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DISCUSSIONS

Did an Ice Sheet Exist in Northeast Asia at the Middle–Late Jurassic Boundary? (Critical Remarks on the Article by Y. Donnadieu et al. (2011) "A Mechanism for Brief Glacial Episodes in the Mesozoic Greenhouse")

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Abstract—Results of climate modeling of Northeast Russia for the Middle–Late Jurassic boundary (Donnadieu et al., 2011) are critically reviewed. Geological and paleontological data are presented that indicate that the giant ice sheet which, according to the model, covered the entire territory in question at the Middle–Late Jurassic boundary did not exist.

Keywords: glaciation, paleoclimate, Callovian, Oxfordian, Arctic

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INTRODUCTION

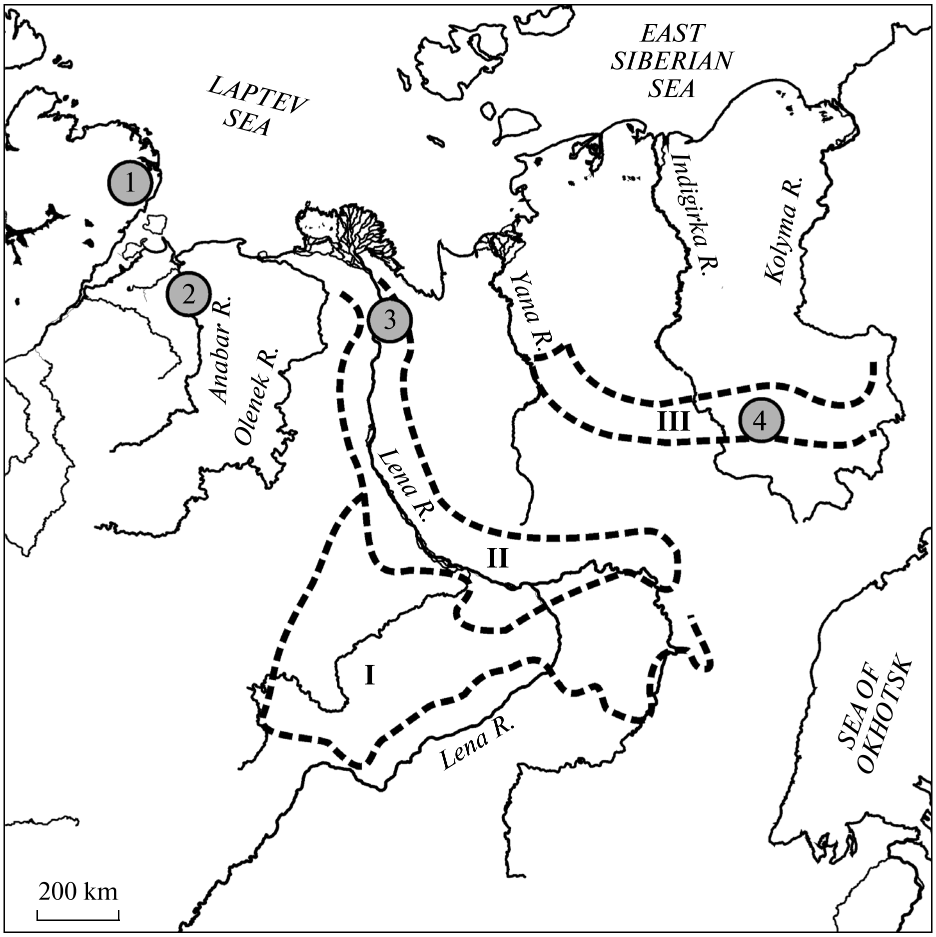
One of the achievements of modern geoscience is the use of computer modeling for paleoclimatology, amongst other subjects. Previously, paleoclimates of latitude belts were evaluated qualitatively (on the basis of the assemblage of lithological and paleontological climate indicators and their averages) for large time intervals, mainly periods (Yasamanov, 1985; Scotese, 2000) and, less often, ages (Chumakov, 2004). The use of a geological framework and realistic initial data for computer models now allows the acquisition of a set of quantitative climate indicators which includes average and seasonal temperatures, precipitation, and a number of others (Valdes and Sellwood, 1992; Valdes et al., 1999; Rees et al., 2000).

