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Similarity of Early and Middle Jurassic brachiopods between the Danubian and Getic tectonic units of eastern Serbia

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ABSTRACT

Rich brachiopod assemblages are known from the Lower and Middle Jurassic deposits of the Danubian and Getic tectonic units (eastern Serbia). A quantitative assessment of the relevant palaeontological data can shed light on the relationship of these units in the palaeospace. In the present study, the brachiopod assemblages from the Danubian and Getic tectonic units are compared with similarity indices (the Jaccard similarity of species, genera, families, and superfamilies, and the Czekanowski and Gower similarity of the genus–species, family–species, and superfamily-species diversity structures). This analysis is applied to five geological time slices when brachiopods flourished regionally, namely the Early Pliensbachian, the Late Bajocian, the Early Bathonian, the Middle Bathonian, and the Late Bathonian. Generally, the values of the indices imply moderate similarity. The similarity was significantly lower in the Middle Jurassic relatively to the Early Jurassic. The similarity of the Early Pliensbachian brachiopods of the Danubian and Getic tectonic units was significant relatively to the similarity between some European regions. The documented decrease in the similarity through the geological time can be explained by the increase in the global palaeobiogeographical differentiation in the Middle Jurassic.

1. Introduction

During the past decades, there has been significant progress in the understanding of the Jurassic palaeogeography, palaeobiogeography, and palaeotectonics (Hallam, 1969, 1975; Vörös, 1993; Westermann, 2000; Stampfli and Borel, 2002; Golonka, 2004; Seton et al., 2012; Damborenea et al., 2013; Dera et al., 2015). However, many particular problems still require solution. For instance, the works of Tchoumatchenco et al. (2006, 2008, 2010, 2011) permitted one to distinguish between the Danubian and Getic tectonic units on the territory of eastern Serbia (Fig. 1), although the relationship of these units in the palaeospace is yet to be fully understood. It appears that application of various palaeobiogeographical techniques can solve this problem efficiently. The most appropriate fossil group, data on which allow detailed, quantitative assessment of the Jurassic regional palaeobiogeographical patterns, is Brachiopoda (cf. Ruban and Vörös, 2015). About a hundred of its species belonging to different genera, families, and superfamilies are known from many localities in eastern Serbia (Radulović, 1995; Ruban et al., 2015).

The Early and Middle Jurassic brachiopods of eastern Serbia were applied tentatively for the purposes of discussion of the palaeobiogeographical affinity of the regional faunas (Radulović, 1995). Recently, Ruban et al. (2015) also compared the brachiopod taxonomic diversity dynamics between the Danubian and Getic tectonic units. The results of this research allowed one to realize that these units were characterized by certain similarity and both units were located near the Boreal–Tethyan transition. The present study differs fundamentally from the previous works. Its main objective is to establish similarity of Early and Middle Jurassic brachiopods between the noted units on the quantitative basis. This will permit one to understand the possible palaeobiogeographical relationship of the Danubian and Getic tectonic units in the palaeospace, as well as to discuss the possible influences of changes in the global palaeobiogeographical differentiation and some other factors on the dynamics of this relationship.

2. Geological setting

Eastern Serbia has a highly-complex geological structure. The works of Radulović (1995) and Tchoumatchenco et al. (2006, 2008, 2010, 2011) permitted to outline several tectonic units (terranes) located on the active northwestern margin of the Neo-Tethys Ocean (Fig. 1). Among the others, these include the Danubian tectonic unit (Danubicum) and the Getic tectonic unit (Geticum). These generally elongated tectonic slices from a kind of "puzzle" in the present-day regional structure. Nonetheless, it is possible to assign the Lower and

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Middle Jurassic deposits of particular localities to these units (Radulović, 1995; Ruban et al., 2015).

The Lower and Middle Jurassic deposits are spread widely in eastern Serbia (Jankičević et al., 1983; Radulović, 1993, 1995; Radulović and Rabrenović, 1993; Andjelković et al., 1996; Tchoumatchenco et al., 2006, 2008, 2010, 2011; Carević et al., 2011; Radulović, 2013). These are dominated by carbonates, although siliciclastic strata are also present. The total thickness is measured by dozens of metres, and it reaches 150 m. Abundant fossils (ammonites and brachiopods are especially good stratigraphical markers) permitted one to develop the regional stratigraphical framework and to establish the presence of formal stages (Fig. 2). Shallow-marine and deep-marine palaeoenvironments are interpreted for the study territory in the Early–Middle Jurassic; there are also continental and sea mount facies (Ruban et al., 2015; see also Andjelković & Mitrović-Petrović, 1992).

Early and Middle Jurassic brachiopods of eastern Serbia have been studied for a long time (Sučić-Protić, 1969, 1971, 1985; Urošević and Radulović, 1990; Radulović, 1993, 1995; Radulović and Rabrenović, 1993; Carević et al., 2011). The available data on their distribution have been summarized recently by Ruban et al. (2015). These authors updated brachiopod taxonomy and brought it in order according to the present systematics (Kaesler, 1997–2007). Rich brachiopod assemblages characterize the Early Pliensbachian, Late Bajocian, Early Bathonian, Middle Bathonian, and Late Bathonian substages. Rare brachiopods were also reported from the other stratigraphical intervals.

