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Sedimentary organic matter characterization of the Triassic–Jurassic boundary GSSP at Kuhjoch (Austria)

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ABSTRACT

The Triassic–Jurassic (T–J) boundary interval coincides with enhanced extinction rates in the marine realm and pronounced changes in terrestrial ecosystems on the continents. It is further marked by distinct negative excursions in the $\delta^{13}C_{org}$ and $\delta^{13}C_{carb}$ signature that may represent strong perturbations of the global carbon cycle. We present integrated geochemical, stable-isotope and palynological data from the Kuhjoch section, the Global boundary Stratotype Section and Point (GSSP) for the base of the Jurassic (Northern Calcareous Alps, Austria). We show that the initial carbon isotope excursion (CIE), coinciding with the marine extinction interval and the formation of black shales in the western Tethys Eiberg Basin, is marked by only minor changes in kerogen type, which is mainly of terrestrial origin. Increased Total Organic Carbon (TOC) concentrations of 9% at the first half of the initial CIE coincide with Hydrogen Index (HI) values of over 600 mg HC/g TOC. The high correlation (with $R^2 = 0.93$) between HI values and terrestrial Cheirolepidiaceaen conifer pollen suggests a terrestrial source for the hydrogen enriched organic compounds. The lack of major changes in source of the sedimentary organic matter suggests that changes in the $\delta^{13}C_{org}$ composition are genuine and represent true disturbances of the global C-cycle. The sudden decrease in total inorganic carbon (TIC) concentrations likely represents the onset of a biocalcification crisis. It coincides with a 4.5‰ negative shift in $\delta^{13}C_{org}$ values and possibly corresponds to the onset of CAMP related volcanic activity. The second half of the initial CIE is marked by the dramatic increase of green algae remains in the sediment. The simultaneous increase of the C_{org}/N_{tot} ratio suggests increased marine primary production at the final stage of black shale formation.

1. Introduction

Large fluctuations in Mesozoic and Palaeozoic climate are often linked to widespread deposition of organic carbon rich sediments along continental margins (Negri et al., 2009). The deposition of black shales at the T–J boundary interval has been reported from the Panthalassic and Tethys Ocean (Hallam, 1995; Wignall et al., 2007; Bonis et al., in press). This important interval in Earth history is marked by elevated extinction rates in the marine realm (Raup and Sepkoski, 1982) and marked changes in continental ecosystems (McElwain et al., 1999; Olsen et al., 2002; Tanner et al., 2004; Bonis et al., 2009). Two distinct negative carbon isotope excursions (CIEs) at the T–J boundary interval have been attributed to major disturbance of the global carbon cycle (Hesselbo et al., 2002) that may be linked to the onset of Central Atlantic Magmatic Province (CAMP) volcanism (Marzoli et al., 1999, 2004). Negative CIEs at the T–J transition interval have been documented in both the marine (e.g. Hesselbo et al., 2002; Ward et al., 2004; Pálfy et al., 2007; Ruhl et al., 2009) and terrestrial realm (McElwain et al, 1999; Hesselbo et al., 2002). The short-lived "initial" CIE concurs with the major end-Triassic biotic turnover and is separated from the longer-lived "main" CIE by a return to Rhaetian base values (Hesselbo et al., 2002). The onset of the main CIE coincides with the base of the Jurassic, which is defined by the first occurrence of the *Psiloceras spelae* ammonite species (Hillebrandt et al., 2007; Ruhl et al., 2009) (*Psiloceras spelae tirolicum* in the Tethys Ocean, after Hillebrandt and Krystyn, 2009). Mass extinction events in the Phanerozoic are often associated with distinct changes in the global carbon cycle, which are reflected by perturbations in carbon isotope records. At the T–J transition, however, it was argued that changes in the bulk C-isotope composition of the sedimentary organic matter (SOM) are largely controlled by changes in type of organic matter (van de Schootbrugge et al., 2008).

We present an integrated geochemical, stable-isotope and palynological study from the Global boundary Stratotype Section and Point (GSSP) for the base of the Jurassic, at Kuhjoch (Austria). In this study, we assess the implications of C-burial events and possible

