Record of the end-Triassic mass extinction in shallow marine carbonates: the Lorüns section (Austria)

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Introduction

The Earth has experienced five major mass extinctions during the Phanerozoic. The end-Triassic Extinction (ETE) (~201 Ma ago) involved a series of climate and environmental changes as well as faunal extinction of both marine and terrestrial taxa. The most likely cause for the ETE was the massive eruptions of the Central Atlantic Magmatic Province (CAMP), linked to the break-up of the Pangea supercontinent. However, the chain of events leading to the mass extinction is still under debate. The most cited hypotheses are cooling, warming, strong regression, acidification of the ocean due to the increased CO_2 or poisoning through mercury or metal ions. Most of the well-known marine records from this time period in the Northern Calcareous Alps are from deeper marine sediments, since the strong regression eroded most of the shallow sections. The Lorüns section from the Austrian Alps is an exception. This shallow marine section shows continuous sedimentation from the latest Triassic until the early Jurassic. To better study the recovery from the ETE the earliest Jurassic formation called the Lorüns oolite is of certain interest. This formation contains large amounts of ooids and other coated grains, which offer a peculiar window into the seawater chemistry during the aftermath of the extinction.

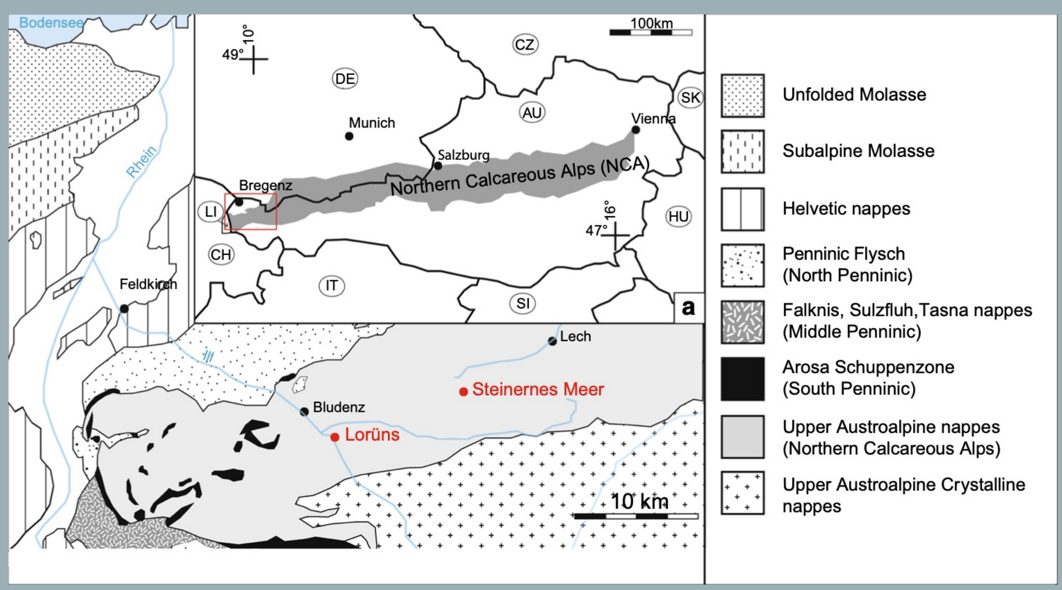


Figure 1. Location of the Lorüns quarry near the town of Bludenz in the Northern Calcareous Alps, Austria. Map from Felber *et al.* (2015).

Aim

The aim of this study is to reconstruct the palaeoenvironmental conditions during the time of deposition of the Lorüns section with petrographic and geochemical analyses. Comparison of the results with previous studies on the ETE conducted in the Arab Emirates will reveal whether the observed changes were globally similar.

