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Carbon isotope excursions in Boreal Jurassic–Cretaceous boundary sections and their correlation potential

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ABSTRACT

The Jurassic–Cretaceous (J–K) boundary is one of the most problematic points on the geological timescale. The boundary is not defined by a Global Stratotype Section and Point (GSSP) because of the absence of well-defined (by significant faunal turnover), widely correlatable biostratigraphic levels to fix the base of the Berriasian. A distinct earliest Berriasian positive carbon isotope excursion is identified in the Boreal marine carbonate (belemnites) carbon records from the Maurynya River (Northern Urals) and the Nordvik Peninsula (northern East Siberia). The excursion is found within the top part of the upper Volgian *Craspedites taimyrensis* ammonite Zone, slightly above the J–K boundary, which was established by palaeomagnetic data. Because a significant positive $\delta^{13}C$ shift was also observed immediately above the J–K boundary in the Tethyan Guppen-Heuberge pelagic-carbonate section (Switzerland), this positive carbon isotope event can be regarded as a useful marker for a Panboreal and Boreal–Tethyan correlation of J–K boundary beds. This $\delta^{13}C$ excursion is interpreted as a record of increased rates of organic carbon burial. The $\delta^{13}C$ data obtained previously for the upper Volgian and Ryazanian in different Boreal regions are also analysed in this paper. Other well-documented carbon isotope excursions with less global significance allow the creation of a composite carbon-isotope curve for Boreal regions that characterises the upper Volgian and Ryazanian in detail.

1. Introduction

1.1. Scope of the study

Carbon isotope variations have been widely used for palaeoclimatological and palaeoecological reconstructions and for precise correlation in many intervals of Earth's history. Previous studies of carbon isotope variations in Jurassic–Cretaceous (J–K) carbonate sections of Tethyan regions have not shown any significant excursions around the J–K boundary (Weissert and Channell, 1989; Weissert and Lini, 1991; Emmanuel and Renard, 1993; Savary et al., 2003; Tremolada et al., 2006; Michalík et al., 2009; Grabowski et al., 2010; Žák et al., 2011). The ranges of $\delta^{13}C$ values during this interval do not exceed 1‰ and are often 0.5‰. The one exception is the Guppen-Heuberge section (Switzerland), where the $\delta^{13}C$ values in the interval of calpionellid zones A and B vary within a relatively wide range from −0.2 to +1.6‰ (Weissert and Mohr, 1996). According to Michalík et al. (2009), carbon-isotope curves from bulk carbonate samples of J–K boundary sequences around the world show smooth trends resulting from equilibrated rates of bio-productivity and organic matter burial.

Reconstructions of carbon-isotope curves for northern palaeobasins with terrigenous sedimentation are based on the analysis of sedimentary organic matter and/or mollusc shell material, especially belemnites, which are best preserved in Boreal sections. Isotope geochemical studies of the J–K boundary interval of Boreal sections are still in progress. Stable isotope data have been collected from many Volgian and/or Ryazanian sections, where the J–K transition beds are poorly represented or absent: Speeton in England (Price et al., 2000); Helmsdale in Scotland (Nunn and Price, 2010); Janusfjellet and Knorringfjellet in central Spitsbergen (Hammer et al., 2012); Gorodischi, Kashpir and Marievka on the Russian Platform (Ruffell et al., 2002; Gröcke et al., 2003; Price and Rogov, 2009); Yatriya in Western Siberia (Price and Mutterlose, 2004); and Boyarka in Eastern Siberia (Nunn et al., 2010). In many instances, either detailed carbon isotope records have not been presented (e.g., Podlaha et al., 1998) or the studied sections have no detailed biostratigraphic subdivision (e.g., Ditchfield, 1997). Compared with the studied Tethyan carbonate sections, the Boreal sections are characterised by significant carbon isotope excursions on the $\delta^{13}C$ curves. Thus, if the excursions from different Boreal sections are shown to be isochronous, Boreal palaeobasins could be more suitable than Tethyan basins for reconstructions of changes in the global carbon cycle.

Until recently, fossiliferous Boreal outcrops with J–K boundary strata escaped the close attention of scientists mainly because of their inaccessibility. The Nordvik section in northern East Siberia was the first Boreal section where $\delta^{13}C$ and $\delta^{18}O$ curves were reconstructed for the J–K

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boundary interval; however, no significant excursions were found in the carbon or oxygen isotope records that could be used for further Boreal–Tethyan correlations around the J–K boundary (Žák et al., 2011). This lack of excursions was partially due to the high concentration of organic matter in the sediments, which could cause significant changes in the isotopic composition of carbonate material during diagenesis. As a result of the oxidation of organic matter and isotope exchange reactions between ^{12}C-enriched CO_2 and carbonate material, the $\delta^{13}C$ values of the carbonate material could be considerably reduced (Vinogradov, 2009).

Another Boreal section with a stratigraphically-complete sequence of sediments spanning the Volgian–Ryazanian boundary is located in the foothills of the Northern Urals on the Maurynya River in Western Siberia (Fig. 1). Well-preserved belemnite rostra that describe the J–K boundary interval in detail were collected from this section. This paper presents the results of the study of the variations of the carbon and oxygen isotopes in the rostra of this collection. Additional sampling of rostra was performed in the same stratigraphic interval in the Nordvik Peninsula.