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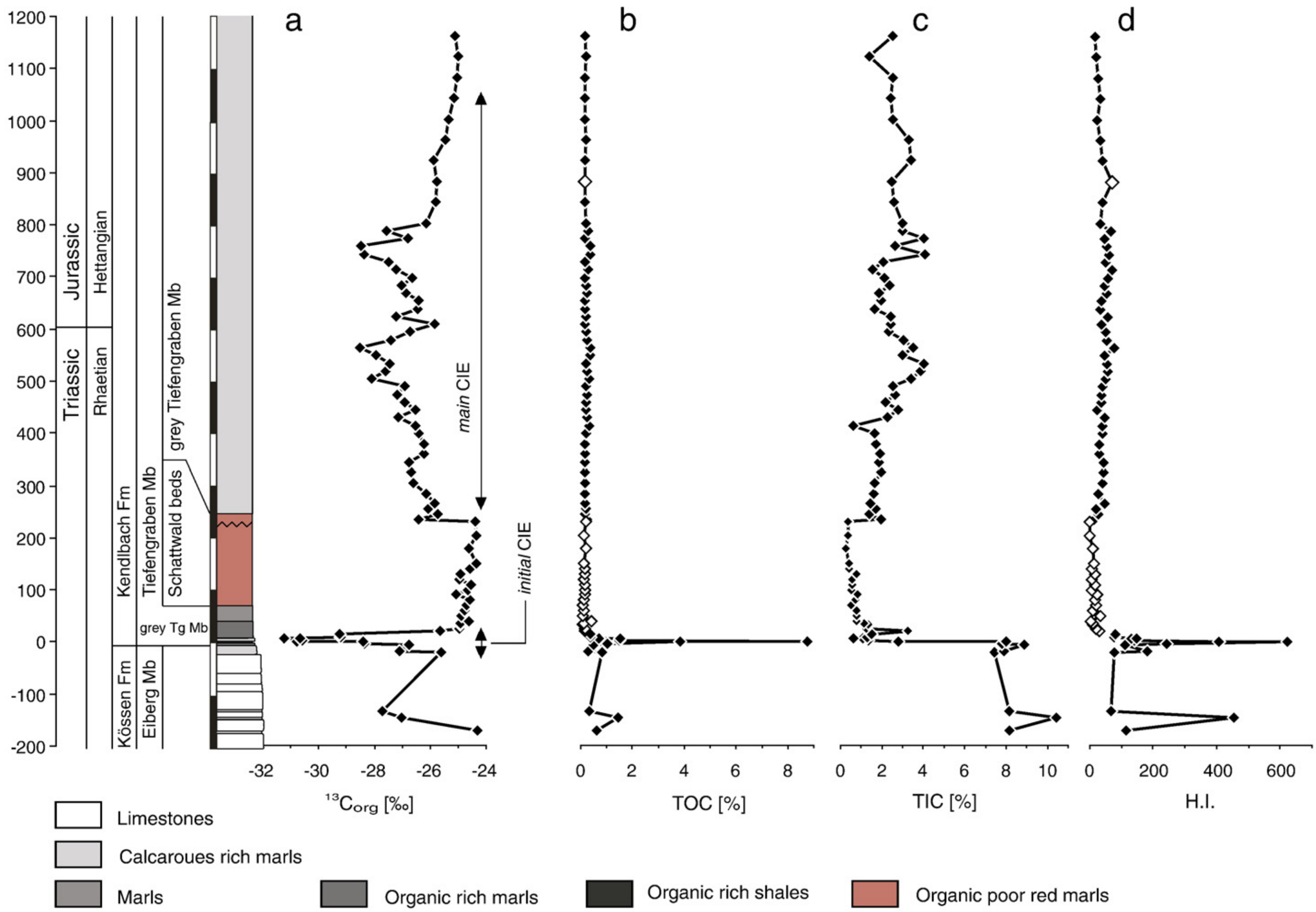

Fig. 1. Geochemical proxy records of environmental change across the T–J boundary in the Kuhjoch section, Eiberg Basin (Austria). (a) The organic C-isotope signature [‰], (b) Total Organic Carbon content [%], (c) Total Inorganic Carbon content [%] and (d) Hydrogen Index values [mg HC/g TOC]. White diamonds in the TOC and HI records show samples with values to low for a reliable S2 determination.

changes in kerogen at the T–J boundary interval, for the size and nature of the $\delta^{13}C_{org}$ negative excursions. Combined high resolution Rock-Eval VI and palynological data are used to constrain the source of sedimentary organic matter and the associated history of environmental changes. We further discuss the stratigraphic relationship between the onset of a biocalcification crisis with the beginning of CAMP volcanism, and events during the T–J transition.

2. Palaeogeography, geology, lithology

Sediments from Kuhjoch and other nearby T–J boundary sections were deposited in the intra-platform Eiberg Basin (Hillebrandt et al., 2007; Ruhl et al., 2009). This basin formed as part of extensive carbonate platforms and between large end-Triassic reef systems, rimming open shelf basins (Ruhl et al., 2009; Fig. 2). The carbonate platforms developed during the late Triassic, along the western end of the Tethyan passive margin, forming an up to 300 km wide and approximately 500 km long shelf strip (Kürschner et al., 2007). Spreading of the Rhaetian (upper Triassic) Kössen Fm over the Hauptdolomite and prograding siliciclastic sedimentation strongly modified and reduced the carbonate shelf (Haas, 2002; Krystyn et al., 2005). During deposition of the late Rhaetian Eiberg Mb, which succeeds the Hochalm Mb at the top of the Kössen Fm, the intra-platform Eiberg Basin deepened between the newly growing carbonate platforms of the Oberrhaet Limestone (Golebiowski, 1990). Sediments from the Kuhjoch section were deposited in the central part of the Eiberg Basin, which underwent continuous subsidence during the late Rhaetian. Deposition was therefore less affected by the end-Triassic sea-level lowering and fully marine conditions prevailed continuously in the deeper parts of the basin (Krystyn et al., 2005).

The Kuhjoch section is located within the western Eiberg Basin in the Karwendel syncline (Ruhl et al., 2009; Fig. 1), an east–west trending, narrow geological subunit of the Lechtal nappe in the western Northern Calcareous Alps (Hillebrandt et al., 2007). The outcrop is located in the increasingly steep to overturned southern flank of the syncline.

A distinct lithological change from limestones of the Eiberg Mb (Kössen Fm) to marly sediments of the Tiefengraben Mb (Kendlbach Fm) characterizes the sedimentary sequences in the Eiberg Basin in the transition from the Triassic to the Jurassic (Fig. 1). Well-bedded and variably thick limestones of the Kössen Fm alternate with thin marly inter-layers in the Kuhjoch section. Several tens of centimetres of grey-brown marls of the Tiefengraben Mb succeed the Kössen Fm. At Kuhjoch, this interval is followed by ~200 cm of reddish oxidized, clayey marls of the Schattwald beds. These beds are succeeded by the main part of the Tiefengraben Mb, containing distinct Jurassic ammonite levels (Krystyn et al., 2005; Hillebrandt et al., 2007). Limestone beds re-occur in the upper part of the Tiefengraben Mb just before the transition to the succeeding Breitenberg Mb. A more detailed (palaeo-) geographical and geological description of this section is reported in Hillebrandt et al. (2007) and Ruhl et al. (2009).