RESULTS AND DISCUSSION

The results of computer modeling and reconstructions based on climate indicators (distribution of coal, bauxites, glendonites, thermo- and cryophilic organisms, presence of glacial deposits, dropstones, etc.) are generally consistent with each other, although for selected time intervals significant discrepancies are observed between the model results and geological data. In this way, the model-derived characteristics of the high-latitude climate of the Late Cretaceous Northern Hemisphere poorly correlate with the results of morphometric analysis of fossil dicotyledonous leaves (CLAMP method; see Spicer et al., 2008; Spicer and Herman, 2010; Craggs et al., 2012); however, reconstructions obtained in different ways are generally similar. The integrated use of these methods ensures mutual control and increases the reliability of the results.

Neglect of geological data in paleoclimatic computer modeling may lead to errors, which can sometimes be unfortunate. An example is the reconstruction presented by Donnadieu et al. (2011) for the boundary interval between the Middle and Late Jurassic of the Northern Hemisphere. This reconstruction shows a giant ice sheet, according to the authors only slightly smaller than Antarctica; its thickness exceeded 5 km and it stretched 4000 km from Chukotka to the western edge of the Siberian Platform.

This alleged shield would have covered many large troughs, containing continental and marine Jurassic deposits, and would have left traces of its existence there. However, no traces of Jurassic glacial deposits have been found to date in these relatively well studied troughs. Occasional glendonites and very rare traces of debris dispersal by seasonal ice rafting are found in several sections; this is not surprising as, on the basis of paleomagnetic data, this region was in the high polar latitudes during the Jurassic, while all the reliably dated glendonites and dropstones are more ancient. In general, they are typical of the Bajocian and Bathonian, are less common in the Lower Callovian, and are known from only two sections (Chernokhrebetnaya River and Bol'shoy Begichev Island) in the Upper



Geographic locations of sections (1–4) and tectonic structures (I–III) in the region which, according to the model discussed, were entirely covered by an ice sheet at the Callovian–Oxfordian boundary. 1—Chernokhrebetnaya River, 2—Anabar River, 3—Cape Chucha, 4—Artyk River; I—Vilyui Basin, II—Verkhoyansk Foredeep, III—In'yali-Debin Synclinorium.

Callovian—but even here glendonites are not found in the terminal part of the stage (Wierzbowski and Rogov, 2011). We should note that Lower Oxfordian glendonites are unknown from the Northern Hemisphere and Upper Oxfordian–Kimmeridgian glendonites (from beds containing *Buchia concentrica*) are very rare and are known only from the In'yali-Debin Synclinorium (Paraketsov and Paraketsova, 1989) and northern Yukon (Poulton, 1982).

Thick continental sections of the Middle and Upper Jurassic have been studied in detail in the Vilyui Basin, located in the east of the Siberian Platform. In the western part of the Vilyui Basin, these deposits have been studied in detail on the fringes of the Kempendyay River salt domes, and in the central part, in boreholes (Chumakov, 1959). Neither glacial deposits nor even the smallest signs of a cold climate, such as glendonites and traces of dispersion by seasonal ice rafting (dropstones), were found in any of these sections. However, over the 300000 year period, the estimated duration of glaciation in the paper in question, considerably thick glacial members (comparable in size to the East European and American Quaternary glacial deposits) should have accumulated in active depressions such as the Vilyui Basin and Verkhoyansk Foredeep. Additionally, both macrofloral (Vakhrameev, 1987) and *Classopolis* pollen content (Vakhrameev, 1980) data from northern Siberian sections indicate that there was a considerable warming of the climate at the boundary of the Middle and Late Jurassic. In the northern part of the Verkhoyansk Foredeep, adjoining the Vilyui Basin from the east, Riphean and Early Paleozoic blocks and fragments of dolomitic limestones and dolomites are found in Bajocian deposits; these occur as relatively fine-grained sandstones and siltstones. These blocks are interpreted as signs of dispersal by seasonal ice rafting (Tuchkov, 1973). Such blocks are not found in the Bathonian–Callovian and Upper Jurassic deposits of the Verkhoyansk Foredeep. There are complete sections of Callovian and Oxfordian boundary deposits in the north of the Verkhoyansk Foredeep; these are well characterized by ammonoids, for example, the Cape Chucha section where the Callovian–Oxfordian boundary runs inside a monotonous member of fine-grained siltstones (Koshelkina, 1963). Analogous sections are also known from more western regions: on the Anabar River, where the boundary of the Middle and Upper Jurassic series also runs through a monotonous bed, and on the Chernokhrebetnaya River (Knyazev, 1975). There are no signs of a gap between the Callovian and Oxfordian, of glacial deposits, or even of such traces of a cold climate as glendonites or dropstones in any of these sections (figure).