1.2. Problems of Panboreal and Boreal–Tethyan correlations

In addition to Mesozoic ammonoid biostratigraphy, great importance has recently been placed on using integrated parallel (independent) zonal scales from different groups of fauna and flora to provide more detailed and reliable correlations (Zakharov et al., 1997; Hardenbol et al., 1998; Shurygin et al., 2000, 2011). Boreal zonal scales for the J–K boundary interval are based on ammonites (mainly Craspeditidae), belemnites (Cylindroteuthididae), bivalves (Buchiidae), microfossils and palynomorphs. High-latitude, mostly Eastern Siberian Boreal zonal successions have been accepted by some authors as a standard for Boreal basins in this interval (e.g., Baraboshkin, 2004; Shurygin et al., 2011; Bragin et al., 2013). These successions are widely distributed in northern Eurasia, northern North America and the Arctic islands, including Greenland, Spitsbergen and other locations (e.g., Surlyk et al., 1973; Saks, 1975; Callomon and Birkelund, 1982; Surlyk and Zakharov, 1982; Jeletzky, 1984; Shurygin et al., 2000, 2011; Nikitenko et al., 2008; Rogov and Zakharov, 2009; Rogov, 2010; Dzyuba, 2012, 2013). These scales work less successfully in low-latitude Boreal sections (northwestern Europe, the Russian Platform without the northern part, the Russian Far East, northeastern China, Western British Columbia and others) due to the provincialism observed to a variable degree in the fauna of these regions (e.g., Jeletzky, 1984; Zakharov, 1987, 2011; Casey et al., 1988; Sey and Kalacheva, 1999; Sha et al., 2003, 2006; Wimbledon, 2008; Rogov and Zakharov, 2009). Consequently, correlating the low-latitude Boreal J–K boundary successions with the Boreal standard is a complex task.

A fundamentally new scheme of subdividing the Ryazanian Stage of the Russian Platform based on ammonites is currently being developed (Mitta, 2007; Mitta and Sha, 2011). The main problem of this scheme, however, is the validity of the placement of the *Hectoroceras kochi* Zone to the base of the Ryazanian Stage before the *Riasanites rjasanensis* Zone (for a discussion see Bragin et al., 2013). The more traditional view on the ammonite zonation of the Ryazanian of the Russian Platform is adopted within this work (Fig. 2). For the upper

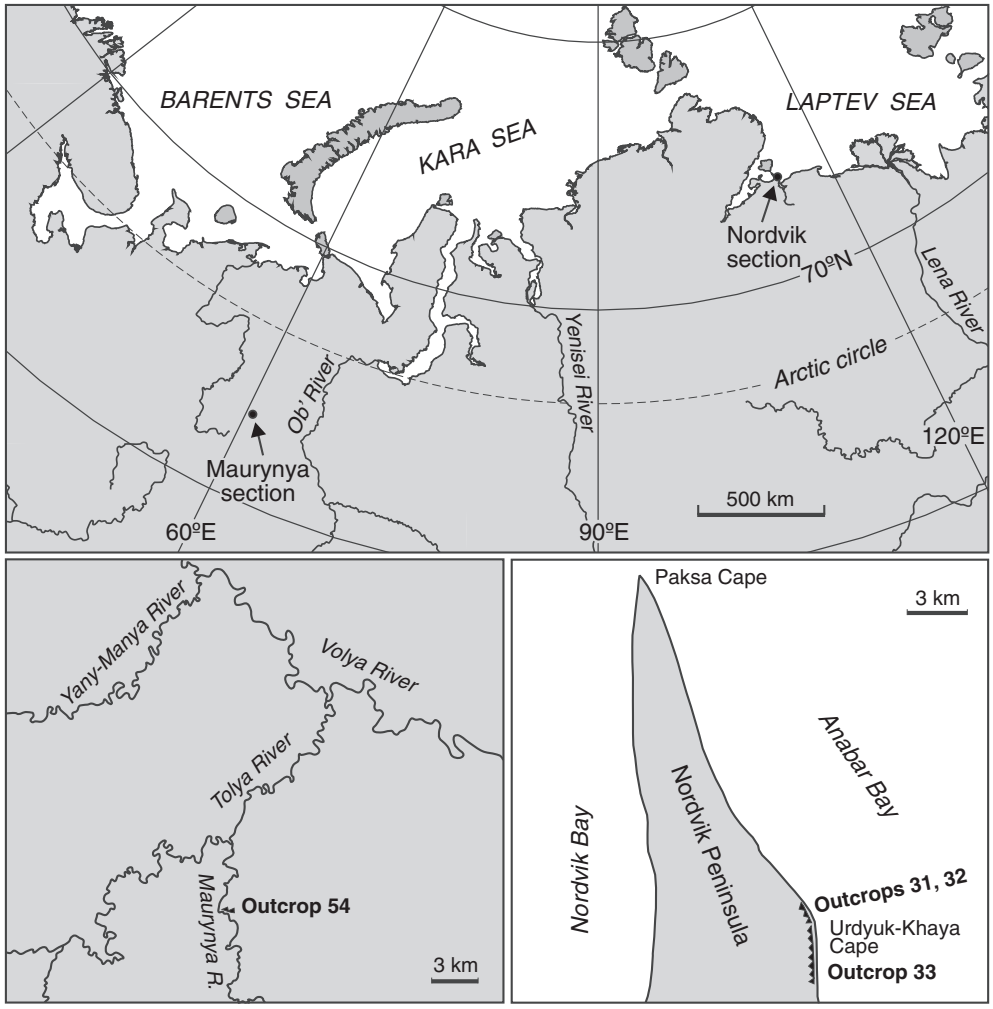

Fig. 1. The locations of the studied Maurynya and Nordvik sections in Siberia.