Palaeogeography, Palaeoclimatology, Palaeoecology 412 (2014) 91–98

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Eustatic, tectonic, and climatic signatures in the Lower Cretaceous siliciclastic succession on the Eastern Russian Platform

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ARTICLE INFO

Article history:
Received 15 May 2014
Received in revised form 17 July 2014
Accepted 28 July 2014
Available online 12 August 2014

Keywords:
Chronostratigraphy
Eustasy
Sea level changes
Tectonic activity
Climatic events
Early Cretaceous

ABSTRACT

A methodical approach to identifying major abiotic events in the siliciclastic succession accumulated in the shallow epicontinental basin on the Eastern Russian Platform during the Early Cretaceous is presented. On the basis of a reliable chronostratigraphic framework a comparison between global and regional sea level curves was undertaken. The intervals during which the global and regional sea level curve trends are similar correspond to a predominance of eustasy in the particular basin. Alternatively, tectonic activity dominates during intervals when there is no similarity between the trends of the global and regional sea level curves. Three intervals of non-coincidences of trends of these two curves matched with major tectonic events that took place within the Eastern Russian Platform in the Early Cretaceous: the Early Hauterivian tectonic uplift, subsequent Late Hauterivian subsidence and the Late Albian uplift. The main consequences of the tectonic activity were two large regional unconformities and hiati. The comparison of main global and regional sea level trends also reveals major climatic events. “The cold snaps” that occurred during the Early Cretaceous greenhouse world (Hu et al., 2012) coincided with simultaneous global and regional sea level lowstands, peak shallowing of the basin and the almost complete absence of sediments. “The cold snap” is identified in the Late Aptian sedimentary sequences on the Eastern Russian Platform.

1. Introduction

An extensive amount of published data on sequence stratigraphy shows that the subdivision of geological successions into sequences, together with the analysis of tectonic activity and eustatic changes, allows for a deeper understanding of basin evolution. Thus, genetic relationships between the Lower Cretaceous sediments of the Russian Platform and global sea level changes in conjunction with tectonic activity and sediment supply were defined by analyzing a voluminous amount of well data from the Central Russian Platform (Sahagian and Jones, 1993; Sahagian et al., 1996) and on the basis of reliable chronostratigraphic analyses of the particular sections and further regional-scale investigations on the Eastern Russian Platform (Zorina, 2009; Zorina et al., 2009; Zorina, 2012). The most important results of the latter were the regional sea level curve and the regional tectonic curve that have been produced for the Mid Jurassic–Lower Cretaceous of the Eastern Russian Platform (Zorina, 2012).

In this study a new methodical approach for identifying major abiotic events in the Early Cretaceous epicontinental Russian sea is presented. It is shown that tectonic subsidences–uplifts and the so-called climatic “cold snaps” can be detected by the comparison between global and regional sea level curves. Importantly, widely discussed Early Cretaceous cooling events can be identified in the geological sections without isotopic and other “high-tech” data. The causes and consequences of major Early Cretaceous abiotic events on the Eastern Russian Platform, including Oceanic Anoxic Event-1a (OAE-1a), are also discussed.

It should be noted that the results of present study, based on the basin depth estimations, strongly differ from the recent analysis attempted by Zorina and Ruban (2012) in which shoreline shifts (reflecting transgressions and regressions) were taken into account. An urgency of such a distinction was previously argued by Ruban (2007) and it was recently clarified by modeling different transgressive–regressive and shallowing–deepening situations in the sedimentary basin (Zorina, 2014).

2. Geologic setting and chronostratigraphic position of the Lower Cretaceous megasequences

Current understanding of the occurrence and distribution of the Lower Cretaceous deposits within the Eastern Russian Platform (Fig. 1) is mainly the result of voluminous stratigraphic data that have been compiled and published (e.g., Sasonova and Sasonov, 1967; Vereshchagin and Ronov, 1969; Chirva, 1993). However, this information is not used for the purposes of chronostratigraphy.