Marine Middle and Upper Jurassic deposits are widespread in the Yana–Kolyma Foldbelt, to the east of the Verkhoyansk Ridge. Several more complete Middle–Upper Jurassic sections were studied in the southwestern and eastern parts of the foldbelt with the aim of finding traces of iceberg and seasonal ice rafting of coarse detrital material (Chumakov and Frakes, 1997). Seasonal ice deposit members (Epstein, 1977) have been described from the Callovian–Oxfordian part of the Artyk River section (Koster Formation) (figure). They turned out to be wild flysch breccias, and not even seasonal ice deposits were found, though there were some glendonite finds (Chumakov and Frakes, 1997). In addition, the age of the Koster Formation was apparently incorrectly identified and it should be dated to the Bathonian rather than the boundary interval of the Middle and Late Jurassic (Wierzbowski and Rogov, 2011). Middle–Upper Jurassic glacial deposits were not found in more eastern regions than the Yana-Kolyma Foldbelt, up to the Chukotka Peninsula (Paraketsov and Paraketsova, 1989; Tibilov and Cherepanova, 2001; Vatrushkina and Tuchkova, 2014).

Signs of gradual climate warming are observed in Callovian deposits in the northern regions of Siberia. This is evidenced by an increase in the carbonate content of deposits and gradual disappearance of glendonites. Interlayers of organogenic detrital and, more rarely, oolitic limestones appear in the top part of the Callovian. The taxonomic diversity of different faunistic groups increases toward the end of the Callovian (Eboraciceras subordinarium Zone, an equivalent of the Quenstedtoceras lamberti Zone) and this is conserved at the start of the Oxfordian in the Cardioceras obliteratum Zone (equivalents of the Vertumniceras mariae Zone). At this time, thermophilic bivalves (oysters, *Isognomon*, *Pinna*, and *Plagiostoma*) were widely disseminated in northern Siberia (Kaplan et al., 1979, p. 63). Twenty bivalve genera, including the thermophilic *Isognomon* and oysters, have been found in the Upper Callovian and Lower Oxfordian of Northeast Asia (Kolyma River and Anyui River basins) (Paraketsov and Paraketsova, 1989).

The reconstruction of the giant ice sheet in Northeast Asia put forward by Donnadieu et al. (2011) is not supported by the numerous geological facts listed above. Moreover, it contradicts these facts. The results of this modeling are clearly erroneous, if not absurd. Geological data indicate a moderately cold climate in the Middle to Late Jurassic in this region with a clear warming trend toward the end of the Middle and beginning of the Late Jurassic. However, to supporters of the "cold snaps" hypothesis in the Mesozoic, the boundary under discussion is one of the good examples of such glaciations, which are suggested by indirect evidence only (eustatic fluctuations and increased $\delta^{18}O$). The authors of the paper in question did not find it necessary to compare the results of their study with existing geological data and limited themselves to abstract reasoning and modeling. This example shows that, in the absence of a geological control, computer modeling of paleoclimates becomes a computer game and compromises a valuable method.

Reviewer A.B. Herman

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