Review of the Jurassic System of Russia: Stages, Boundaries, and Perspectives

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Abstract A review of the state-of-the-art of Jurassic stages in Russia is presented. The Jurassic system is represented here mainly by Boreal deposits, and direct correlation of boundaries based on global stratotype sections and points (GSSPs) with stage boundaries of the Boreal succession remains mostly unclear for the Lower and Middle Jurassic. These Boreal boundaries could be better fixed by selecting secondary stratotype section and point (SSSP) sections. Callovian and Upper Jurassic stage boundaries are directly traced throughout in the Boreal areas.

Keywords Jurassic · Russia · Stage boundaries · GSSP · SSSP

Introduction

Jurassic deposits are widely distributed across Russia, but with the exception of the Northern Caucasus region they belong palaeobiogeographically to the Boreal and Sub-Boreal types, whereas Jurassic GSSPs are based mainly on Sub-Mediterranean or Mediterranean successions (below, these are given after Ogg et al. 2012). However, all international stages can be traced in Russia and only the uppermost Jurassic requires the Volgian Stage to be used. The "Boreal" nature of the Russian Jurassic deposits has led to common usage of the Boreal Standard, which is based primarily on Boreal ammonite successions but also includes parallel zonal scales of other fossil groups (Zakharov et al. 1997; Shurygin et al. 2011). Here, we review the Jurassic marine deposits and stages boundaries in Russia (Figs. 1 and 2). Further boundaries of the Jurassic stages in the Boreal areas could be fixed using SSSPs.

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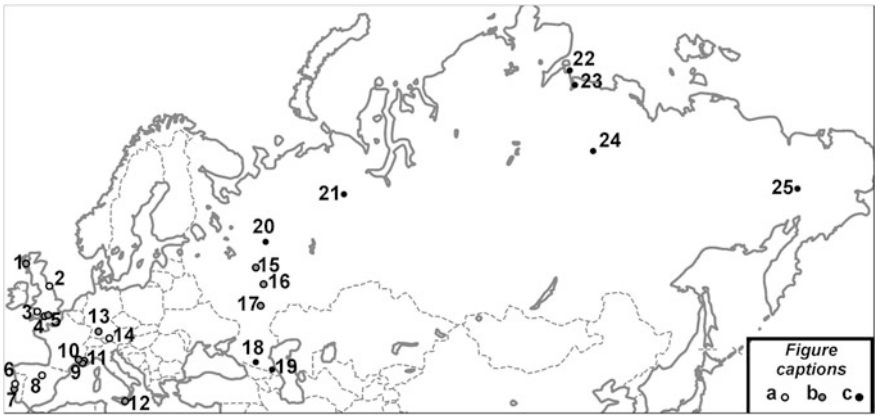

Fig. 1 Jurassic GSSP sections, GSSP candidates (**a**) ratified, (**b**) candidates, and reference sections of the Jurassic in Russia (**c**). 1—Flodigarry (j_3k), 2—Wine Haven, Robin Hood's Bay (j,p), 3—East Quantoxhead (j,s), 4—Redicliff point (j_3o), 5—Kimmeridge Bay (j_3t/v), 6—Murtinheria, Cabo Mondego (j_2b), 7—Peniche (j,t), 8—Fuentelsaz (j_2a), 9—Thuoux (j_3o), 10—Conjures (j_3t), 11—Ravin du Bès (j_2bt), 12—Fornazzo (j_3t), 13—Pfeffingen (j_2k), 14—Kuhjoch (j,h), 15—Prosek (j_3k), 16—Gorodischi (j_3tv), 17—Saratov (j_2bt, j_3o), 18—Bolshaya Laba river basin (j_1p), 19—Daghestan (j_2a-bt), 20—Mikhalenino, Makariev (j_3k), 21—Lopsia, Jatriya rivers (j_3v), 22—Nordvik Peninsula (j_3k, J/K boundary), 23—Anabar Bay (j_2bt), 24—Mollodo river basin (j_2a-b), 25—Kedon river basin (j_1s_1 j_1t)

Descriptions of Stages

Hettangian Stage

Hettangian marine deposits are known only from the north of Siberia and northeastern Russia (Krymholts et al. 1988). The lowermost Hettangian is characterized by *Psiloceras* ex gr. *planorbis* occurrences, but below these records ammonites are missing and there is no evidence for the *Spelae* Zone still recorded. A further lower boundary of the Jurassic System in these regions could be recognized through chemostratigraphic studies using records of carbon isotope shift associated with this boundary.