3. Material and methods

The present study is based on the palaeontological data summarized by Ruban et al. (2015), who outlined the stratigraphical distribution of brachiopod species, genera, families, and superfamilies in the Lower–Middle Jurassic substages. These data have been updated for the purposes of this study (e.g., "deeper" taxonomic correction has been made). Attention is paid only to the five geological time slices that are characterized by rich brachiopod assemblages, namely the Early Pliensbachian, the Late Bajocian, the Early Bathonian, the Middle Bathonian, and the Late Bathonian (Supplementary material). A total of 80 brachiopod species and dozens of taxa of the higher ranks are taken into consideration.

The similarity of brachiopods between the Danubian and Getic tectonic units is assessed quantitatively with several indices for each geological time slice. The first method is based on the Jaccard index (J) that permits to establish "simple" similarity between two assemblages on the basis of the presence/absence of taxa (Jaccard, 1901):

$$J = C/[(N_1 + N_2) - C], \quad (1)$$

where C is the number of common taxa for two time intervals and N_1 and N_2 are the numbers of taxa in the earlier and later intervals respectively. In this study, the J similarity is calculated for species, genera, families, and superfamilies. The second and third methods are based on the Czekanowski's Quantified Coefficient (QC) (Sepkoski, 1974) and the Gower index (G) (Gower, 1971) respectively (there are not simple formulae, and detailed explanations of the relevant approaches can be found in the noted original works). These permit to evaluate similarity between two assemblages, where the presence of higher-ranked taxa is indicated as the number of the relevant lower-ranked taxa. In other words, the similarity of the taxonomic diversity structure is analyzed in such a case. In the present study, the superfamily–species, family–species, and genus–species diversity structures are analyzed (Table 1). The validity of these two methods for the purposes of palaeobiogeographical analysis has been demonstrated, particularly, by Ruban and Vörös (2015); it is sensible to use these methods together, and the difference between their results indicate the degree of methodological error that should be taken into consideration in further interpretations. The values of the J, QC, and G indices vary between 0.00 (total dissimilarity) and 1.00 (total similarity).

The values of the above-mentioned indices calculated for several geological time slices (Early Pliensbachian, Late Bajocian, Early Bathonian, Middle Bathonian, and Late Bathonian) permit one to judge about changes in the similarity of Early and Middle Jurassic brachiopods between the Danubian and Getic tectonic units. Such dynamics allows discussion of the possible influences of some global and regional factors on the assemblage similarity.

4. Results

In all analyzed geological time slices, the J similarity of brachiopods between the Danubian and Getic units increases from the level of species to the level of superfamilies (Table 2), which seems to be a kind of self-evident relationship. For species and genera, the J similarity was the highest in the Early Pliensbachian and the lowest in the Early Bathonian. The only difference for families is the lowest similarity in the Middle Bathonian, and the only difference for superfamilies is the equally minimal values in the Early and Middle Bathonian. The assemblage similarity can be judged low on the level of species, because the values are below 0.2 in all cases except for the Early Pliensbachian (Table 2). On the level of genera, the situation is the same, although the value for the Late Bathonian can be judged moderate. Things are different on the levels of families and superfamilies, where the index values are either high or moderate. On the basis of all absolute values of the J similarity, one can conclude about generally moderate similarity of the brachiopod assemblages of the Danubian and Getic units.

The conclusion made above is confirmed by the results of the assessment of the QC and G similarity (Tables 3 and 4). These values are chiefly neither too high, nor too low. One should note that the QC similarity was not as high in the Early Pliensbachian (relatively to the other time slices) as the J similarity, and the differences in the QC similarity between the analyzed geological time slices were not very strong (Table 3). However, this difference from the results of the J similarity assessment should be interpreted as the only terms of methodological peculiarities, because the G values show generally the same tendencies as the J values.

The results of the analysis (Tables 2–4) permit one to describe the dynamics of the brachiopod similarity between the Danubian and the Getic tectonics units. This similarity was relatively high in the Early Pliensbachian. It was lower in the Late Bajocian and decreased significantly in the Early–Middle Bathonian, when assemblages from different tectonic units were relatively dissimilar. The similarity rose again in the Late Bathonian and reached more or less the same degree as it was in the Late Bajocian. Particularly, this dynamics is demonstrated well by species and genera (Fig. 2). Generally, the similarity was about twice weaker in the Late Bajocian–Late Bathonian than in the Early Pliensbachian. Moreover, the difference between the highest and lowest values of the indices is very strong. For instance, the J similarity of species decreased from the Early Pliensbachian to the Early Bathonian by ~6 times, and the G similarity of the genus–species diversity structure decreased between the same geological time slices by ~5 times. These findings echo the earlier conclusion of Radulović (1995) about similarity changes, although provide significantly more accurate record of the similarity dynamics.

5. Discussion

The results presented above permit one to judge about the absolute strength of similarity of Early and Middle Jurassic brachiopods between the Danubian and Getic tectonic units of eastern Serbia. However, understanding of whether the registered similarity was really big or not requires comparison with the similarity established between the other regions with the same methods as employed for the purposes of the present study. Such information is available for the Early Pliensbachian.