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http://dx.doi.org/10.1016/j.palaeo.2014.07.029
0031-0182/

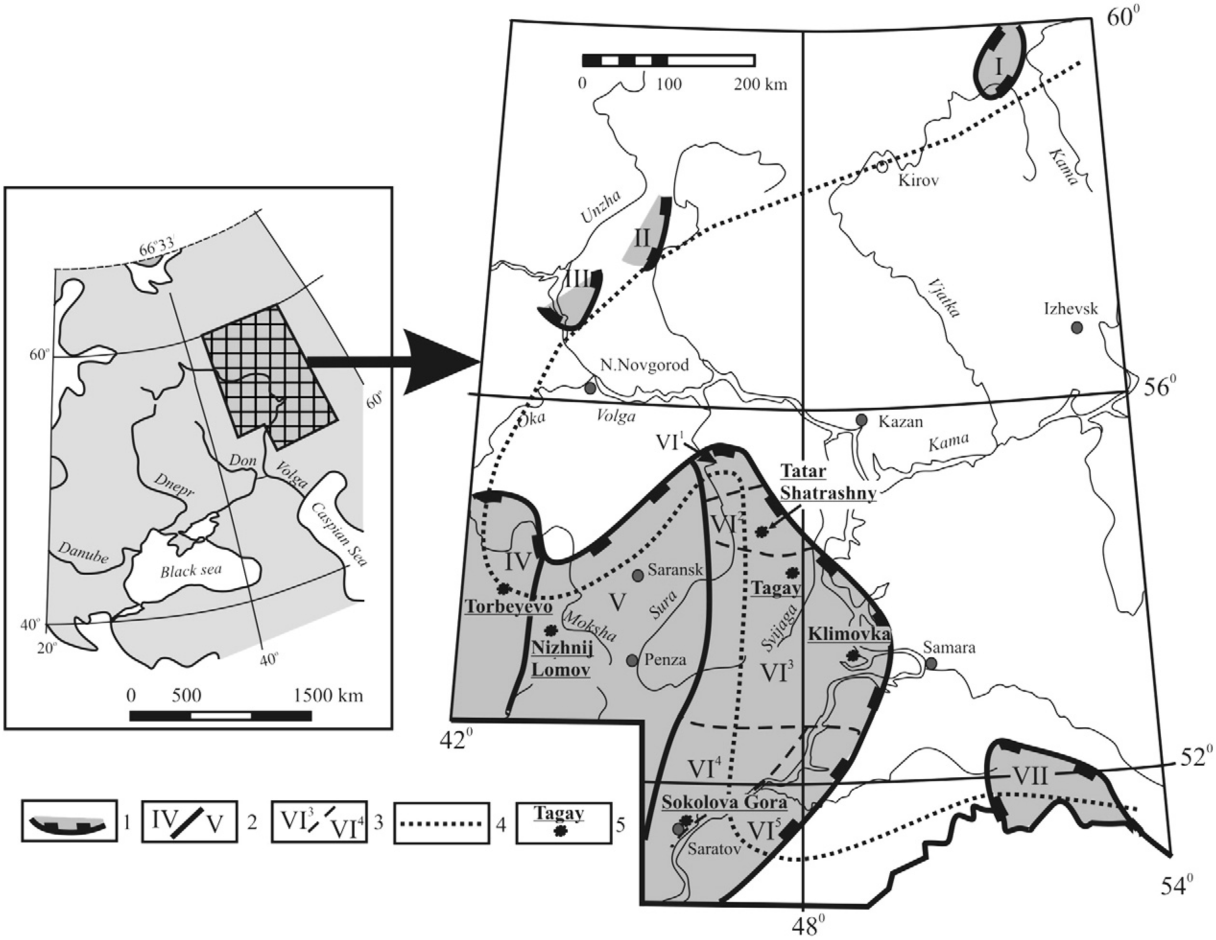

Fig. 1. Location of studied territory and structural zoning of the Lower Cretaceous deposits of the Eastern part of the Russian Platform. Legend: 1 — spread of the Lower Cretaceous; 2 — boundary of structural-geological zones; 3 — boundary of structural-geological subzones; 4 — the profile line through all the zones and subzones; and 5 — location of Boreholes. Structural-geological zones and subzones according to the Unificated Stratigraphic Scheme of the Lower Cretaceous Deposits of the Russian Plate (Chirva, 1993) with adds (Zorina, 2009). I — Vjatka–Kama Depression; II — Moscow Syneclise; III — Kovernin Depression; IV — Oka–Don Depression; V — Murom-Lomov Trough; VI — Ulyanovsk–Saratov Trough: VI^1 — Cheboksary Volga Region, VI^2 — NE part of the Ulyanovsk–Saratov Trough, VI^3 — Ulyanovsk–Samara Volga Region, VI^4 — Saratov Right Bank Region, and VI^5 — Saratov Left Bank Region; and VII — Buzuluk Depression.

The Lower Cretaceous siliciclastic sediments are represented mainly by clays and sandstones, with a maximum thickness of 450 m. They are underlain by the Upper Tithonan sandstones with pebbles, bituminous shales and clays, or by the Callovian clays in some areas. The Lower Cretaceous deposits are overlain by the Cenomanian calcareous sandstones, or by the Turonian–Coniacian marlstones or chalks.

In the Early Cretaceous the Eastern Russian Platform was an area of inner shelf sea, which was connected episodically by N–S oriented channels with the South and Boreal seas (Sasonova and Sasonov, 1967). Based on quantitative analyses of benthic foraminiferal communities, its depth is estimated at about 200 m, varying in the range from 150 m to 350 m (Zorina, 2013).

It was established (Zorina, 2009, 2012), that Lower Cretaceous strata within the Eastern Russian Platform stack to form three siliciclastic megasequences that were developed as a result of regional sea level fluctuations and climate changes.