Sinemurian Stage

The base of the Sinemurian Stage in the GSSP is defined by the first appearance datums (FADs) of *Vermiceras* and *Metophioceras* genera. Sinemurian deposits are known not only from Siberia and northeastern Russia, but also occurred in the Northern Caucasus, although the basal portion of the stage is possibly missing in the latter area. The most complete Sinemurian succession, overlying Hettangian rocks, crops out in the Omolon Block (Kedon River, see Krymholts et al. 1988).

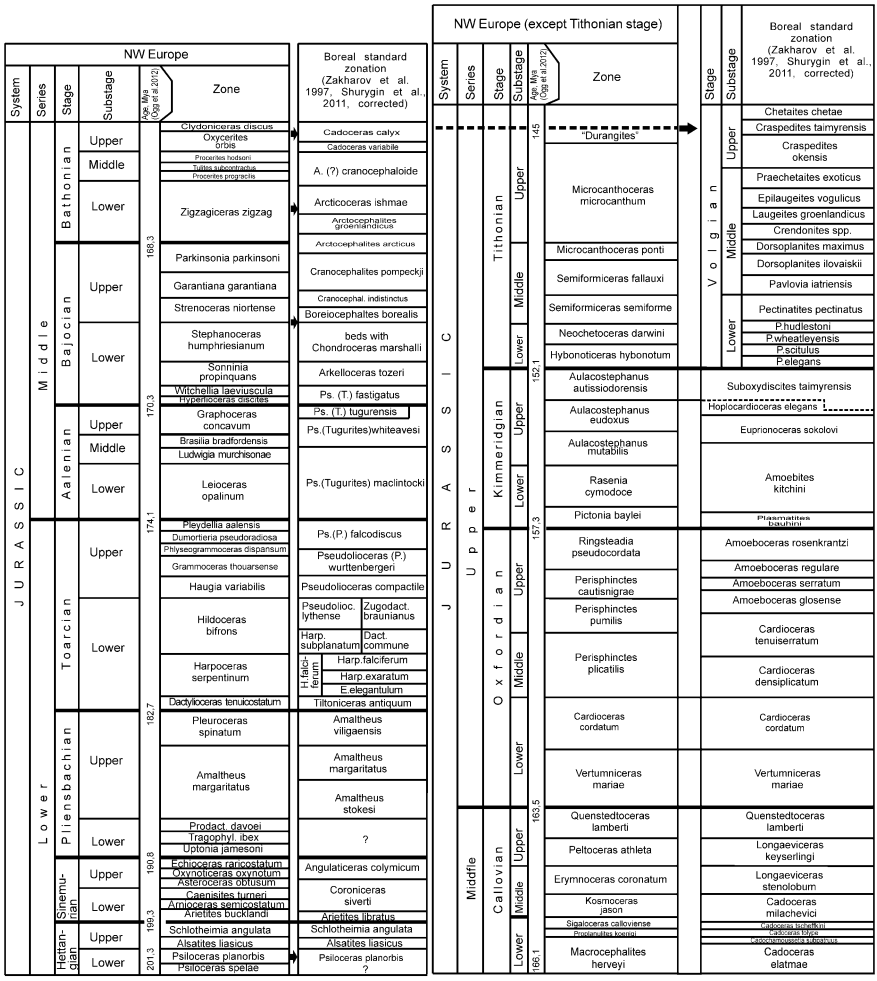

Fig. 2 Boreal ammonite zonation and its correlation with the standard succession. Tentatively correlated boundaries are marked by a *grey pattern*, nearby levels of direct correlation are indicated by *arrows*

Pliensbachian Stage

The key events for recognizing the base of the Pliensbachian are the FADs of *Bifericeras donovani* and *Apoderoceras* sp. In Russia, the Sinemurian–Pliensbachian boundary is strongly characterized by ammonites only in the Northern Caucasus (a succession near the junction of the Bolshaya Laba and Zelenchuk rivers).

This area is the most promising for a detailed study of the discussed boundary. In the north of Siberia and northeastern Russia, records of lower Pliensbachian ammonites are unknown and the lower boundary of this stage is only tentatively drawn.

