Palaeogeography, Palaeoclimatology, Palaeoecology 273 (2009) 41–49

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

An isotopic appraisal of the Late Jurassic greenhouse phase in the Russian Platform

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ARTICLE INFO

Article history:
Received 3 July 2008
Received in revised form 31 October 2008
Accepted 27 November 2008

Keywords:
Belemnites
Russian Platform
Oxygen and carbon isotopes
Late Jurassic

ABSTRACT

Oxygen- and carbon-isotope ratios have been determined from Late Jurassic (Callovian–Volgian) belemnites from three locations on the Russian Platform (Gorodischi, Khanskaya Gora and Marievka). All samples were examined by means of trace element geochemistry and petrography in order screen for diagenetic alteration. Oxygen and carbon isotopes from well-preserved belemnites range from −2.24 to −0.09‰ and −0.57 to 1.77‰ respectively. Oxygen isotopes, if interpreted in terms of temperature, reveal a rise of temperatures during the Oxfordian–Early Kimmeridgian and indicate a prolonged episode of warmth during the Kimmeridgian–Volgian. The isotope data only equivocally reflect a number of significant changes in Boreal–Tethyan ammonite assemblages. A positive carbon isotope excursion is observed within the Volgian, but not seen within composite carbon-isotope stratigraphies of the western Tethys. Hence the Jurassic may have been characterised by regional $\delta^{13}C$ excursions related to non-simultaneous organic matter deposition resulting from localised ponding, semi restricted ocean circulation and a lack of tidal mixing.

1. Introduction

Records of ocean temperatures in the Northern Hemisphere based upon the isotopic thermometry of fish and shark tooth enamel (Lécuyer et al., 2003; Dromart et al., 2003) indicate a severe cooling and subsequent rapid warming during the middle to Late Jurassic transition. For this reason Dromart et al. (2003) suggested that the middle to Late Jurassic transition may represent one of the major turning points of the climate history of the Earth. A number of compilations of Jurassic isotopic data (largely belemnite-derived) (e.g. Veizer et al., 1999; Barskov and Kiyashko, 2000; Jenkyns et al., 2002; Veizer, 2005) are supportive of this possible icehouse–greenhouse transition. Such isotopic databases frequently consist, however, of data from numerous dispersed locations where presumably potential differences exist with respect to temperature and the isotopic composition of seawater, hence making any global palaeotemperature reconstruction inherently complex. Certainly the Late Jurassic and in particular the Kimmeridgian has been identified as a period of time when temperatures reached a maximum (e.g. Frakes, 1979; Valdes and Sellwood, 1992; Abbink et al., 2001). Detailed isotopic records through this potential greenhouse interval are, however, limited (c.f. Price and Grocke, 2002; Gröcke et al., 2003; Wierzbowski, 2004; Zakharov et al., 2005). This study presents new (belemnite-derived) isotopic data from the Kimmeridgian–Volgian of the Russian Platform (Gorodischi, Khanskaya Gora and Marievka) combined with data from previous studies (also from the Russian Platform). A comprehensive ammonite zonation permits these data to be placed within a recognized and detailed biostratigraphical scheme.

2. Geological setting

During the Late Jurassic, the Russian Platform was located between palaeolatitudes ~35–50°N (Fig. 1; Smith et al., 1994; Thierry et al., 2000). Based on the palaeogeographic reconstructions of Sazonova and Sazanov (1967), land areas may have existed to the east and west of the study area, with marine connections to the Boreal and Tethyan seas. The width of the basin varied through time (Baraboshkin, 1997) but in the Late Jurassic was about 1200 km east to west and over 2000 km north to south.