Methods

71 whole-rock samples from the Lorüns section were picked in the field. From these, 36 thin-sections were produced for analysing the lithologies and their fossil content. Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analyses were performed on 6 thin sections. Elements useful for assessing palaeoenvironmental conditions e.g. bulk composition of the carbonates (Mg, Sr), weathering proxies (Al, Ti, Si), bioctivity markers (P, Ba) or redox proxies (Ce, U) were analysed. From the thin sections used for LA-ICP-MS we picked 52 spots which were divided into the following categories: coated grain nuclei (14 spots), coated grain cortices (20 spots), cement (4 spots), matrix (6 spots), bivalves (3 spots) and echinoderms (5 spots). After the measurements the data were processed using the *Iolite* Software and further analysed in *Microsoft Excel*.

Elemental analysis with LA-ICP-MS

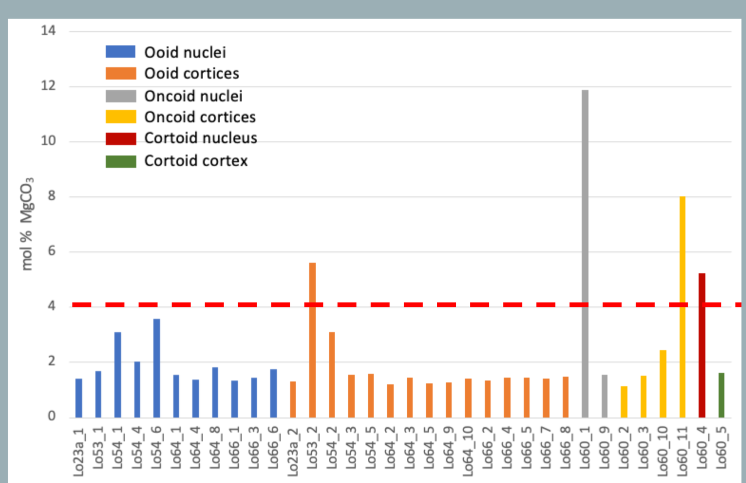


Figure 7. Mol% $MgCO_3$ in coated grains from the Lorüns section. The samples are presented for each coated grain in stratigraphic order from left to right. Low-Mg calcite has <4 mol% $MgCO_3$ (red line). Most coated grains are composed of low-Mg calcite, which is consistent with studies from the Arab Emirates. The values >4 mol% are attributed to slight dolomitisation that was observed in some of the thin sections (Fig. 6c).

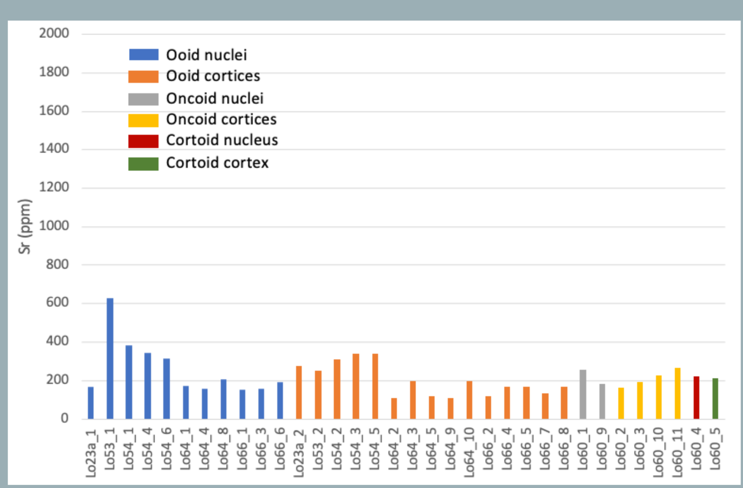


Figure 8. Sr (ppm) in coated grains from the Lorüns section. The samples are presented for each coated grain in stratigraphic order from left to right. Sr^{2+} can easily substitute for Ca^{2+} in aragonite. High Sr values can indicate occurrence of an aragonite precursor even if the aragonite has been recrystallised in calcite. Sr values are consistently low for the coated grains, indicating a probable deposition as low-Mg Calcite.