Meanwhile, the major features of the geologic history of the studied area (Fig. 1) can only be identified using a reliable chronostratigraphic framework. A reliable and accurate basis for sequence stratigraphic and paleoenvironmental reconstructions was made as the results of the comprehensive litho- and biostratigraphic investigations of more than 200 borehole sections and outcrops (Figs. 2, 3). More than 100 of them were used in the compilation of the composite section of the northeastern Ulyanovsk–Saratov Trough (Zorina, 2009) (Fig. 4). The latter was compared with the regional stratigraphic scheme of the Lower Cretaceous deposits of the Eastern Russian Platform (Chirva, 1993) and correlated with the Geological Time Scale (Gradstein et al., 2012) (Fig. 4).

To ensure a robust and complete chronostratigraphic description of the study deposits, a comparison of regional composite sections of the Eastern Russian Platform was undertaken. Each of the sections has the detailed ammonite zonation, with the Boreal standard ammonite zone of the Lower Cretaceous (Baraboshkin, 2004) (Fig. 4). In addition, all the sections were tied to the timescale of Gradstein et al. (2012) that provided absolute ages for eustatic, tectonic and climatic events. Thus, the proposed chronostratigraphic scheme of the Lower Cretaceous of the Eastern Russian Platform (Fig. 4) reflects the state-of-the-art stratigraphy of the study area and certainly requires a continuous updating by new stratigraphic data.

The chronostratigraphic differentiation of the Lower Cretaceous sections revealed a series of continuously accumulating sediments with large dividing stratigraphic hiati (Fig. 4). As the duration of each of these continuous lithologic series varies from 5 to 20 Myr they are distinguished as megasequences according to the hierarchy by Vail et al. (1991).

In the studied area three megasequences are clearly identified (Fig. 4): Valanginian, Upper Hauterivian–Aptian, and Albian. They are well characterized by ammonites belonging to ammonite zones (Baraboshkin, 2004), which allow the studied strata to be correlated with Geological Time Scale (Gradstein et al., 2012).