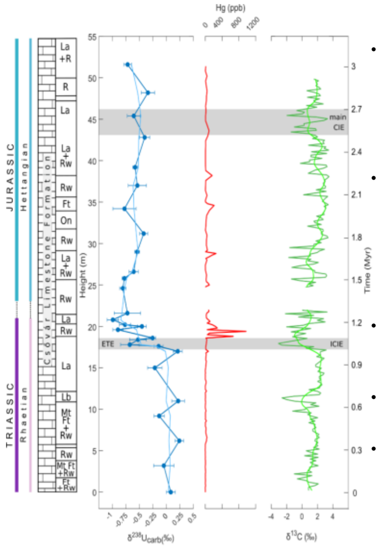

Fig.1. Uranium isotope, mercury (Kovács et al., 2020), and carbon isotope data (Kovács et al., 2020) from the Csővár section.

- A major negative uranium isotope anomaly was detected immediately below the Triassic-Jurassic boundary indicating widespread anoxia
- The $\delta^{238}U$ anomaly coincides with the previously detected carbon isotope anomaly and Hg peaks, which are associated with the volcanism of the CAMP and mark the extinction horizon
- Cause and effect relationship between volcanism, anoxia and extinction
- The $\delta^{238}U$ values remain low throughout the Hettangian
- The Hettangian is marked by further minor Hg-peaks and negative carbon isotope anomalies

Earth system modeling

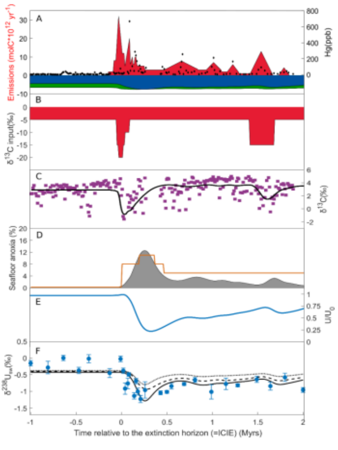

Fig. 4. Modeling of anoxia as a consequence of CAMP volcanism. (*A*) Estimated odel forcing carbon input (red peaks); calculated removal rates due to silicate weathering (green) and marine organic carbon burial (blue). (*B*) Estimated $\delta^{13}C$ composition of carbon input. (*C*) Modeled $\delta^{13}C$ curve (black solid line) (*D*) Estimated extent of seafloor anoxia based on the C-P-U model (grey) and U-cycle box model (orange line). (*E*) Calculated response of marine U-cycle (*F*) Modeled evolution of $\delta^{238}U_{sw}$ using different $\Delta^{238}U_{anox.}$ estimates (black lines).

- The coupled behaviour of carbon, phosphorus and uranium cycles after volcanic carbon emissions were modelled
- Constrained by astrochronological age model of the section (Vallner et al. 2023)
- Anoxia reached its maximum extent (13%) 200–250 kyr after the extinction
- The extent of seafloor anoxia remained high (1–6%) throughout the Hettangian

Methodology

- NEPTUNE Plus™ MC-ICP-MS instrument
- Institute for Nuclear Research (ATOMKI), Debrecen
- Good external reproducibility: modern seawater standard gave a mean $\delta^{238}U$ value of −0.409 142 ± 0.029‰

Conclusions

- Marine anoxia was likely developed as a consequence of CAMP activity and subsequent volcanic pulses are responsible for protracted anoxia
- Our geochemical and modelling results suggest that marine anoxia played a key role in hindering the biotic recovery after the end-Triassic extinction

References

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