Toarcian Stage

The base of the Toarcian Stage is defined by the FAD of *Eodactylites*, which co-occurs with *Paltarpites*, *Tiltoniceras*, and *Lioceratoides*. Toarcian deposits are the most widely distributed of the Lower Jurassic in Russia, but the basal part of this stage is mainly missing. The lowermost part of the Toarcian is completely absent in the Northern Caucasus. In northeastern Russia and the north of central Siberia, as well as in western Siberia, lower Toarcian clayey sediments are clearly recognized, but the lower zone of the stage is rarely present (Knyazev et al. 2003). The full succession of the Toarcian, characterized by ammonites, is recognized at the Kedon River basin. This section has been chosen as a reference for the Toarcian of northeast Asia (Knyazev et al. 2003).

Aalenian Stage

The lower boundary of the Aalenian Stage is marked by the appearance of *Leioceras opalinum*. Complete sections of the Aalenian, in which this event can be directly recognized, are located at Daghestan, Northern Caucasus (see Kazakova 1984), although these sections were not studied for more than 30 years. Marine Aalenian rocks are also widely distributed in Siberia and northeastern Russia, but the position of the Toarcian–Aalenian boundary still remains unclear. Traditionally, the base of the Aalenian has been marked by the FAD of *Pseudolioceras* (*P.*) *beyrichi*, but in the European succession this species appears in the upper Toarcian, as noted by Knyazev et al. (2007). Those authors proposed the level of the FAD of *Pseudolioceras* (*Tugurites*) as the marker of the lower boundary of the Aalenian, but the proximity of this level to the FAD of the genus *Leioceras* is still not certain.

Bajocian Stage

The base of the Bajocian Stage is denoted by the FAD of ammonite genus *Hyperlioceras*. In Russia, the marine Bajocian deposits are distributed in the same areas as the Aalenian. The best Russian Bajocian sections, in which the lower boundary of the stage can be recognized directly, are located in central Daghestan. Full Bajocian successions are also known from northern Siberia and northeastern

Russia (Meledina and Shurygin 2000), but correlation of the Boreal base of the Bajocian (FAD of the *Pseudolioceras* (*Tugurites*) *fastigatus*) with the GSSP boundary still remains tentative. A section by the Molodo River has recently been proposed as the reference section for the Aalenian and lower Bajocian of northern Siberia (Knyazev et al. 2007).

Bathonian Stage

At the GSSP of this stage, the lower boundary is recognized by the FADs of *Gonolkites convergens* and *Morphoceras parvum*. This level is very clearly recognized in Daghestan and can be easily traced northwards to the Saratov region, in which it is marked by the FAD of *Oraniceras* (Mitta 2009). The position of the Bajocian–Bathonian boundary in the Arctic is tentative and drawn either at the base (Shurygin et al. 2011) or at the top (Mitta 2009) of the *Arcticus* Zone. However, correlation levels lie either below (base of the upper Bajocian) or above (base of the *Ishmae* Zone) this boundary. The best sections of the Boreal Bathonian are found in northern Siberia (Anabar Bay).

Callovian Stage

The base of the Callovian, defined by the FAD of Sub-Boreal ammonite *Kepplerites keppleri*, is clearly recognized in the European part of Russia, and can be easily traced throughout the Arctic by using the cardioceratid succession (Kiselev and Rogov 2007).

Oxfordian Stage

The Oxfordian Stage is the single Jurassic stage, of which the key event for GSSP recognition is based on the FAD of the Boreal ammonite genus *Cardioceras*, thus it is easily recognized in those regions of Russia where Middle–Upper Jurassic transitional beds are exposed.

Kimmeridgian Stage

The base of the Kimmeridgian Stage is defined by the FAD of the Sub-Boreal genus *Pictonia*, which corresponds closely to the FAD of the Boreal genus *Plasmatites* and which can be effectively traced throughout the Boreal and Sub-Boreal areas (cf. Wierzbowski 2010).

Tithonian (Volgian) Stage

The Tithonian Stage is represented only for the southernmost part of European Russia, the Northern Caucasus, but it is still poorly studied here. For the Sub-Boreal and Boreal areas in Russia, the Volgian Stage is used. It should be noted that the base of the Volgian, defined by the last appearance datum (LAD) of *Aulacostephanus* (Gallois 2011), is very clearly traced in the Sub-Boreal Realm and coincides with the base of the Tithonian (FAD of *Hybonoticeras hybonotum*).

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