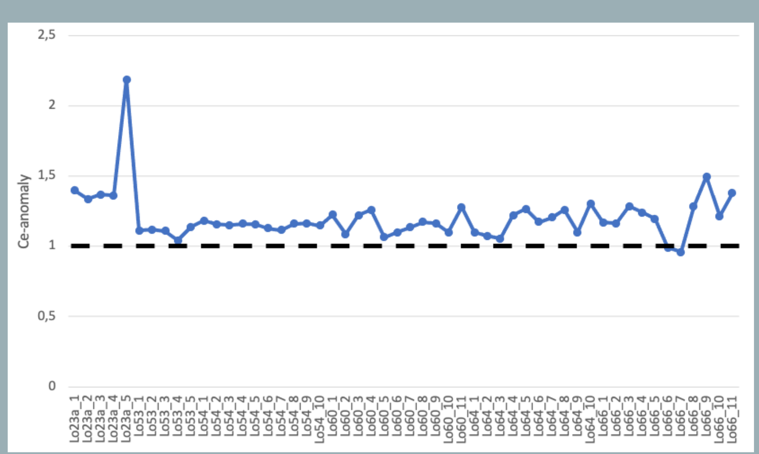


Figure 9. The Ce-anomaly for all spots analysed with LA-ICP-MS at Lorüns. The samples are presented in stratigraphic order from left to right. If the anomaly is >1 (black line) the environment is oxygenated and if the anomaly is <1 the environment is more dysoxic. All analysed spots show values above or close to 1, which means that conditions were oxygenated during and after the ETE. U, Mo, and V are other redox proxies, which are confirming this observation.

Stratigraphy

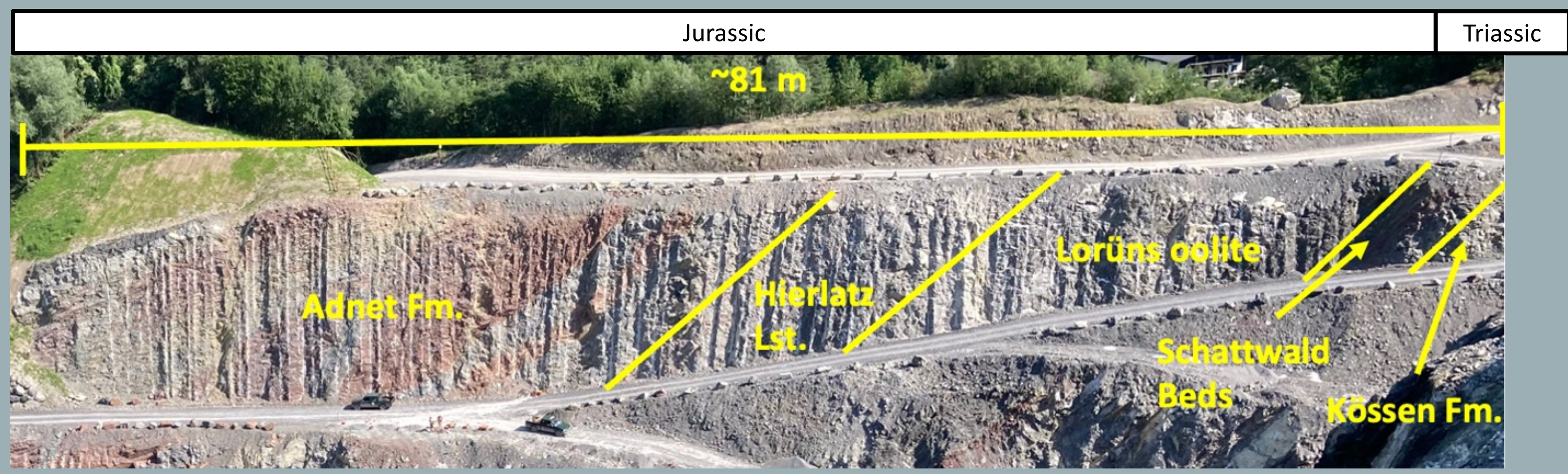


Figure 2. Picture of the Lorüns section in the active Lorüns quarry, Austria with indicated stratigraphy and geologic periods. Samples were taken from all formations.

