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Palaeoenvironmental changes in the northwestern Tethys during the Late Campanian *Radotruncana calcarata* Zone: Implications from stable isotopes and geochemistry

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ABSTRACT

This paper investigates the palaeoceanographic setting and evolution of two biostratigraphically well constrained Upper Cretaceous sections in the Eastern Alps of Austria. The duration of the investigated time interval is confined by the total range zone of *Radotruncana calcarata* which was a very short lived (806 000 yrs) species as calibrated using orbital parameters. This results in a precise time frame for paleoenvironmental interpretations within this interval. Stable isotope stratigraphy links both sections to published records. The two studied sections are located at the passive (northern) margin of the European Foreland and at the active (southern) margin of a northwestern Tethys ocean branch, respectively. We use mineralogy, clay mineralogy, element geochemistry, carbonate-associated elements and element ratios, Sr isotope stratigraphy and stable C and O isotopes to characterize the profiles. Mn/Sr ratios as well as stable C and O isotopes indicate that the sediments are largely diagenetically unaltered. Both sections have a similar history concerning their sea-level evolution, i.e. a gradual third-order regression with short fourth-order transgressive intervals. The inferred water temperature increases at both locations and the overall primary production and nutrient availability increased slightly with time. Predominately suboxic conditions are confined to the southern profile and were interrupted by oxic spells of ~50 kyr duration and even shorter periods of increases in primary production. We also found evidence of a strong aeolian influence on the cyclic deposition of marl–limestone couplets in the southern profile.
The similar history at both geodynamic settings indicates that the southern block close to the subduction zone was relatively stable for the duration of *R. calcarata* total range zone.

1. Introduction

The Late Cretaceous was a time of accelerated evolution of climate and palaeoceanographic changes starting from the mid-Cretaceous super-greenhouse (hothouse) world to the Paleogene transition into icehouse conditions. Within this long-term evolution the Campanian marks a time of subtle but significant climate oscillations during the major cooling trend from the Cenomanian–Turonian hothouse into cooler greenhouse conditions (e.g. Barrera and Savin, 1999; Li et al., 1999, 2000; Pucéat et al., 2003; Hay and Floegel, 2012; Linnert et al., 2014).

In this article we compare two coeval and chronostratigraphically well-constrained pelagic marl sections using elemental geochemistry including carbonate-associated elements and oxygen and carbon isotopes. Both sections cover the total range zone (TRZ) of *Radotruncana calcarata* in the Late Campanian. Due to the fine-grained nature of the sediments at both locations we did not apply conventional sedimentological methods but examined variations in carbonate content, mineralogy, total organic carbon (TOC) as well as elemental and stable isotope changes. The astronomically refined biostratigraphic framework (Wagreich et al., 2012, 2014) established for the two sections allows to correlate palaeoclimate and palaeoceanographic changes at high-resolution during a short (<1 myr) time interval of the Late Cretaceous.

The Oberhehenfeld section is located at the northern (passive) margin of the western Tethys (i.e. Penninic Ocean or Alpine Tethys, Fig. 1a). The Postalm section is located at the south, close to the former active margin of the Austroalpine microplate. This section was described in detail by Wagreich et al. (2012) with a focus on orbital signals which constrain the duration of the *R. calcarata* TRZ. The Campanian is the period

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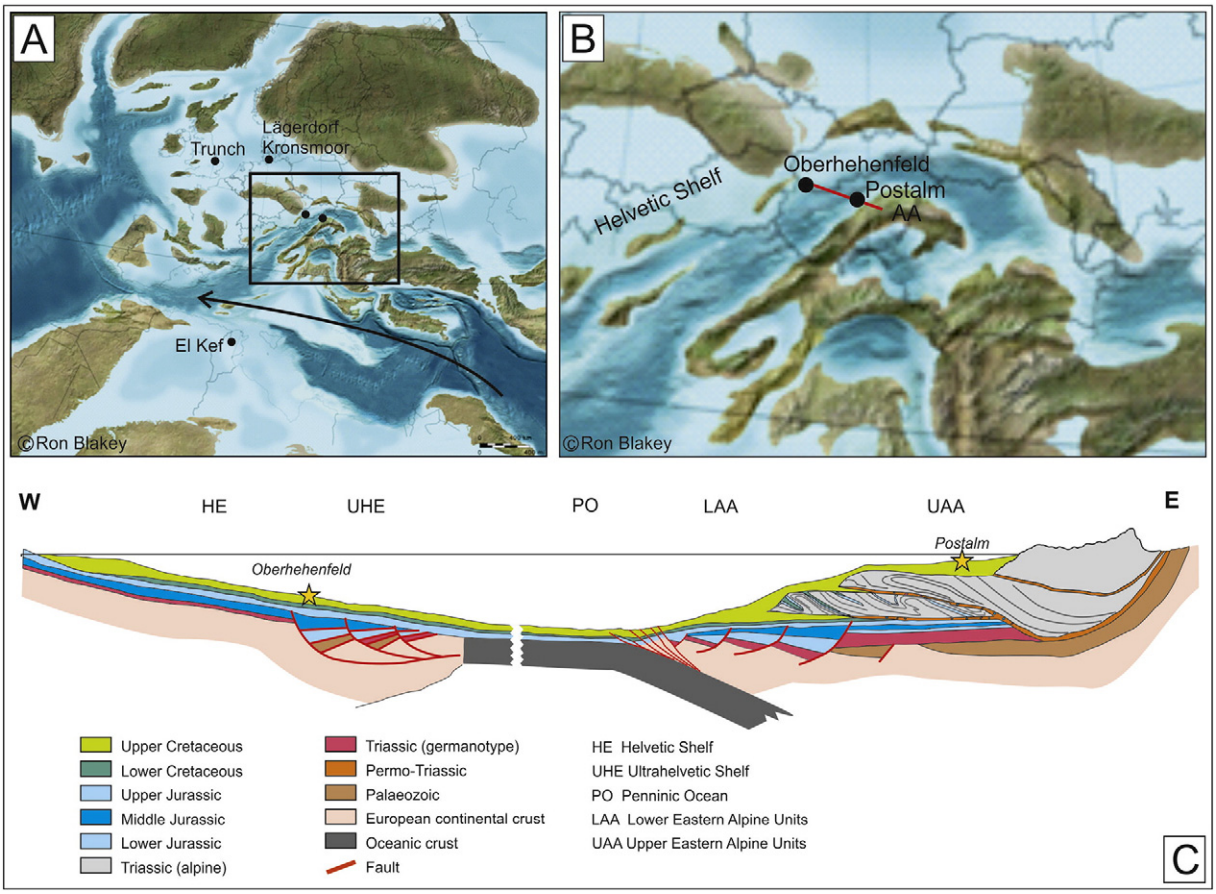

