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Seawater temperatures and carbon isotope variations in central European basins at the Middle–Late Jurassic transition (Late Callovian–Early Kimmeridgian)

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ABSTRACT

Oxygen and carbon isotope values and elemental ratios of well-preserved belemnite rostra, brachiopod shells and bulk-carbonates from the Upper Callovian–Lower Kimmeridgian of the Polish Jura Chain, Kujawy (Poland) and Swabian Alb (Germany) are investigated to reconstruct environmental conditions and perturbations in the marine carbon cycle. Belemnite $\delta^{18}O$ values show relatively constant temperatures (ca. 12 °C) of bottom waters in the Polish Jura Chain basin during a major part of the Late Callovian–Middle Oxfordian, except for a short-term cooling (to ca. 9 °C) at the Callovian–Oxfordian transition. Belemnite and brachiopod $\delta^{18}O$ values show a gradual increase in temperature during the Submediterranean Late Oxfordian; the highest temperatures (ca. 16 °C) are calculated for the Submediterranean Oxfordian–Kimmeridgian transition. Belemnite and brachiopod Mg/Ca and Sr/Ca ratios are disregarded as a paleotemperature proxy because of their weak correlation with $\delta^{18}O$ values. The belemnite and brachiopod isotope data confirm that the carbon isotope composition of belemnite rostra is affected by a metabolic effect, which results in a depletion of belemnite calcite in the ^{13}C isotope. Belemnite rostra are considered, nevertheless, as a valuable tracer of temporal variations in the carbon isotope composition of marine carbonates. Belemnite $\delta^{13}C$ data show the presence of two positive excursions (in the Upper Callovian and the Middle Oxfordian) in the carbon isotope record of peri-Tethyan carbonates. The excursions are divided by a Lower Oxfordian interval characterized by decreased $\delta^{13}C$ values. This is most likely a regional feature caused by upwelling. Lowest belemnite and brachiopod $\delta^{13}C$ values are observed in the lower part of the Submediterranean Upper Oxfordian and are linked to a well-mixed state of the seawater in the basins studied. The carbon isotope record of bulk carbonates differs from those of belemnites and brachiopods probably because of strong variations in carbonate production in the Polish Jura Chain basin.

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1. Introduction

Isotope, faunistic and sedimentologic data show, depending on the study area, a short term or a long term cooling at the Callovian–Oxfordian transition, no change or a warming (Kaplan et al., 1979; Abbink et al., 2001; Dromart et al. 2003a, 2003b; Tremolada et al. 2006; Brigaud et al., 2008; Nunn et al., 2009; Wierzbowski et al., 2009, 2013; Rogov and Zakharov, 2010; Wierzbowski and Rogov, 2011; Alberti et al., 2012a, 2012b; Jenkyns et al., 2012; Chumakov et al., 2014; Pellenard et al., 2014a, 2014b). A subsequent Late Oxfordian–Early Kimmeridgian warming is noted in the oxygen isotope record of various paleogeographical areas (Abbink et al., 2001; Brigaud et al., 2008; Nunn et al., 2009; Žak et al., 2011; Alberti et al., 2012a, 2012b; Jenkyns et al., 2012; Wierzbowski et al., 2013).

The carbonate and organic matter $\delta^{13}C$ values show a long-lasting positive excursion comprising the Upper Callovian–Middle Oxfordian (Nunn et al., 2009; Wierzbowski et al., 2013) or the presence of two positive excursions in $\delta^{13}C$ values of marine carbonates in this interval (Wierzbowski, 2002, 2004; Wierzbowski et al., 2009).

Because of the discrepancy of the data published, there is a need to study more high resolution and reliable paleoclimatic proxies from various regions. Central European basins had wide connections with the Tethys at the Middle–Late Jurassic transition and their sediments may be a proxy for environmental changes in open marine waters. Upper Callovian–Oxfordian oxygen and carbon isotope records of belemnite rostra and brachiopod shells from central Europe were presented by Wierzbowski (2002, 2004) and Wierzbowski et al. (2009). The data show relatively constant temperatures of bottom waters in the peri-Tethyan basins of these areas during the Late Callovian–Middle Oxfordian, and two positive excursions in $\delta^{13}C$ values of marine carbonates (Wierzbowski, 2002, 2004; Wierzbowski et al., 2009). An offset between coeval belemnite and brachiopod $\delta^{13}C$ values points to the uptake of respiratory carbon during precipitation of belemnite skeletons (Wierzbowski 2002).

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The Oxfordian samples from the Polish Jura Chain (Kraków–Częstochowa–Wieluń Upland) in central Poland, whose data were published by Wierzbowski (2002), were screened for the state of preservation using cathodoluminescence analysis only. The samples were not analyzed for Mn, Fe and Sr content, which makes the data not fully reliable (cf. Wierzbowski, 2002; Wierzbowski et al., 2009). The time-span of the Polish Jura Chain dataset is limited because of a stratigraphic gap in the uppermost Callovian and diagenetic alteration observed in youngest samples from this area (Wierzbowski, 2002; Wierzbowski et al. 2009). In addition, the stratigraphy of the Zawodzie II section comprising the Bifurcatus Zone of the Upper Oxfordian has been amended by Głowniak (2006a), which results in the necessity of re-dating of the data presented previously (cf. Wierzbowski, 2002). The continuous carbon isotope record of Upper Callovian–Lower Kimmeridgian bulk carbonates of central European basins has also never been presented.