Pre-extinction

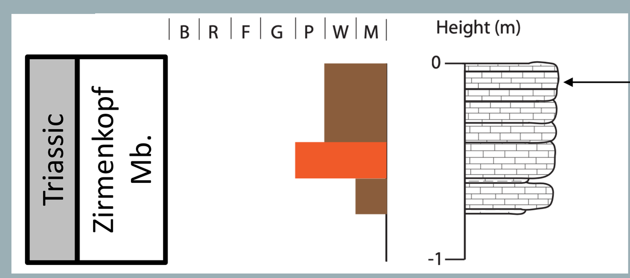
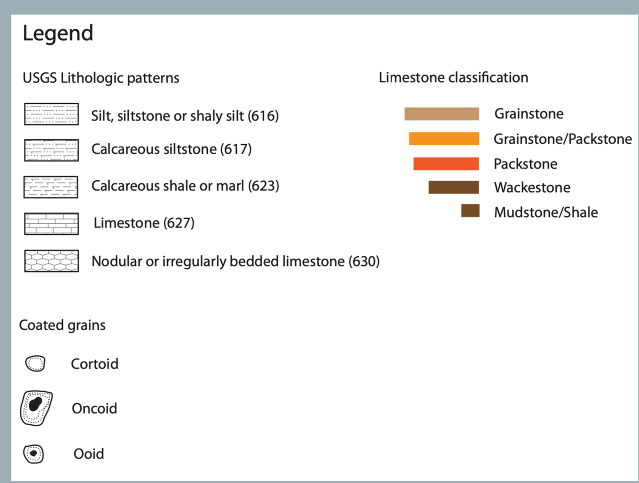


Figure 3. Log of the late Triassic Kössen Formation. The formation consists mostly of a wackestone with a rich fossils diversity.



Explanation for letters in Fig. 3-5

a) Wackestone
b) Bivalve packstone
c) Coated bioclastic packstone
d) Oolite packstone
e) Oncoid packstone
f) Oolite grainstone