The succession of Gorodischi village (25 km north of Ulyanovsk, Fig. 1) represents the stratotype of the Volgian (Gerasimov and Mikhailov, 1966) and ranges from the Kimmeridgian Eudoxus Zone to the Nodiger Zone in the Upper Volgian (Hantzpergue et al., 1998; Rogov, 2002; 2004, Fig. 2). Notably the base of Volgian and Tithonian are considered by some authors to be coincident (but see discussion by Scherzinger and Mitta, 2006). The succession is exposed over a distance of 15 km along the right bank of the Volga River and was first described by Murchison et al. (1845). Sediments of the lowermost ammonite zone seen (Eudoxus Zone) are composed of grey calcareous clays that locally grade into marl and yields a number of ammonites including *Aulacostephanus eudoxus*, *Sutneria* aff. *cyclodorsata*, *S. ex* gr. *Eumela*, *Aspidoceras quercynum*, *Discosphinctoides* sp., *Tolvericeras* cf. *sevogodense* and *Amoeboceras* spp. (Hantzpergue et al., 1998; Rogov, 2002). The overlying succession of the Autissiosorensis Zone (Fig. 2) is composed of a series of calcareous bioturbated light-grey clays locally

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doi:10.1016/j.palaeo.2008.11.011

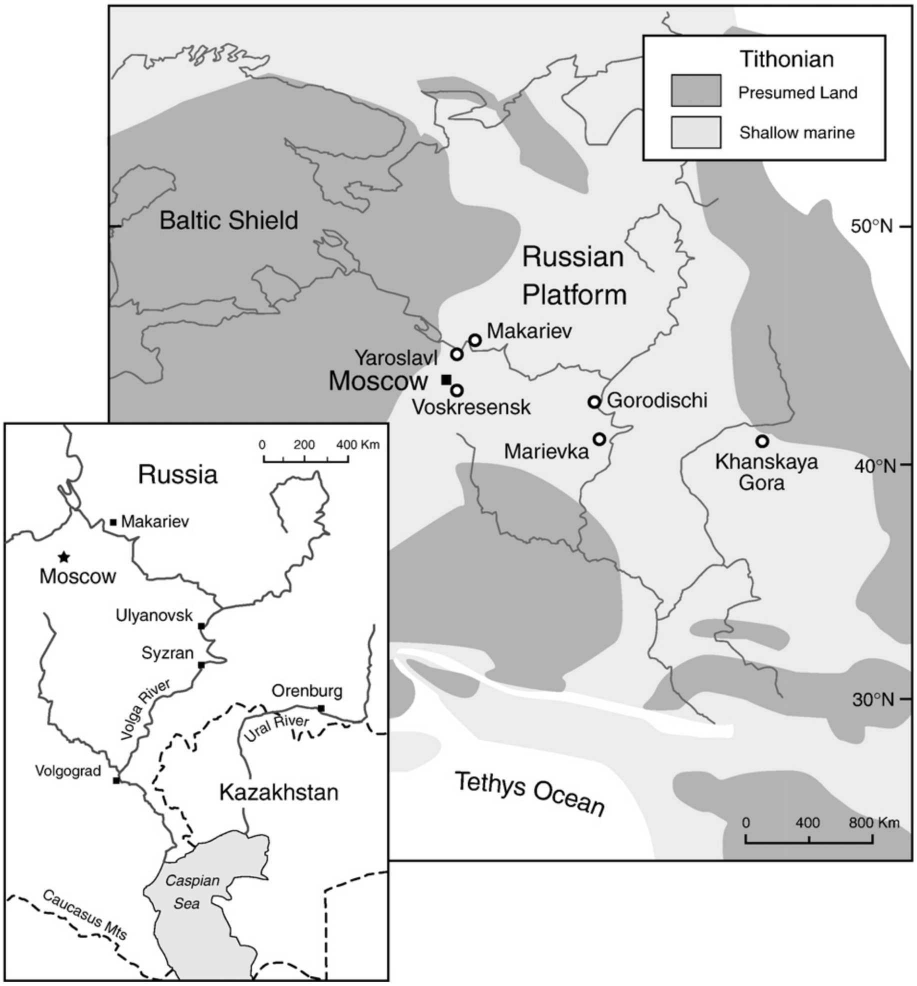

Fig. 1. Palaeogeographic setting of the Russian Platform during the Tithonian (modified from Smith et al., 1994; Thierry et al., 2000). Inset shows the locations of Ulyanovsk, Syzran and Orenburg.