Because of the limitations of the central European datasets studied so far, additional investigations of marine carbonates from this area have been undertaken. Chemical analyses of previously studied and stored belemnite and brachiopod materials from the Oxfordian in the Polish Jura Chain have been conducted. The isotope dataset has been supplemented with analyses of new, well-preserved and stratigraphically well-dated belemnite and brachiopod samples from the Callovian–Oxfordian boundary and the Upper Oxfordian–lowermost Kimmeridgian from the Polish Jura Chain and Kujawy (Poland). Some samples have also been re-positioned in the stratigraphic chart according to new stratigraphic data of Głowniak (2006a). In addition, the carbon isotope composition of Upper Callovian–lowermost Kimmeridgian bulk carbonates from the Polish Jura Chain has been studied.

The aim of the current paper is a discussion of amended and supplemented oxygen and carbon isotope datasets from the Upper Callovian–Lower Kimmeridgian of central Europe. The data document temporal variations in temperature of bottom waters in the peri-Tethyan basins during the Late Callovian–Early Kimmeridgian, changes in the carbonate carbon isotope composition, and corroborate the presence of a metabolic vital effect in belemnites. Local and global paleoclimatic changes may be deciphered based on the comparison of the presented data with the isotope records of other areas. The data may also be used to show the evolution of the temperature of the bottom waters of the Polish Jura Chain basin on a longer time-span i.e. Middle–Late Jurassic (Late Bajocian–Early Kimmeridgian) and to reconstruct long-term fluctuations of the Jurassic climate (cf. Wierzbowski and Joachimski, 2007; Wierzbowski et al., 2009).

2. Geological setting

2.1. Lithology and depositional environment

Peri-Tethyan basins of the Polish Jura Chain, Kujawy and the Swabian Alb were incorporated into the northern shelves of the Tethys Ocean during the Middle Callovian as a result of a global sea-level rise (cf. Feldman-Olszewska, 1998; Thierry et al. 2000; Wierzbowski et al. 2009; see also Fig. 1). The Upper Callovian sediments of these areas consist of nodular limestones and deep-water stromatolites with abundant hiatuses and condensations (Geyer and Gwinner, 1984; Norris and Hallam, 1995; Kopik, 1997; Dembicz and Praszkier, 2003b; Wierzbowski et al., 2009). The absence of sedimentation or erosion resulted in the general paucity of lowermost Lower Oxfordian (Mariae Zone) deposits in the Polish Jura Chain and the Swabian Alb, and the Lower Oxfordian stratigraphic gap in Kujawy (Różycki, 1953; Geyer and Gwinner, 1984; Matyja and Wierzbowski, 1985; Matyja et al., 1985; Matyja, 1992; Wierzbowski et al., 2009). Deep-neritic, siliceous sponge and microbial deposits, which formed the so called sponge megafacies, dominate in the Oxfordian in the areas studied (Matyja and Wierzbowski, 1985, 1996). Thin-bedded marly-limestone and mudstone beds, rich in sponges and sponge spicules, were deposited during the late Early Oxfordian (Cordatum Chron) and the earliest Middle Oxfordian (the early Plicatilis Chron) in the Polish Jura Chain, during the Middle Oxfordian in Kujawy, and during the late Early to the Submediterranean Late Oxfordian (Cordatum–Bimammatum chrones) in the Swabian Alb (Różycki, 1953; Geyer and Gwinner, 1984; Matyja et al. 1985; Głowniak, 1997, 2000, 2002, 2006b; Matyja and Głowniak 2003; Wierzbowski et al., 2009).

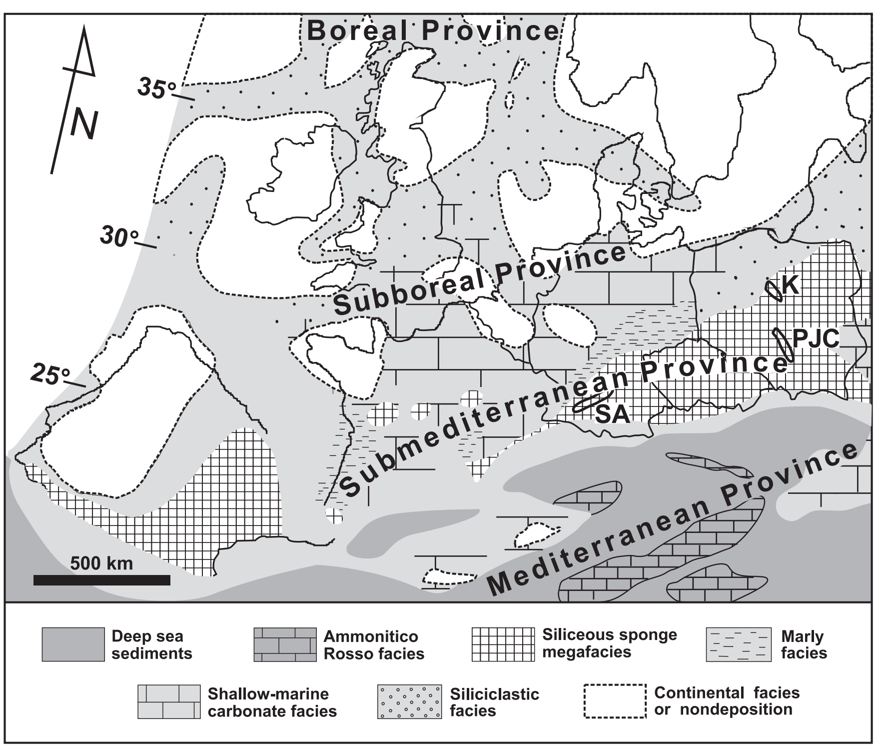

Fig. 1. Paleogeography and distribution of the main facies types during the Middle Oxfordian in Europe (after Matyja and Wierzbowski, 1995; Wierzbowski, 2004; modified). Areas of stable isotope studies: K — Kujawy; PJC — Polish Jura Chain; SA — Swabian Alb.

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