Fig. 1. A Paleogeographic setting (source: http://cpgeosystems.com/paleomaps.html) showing the locations of the Oberhehenfeld and Postalm profiles, as well as of other sites mentioned in the text. Arrow indicates dominant paleocurrent direction (Pucéat et al., 2005). B close-up of Alpine Tethys region. C Schematic cross section of the Alpine Tethys/Penninic Ocean (HE: Helvetic shelf, UHE: Ultrahelvetic passive margin, PO: Penninic Ocean, LAA: Lower Austroalpine, UAA: Upper Austroalpine units including the Northern Calcareous Alps, light green: Cretaceous sediments; Penninic Ocean not to scale; modified after Mandl, 1999 and Egger and VanHusen, 2011).

of most widespread deposition of Cretaceous Oceanic Red Beds (CORBs, e.g. Hu et al., 2005) which occur at both Tethyan margins of the Eastern Alps (Wagreich and Krenmayr, 2005; Neuhuber and Wagreich, 2009), including the Postalm section.

1.1. Palaeogeography

The two investigated sections were situated at opposite margins of the northernmost branch of the Tethys (Alpine Tethys of Stampfli et al., 2002; Penninic Ocean of Faupl and Wagreich, 2000). Following a palaeogeographic north–south transect that starts at the (former) European passive margin and terminates at the (former) Austroalpine active margin we find following Campanian successions within the Alps (Fig. 1):

The stable European foreland (Bohemian Massif) is characterized by a basement of metamorphic and magmatic rocks. Sediments at the proximal Helvetic (European) shelf are silty and sandy marls and muds and micritic limestones (Föllmi, 1989). The Ultrahelvetic unit was originally located to the south of the Helvetic shelf at the northwestern margin of this ocean (Fig. 1) and consists of pelagic, fine-grained limestone and marl. Distal and deeper settings to the south of the Ultrahelvetic units (Rhenodanubian Flysch Zone) record widespread deposition of calcareous and siliciclastic turbidites below the calcite compensation depth, and include red claystones of Cretaceous Oceanic Red Beds (Egger and Schwerd, 2015). At the same time pelagic marl–limestone successions and slope turbidites were deposited at the active Austroalpine margin to the south (Gosau Group, Wagreich and Krenmayr, 2005) up to Romania (Melinte and Jipa, 2005), at a palaeolatitude of ca. 30° N (Wagreich and Faupl, 1994). This unit rests unconformably on thrusted Triassic and Jurassic carbonate rocks of the Northern Calcareous Alps nappe system.

South of the Austroalpine and South Alpine realms coeval sediments from the southern Tethys margin (Fig. 1A) and the North African shelf record a zone of high primary production located at the (Cretaceous) equator (Edelmann-Fürstenberg, 2008). Here upwelling is documented by the presence of phosphorites and black shales (Luning et al., 2004) with highest phosphate accumulation rates during the middle Campanian (~75 Ma) and low sediment accumulation rates (Soudry et al., 2006).

The ocean circulation was dominated by a strong E–W current in the central Tethys (Poulsen et al., 1998; Pucéat et al., 2005).

Our two time-equivalent sections at Oberhehehenfeld and Postalm are located at the Ultrahelvetic passive margin and at the Austroalpine active margin (Gosau Group). Before the onset of Alpine collision, the two sections were 400–1000 km apart (e.g. Handy et al., 2010, see Fig. 1A).

1.2. Geologic setting

The Oberhehenfeld section is located in a small valley (Schönbachgraben) east of Lake Attersee, south of Seewalchen (coordinates WGS84 13° 38′ 09″ E; 47° 55′ 19″ N). An Upper Cretaceous succession of gray and red marls and marlstones crops out along the banks of Schönbach creek (Hradecká and Lobitzer, 2003). The succession is part of a tectonic window of Ultrahelvetic rocks within the Rhenodanubian Flysch Zone. Ultrahelvetic marls and marlstones are referred to as “Buntmergelserie” (variegated marls; Geological Map of Austria 1:50.000; sheet 66, Gmunden, Egger, 1996, 2007). The Santonian to