Extinction/Recovery

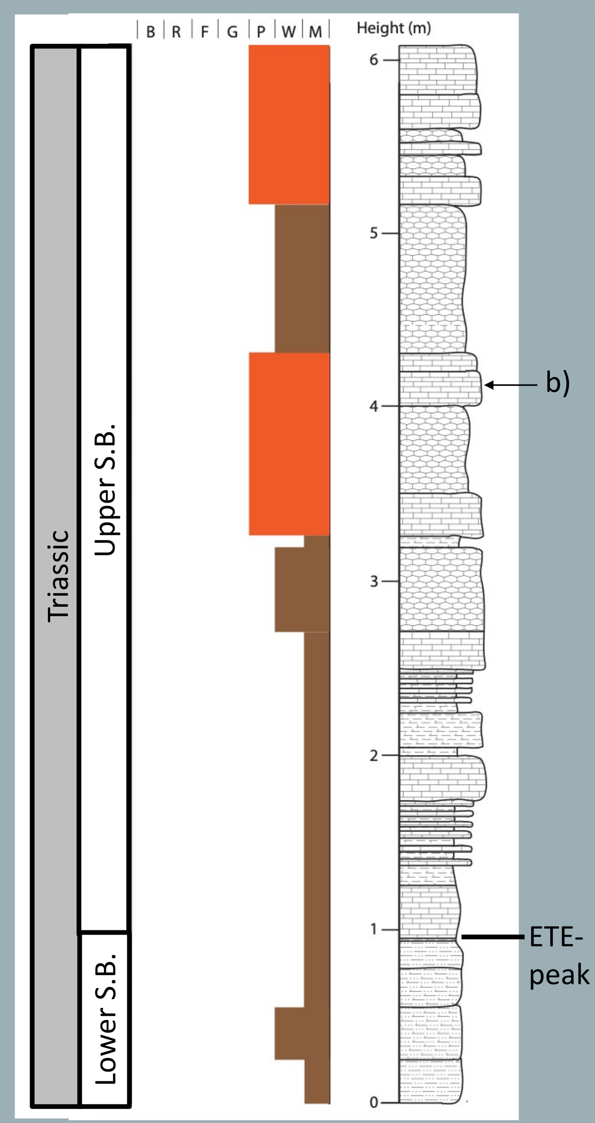


Figure 4. Log of the late Triassic Schattwald Beds (S.B.). The base of the Lower Schattwald Beds records a shift towards siliciclastic sedimentation with rarely occuring fossils. The "ETE-peak" is located in the topmost part of this unit. Carbonate sedimentation resumes in the Upper Schattwald Beds.. The Upper Schattwald Beds are coarsening-upward from mudstone to packstone and show an increase in fossils upsection.

Recovery

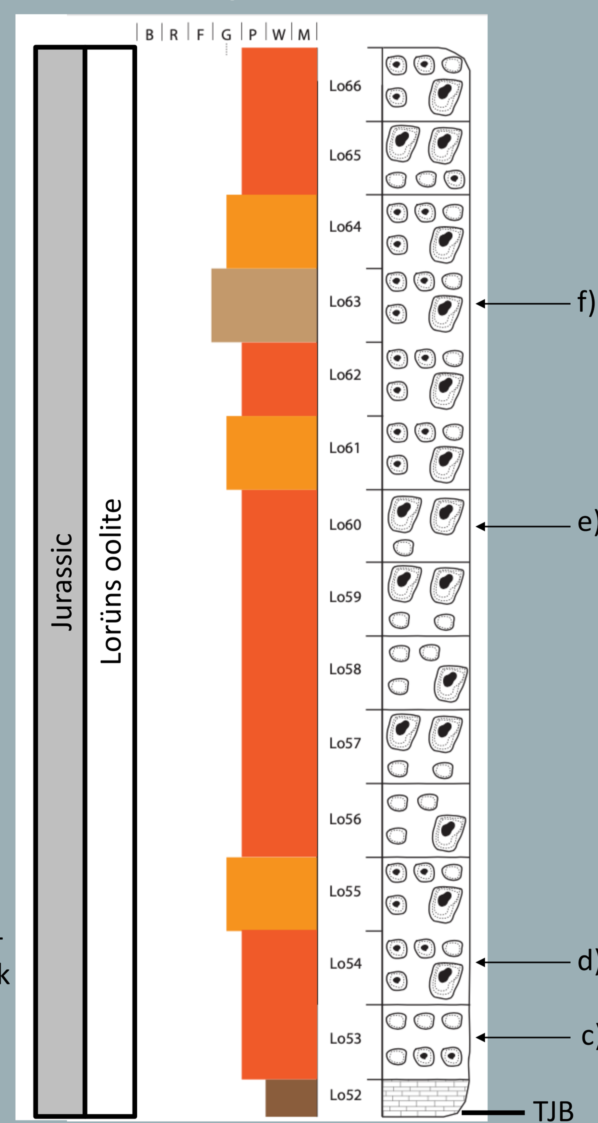


Figure 5. Log of the early Jurassic Lorüns oolite. This is a massive unit marked by regular shifts between more ooid-dominated grainstone/packstone and oncoid-dominated packstone. The log shows the dominating coated grains from the analysed samples. Fossils occur but are more rare than coated grains.