bearing calcareous concretions. These clays yield belemnites, bivalves and gastropods which frequently coexist with ammonites including *A. autissiosorensis* and its dimorphs *A.* cf. *kirghisensis*, *A.* ex gr. *undorae* (Hantzpergue et al., 1998) as well as numerous *Sarmatisphinctes*. The part of the succession assigned to the Klimovi Zone consists of alternating grey and dark grey bioturbated calcareous clays (Fig. 2). These clays have yielded belemnites, bivalves and gastropods and pyritized ammonites (Rogov, 2002). The overlying ~1 m of sediments contains the ammonites *Ilowaiskya* cf. *sokolovi*, and *Subdichotomoceras* cf. *subcrassum* characteristic of the Sokolovi Zone. The Pseudoscythica Zone contains the '*neoburgensis* horizon' (of Rogov, 2002, 2005), which is rich in small *Hibolithes* belemnites and is dominated by Submediterranean ammonites such as *Anaspidoceras neoburgensis*. The sediments assigned to the *puschi* horizon and Panderi Zone are grey calcareous bioturbated clays dominated by Subboreal ammonites belonging to the *Pseudovirgatites–Zaraiskites* lineage with also *Buchia* sp., *Liostrea* sp., *Astarte* sp., *Dicraloma* sp. and *Oxytoma* sp. The upper part of the succession, comprising calcareous mudstones interbedded with a number of prominent black shale horizons, is overlain by a condensed (~2 m) silty–sand unit with abundant phosphatic nodules (Fig. 2). Invertebrates from this highly fossiliferous part of the succession include belemnites, ammonites and bivalves (Kuleva et al., 1996; Hantzpergue et al., 1998). The black shales are extremely enriched in organic carbon and reach a maximum of 40–50 wt.% (Hantzpergue et al., 1998; Riboulleau et al., 2003). Equivalent organic-rich deposits to those seen at Gorodischi are widely distributed on the eastern and middle parts of the Russian Platform, with a total outcropping and sub cropping area of more than 100 000 km^2 (Vishnevskaya et al., 1999; Riboulleau et al., 2003; Gavrilov et al., 2008). The black shales of Gorodischi are also the lateral equivalent of the lower part of the Bazhenov Formation, the main source rock of the west Siberian oil fields (Riboulleau et al., 2003).

A further 13 belemnite samples were obtained from Belyaevka Village, Khanskaya Gora located ~60 km southeastwards from Orenburg (Fig. 1), on the left bank of Berdjanka river. They are derived from the Upper Kimmeridgian Eudoxus Zone to the Lower Volgian Tenuicostatum Zone. This part of the succession is ~9 m thick and consists of interbedded silts and sandstones with chert concretions and yielded abundant ammonites described by Ilovaiskii and Florenskii (1941) and Mikhailov (1966). A number of belemnites (*Cylindroteuthis* sp.) were also obtained from this section (Table 1). A further 5 belemnites were obtained from the Marievka Village section, located 40 km west of Syzran (Fig. 1). This small section consisted of a 3 m thick unit of calcareous sands overlain by a phosphatic nodule-rich layer and ranged from the Nikitini to Nodiger Zone. Belemnites (*Acroteuthis* (*Microbelus*) sp.) were sampled from the Nodiger Zone only.

3. Materials and methods

Oxygen and carbon isotopic compositions have been determined from well preserved specimens of the belemnite genera *Cylindroteuthis*, *Pachyteuthis* (*P.*), *A.* (*Microbelus*), and *Hibolithes*. Where possible, multiple samples were collected from the same stratigraphic horizon. Diagenetic