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An evaluation of inoceramid single-prism sclerochronology

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ABSTRACT

Inoceramid prisms are among the most common microfossils that can be found in Late Cretaceous strata. Since these biomineral units were formed by sequential accretion in the outer shell layer of the bivalves, they potentially serve as archives of short-term (circa-annual) paleowater temperature fluctuations. In the present study, we tested to what extent intra-prismatic stable isotope variations of individual inoceramid prisms reflect sub-annual $\delta^{13}C$ and the $\delta^{18}O$ patterns. We obtained multiple carbonate samples from prisms recovered from the sediment and from a cross-sectioned inoceramid shell fragment and compared data from these samples to data from classical sclerochronological sampling (i.e., sequential drilling). The analyzed shell material belonged to the species *Platyceramus platinus* from the Smoky Hill Chalk Member (Niobrara Formation, Kansas, USA). Scanning electron microscopy (SEM) was used to evaluate the diagenetic alteration of the studied prisms and allowed to identify suitable material for stable isotope analyses. The $\delta^{18}O$ values of drilled carbonate samples ($\delta^{18}O_{Drill}$) and of prisms ($\delta^{18}O_{IP}$) compare very well to each other when temporally aligned ($R^2 = 0.98$). The stable carbon isotope values ($\delta^{13}C_{Drill}$; $\delta^{13}C_{IP}$), however, show less agreement ($R^2 = 0.28$), which is likely attributable to different time-averaging of the samples. We discuss how to identify the most suitable prisms for sub-annual paleotemperature reconstructions from disarticulated material using microgrowth patterns and geometrical features of the prisms as proxies for changing growth rates. Finally, we apply the novel sampling strategy to naturally occurring disarticulated prisms from the sediment and compare their intra-prismatic isotope values ($\delta^{13}C_{IPS}$ and $\delta^{18}O_{IPS}$) to those of bulk-analyzed prism fragments from the sediment ($\delta^{13}C_{BPS}$ and $\delta^{18}O_{BPS}$). Sclerochronological analysis of the prisms from the sediment yields $\delta^{18}O_{IPS}$ fluctuations of 1.89‰, virtually identical to the $\delta^{18}O_{IP}$ chronologies of the prisms extracted from the shell cross-section (1.90‰). The overall ranges of the $\delta^{18}O_{IP}$ and $\delta^{18}O_{IPS}$ values are identical (2.60‰) and capture very well the expected seasonal stable oxygen isotope oscillation derived from the $\delta^{18}O_{Drill}$ values (2.61‰). The range of the $\delta^{18}O_{IPS}$ data is two-fold larger than that of the $\delta^{18}O_{BPS}$ values (1.19‰), suggesting a strong effect of time-averaging on the stable oxygen isotope data of the bulk-analyzed prisms fragments. According to our novel statistical model, the resolution of $\delta^{18}O_{BPS}$ data can be increased by preferentially analyzing short (ca. 300 µm) individual prisms fragments (at least n = 20).

1. Introduction

Inoceramids were among the most abundant bivalve taxa of the Late Cretaceous macrofauna, inhabiting nearly all benthic marine environments from very shallow waters (e.g., Wagreich et al., 2010; Kumagae et al., 2011) to bathyal depths (e.g., MacLeod et al., 1996; Crampton, 2004), and their remains can be found in strata worldwide. Because of their widespread distribution, shells of inoceramids represent an extraordinary geochemical proxy archive for paleoclimate studies. Recent sclerochronological works have also shown the potential of this archive for stable carbon and oxygen isotope-based sub-seasonally to inter-annually resolved reconstruction of environmental variability (Jiménez Berrocoso et al., 2008; Walliser et al., 2018). The recovery of suitable shell material for sclerochronological analysis, however, can be sometimes difficult, because inoceramid shells were particularly prone to fragmentation during taphonomy (e.g., MacLeod and Orr, 1993). The outer shell layer (OSL) of inoceramids is composed of tightly packed, polygonal, LMC (low-Mg calcite) biomineral units (i.e., prisms) of about 100 µm in diameter (Fig. 1). Each prism was enveloped by a proteinaceous organic matrix which acted as an adhesive component for the entire shell (e.g., Zuschin et al., 2003) (Fig. 1C). Because of the decay of the organic matrix during taphonomy (Clark, 1999), inoceramid shells lost coherence, thereby promoting fragmentation and, ultimately, complete disaggregation into thousands to millions of individual prisms

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