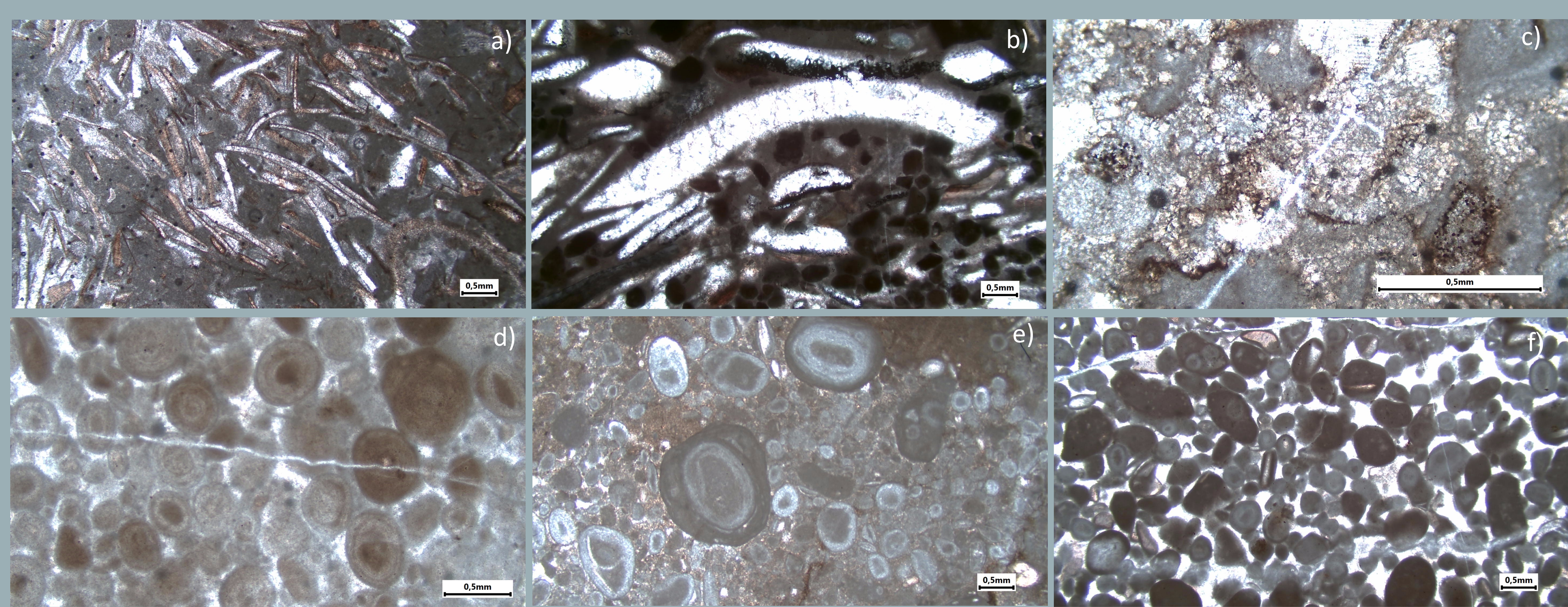


Figure 6. Pictures from some of the thin sections from Lorüns. Stratigraphic positions are indicated in the figures 3-5. a) Wackestone with bivalve fragments and sponge spicules. b) Bivalve packstone. c) Dolomitisation in coated bioclastic packstone. d) Oolite packstone, with micritised ooids. e) Oncoid packstone, containing oncoids and cortoids. f) Oolite grainstone, with micritised ooids.

Conclusions

- The lithology of the Lorüns oolite shifts between an ooid-dominated grainstone/packstone and an oncoid-dominated packstone. Usually the samples contain several different types of coated grains.
- The coated grains were deposited as low-Mg calcite just after the ETE at Lorüns. This is supported by low mol% $MgCO_3$ and low Sr values in the coated grains as well as petrographic observations. Studies from the Arab Emirates also indicate a deposition as low-Mg calcite for the same time interval, which means that this could have been global.
- Dolomitisation, observed in thin sections, might explain why some coated grains exceed the threshold value of low-Mg calcite of 4 mol% $MgCO_3$.
- Following the model of Hardie (1996) and Stanley & Hardie (1998), the Upper Triassic and lowermost Jurassic should be an "aragonite sea", with a deposition of ooids mainly in aragonite. Our study is thus in contradiction with this model.
- The peculiar seawater chemistry just after a major mass-extinction could explain this discrepancy, with large amount of Ca^{2+} not bioprecipitated.
- The Ce-anomaly is nearly always >1, which means that the sea was oxygenated in Lorüns during and after the ETE.

References

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