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THE PALAEOGEOGRAPHIC POSITION OF THE JADAR BLOCK (VARDAR ZONE, NW SERBIA) IN THE EARLY CARBONIFEROUS

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Abstract: The Milivojevića Kamenjar section in Družetić (NW Serbia) is the most diverse Carboniferous ammonoid occurrence on the Balkan Peninsula. It contains two faunal complexes, an early Late Viséan and a fauna from the Viséan-Serpukhovian boundary. The early Late Viséan assemblage is similar to time equivalent occurrences of the North Variscides and north-western Africa. It is integrated in a cosmopolitan ammonoid distribution of this time interval. The Viséan-Serpukhovian boundary assemblage is very different to its time equivalents from the North Variscides and as a result indicates provincialism; it belongs to the South Variscan–North Gondwanan faunal realm and is closely related to the occurrences in the Cantabrian Mountains of Spain and the South Urals.

Keywords: Viséan, Serpukhovian, palaeobiogeography, Ammonoidea, NW Serbia

1. Introduction

The distribution of Palaeozoic terranes between the supercontinents Laurussia and Gondwana is poorly understood, in particular, the precise palaeogeographic position of the occurrences of Carboniferous sedimentary rocks on the Balkan Peninsula is still an unsolved problem. Another point of contention is the timing of the closure of the Palaeotethys Ocean; the traditional model postulates a very close approximation of Laurussia and Gondwana in Early Carboniferous times (e.g., Matte, 1991), whereas other authors (e.g., Stampfli and Borel, 2002; Cocks and Torsvik, 2006) postulate a wide ocean between the two supercontinents at this time.

Analyses of time-equivalent ammonoid assemblages, including the occurrences on the Balkan Peninsula, may help to understand the relationships between the various regions with Carboniferous rock successions. We analysed the faunal spectrum of two time intervals, which are widely represented by ammonoid faunas, (1) the early Late Viséan (middle Asbian), and (2) the early Serpukhovian (Pendleian) with respect to similarity and dissimilarity between the regions. Based on the occurrence of ammonoid genera, a cluster analysis was achieved, and the results can be discussed in the context of geological data.

Up to now, only one occurrence of Early Carboniferous ammonoids is known from the Jadar Block, and only one further occurrence, i.e. Prača near Sarajevo (Kittl, 1904), has been described from the Balkan Peninsula. At the Milivojevića Kamenjar site in Družetić (which will be referred to later in the text as Družetić) in north-western Serbia (first described by Stevanović and Kullmann, 1962), two ammonoid-bearing intervals are exposed: (1) an early Late Viséan horizon containing the genera *Entogonites*, *Beyrichoceras*, *Goniatites*, and *Prolecanites*, and (2) a latest Viséan – early Serpukhovian horizon with *Pachylyroceras*, *Dombarites*, *Rhymmoceras*, *Irinoceras*, and *Uralopronorites*. Both intervals can be rather precisely correlated with the time-equivalent ammonoid occurrences in Central and North-western Europe, North Africa, the South Urals, western United States, etc.

2. Geographic and geologic position of the Jadar Block

The Jadar Block is located at the southern margin of the Pannonian Basin: mostly in north-western

Serbia, southern Srem, and partially westward over the Drina River in eastern Bosnia. The name of this tectonostratigraphic unit, which is presently a part of the Vardar Zone, derived from the 'Jadar development of Palaeozoic' (Simić, 1938). The Jadar Block is considered as an isolated, exotic block terrane, in which Dinaridic features predominate. It was incorporated into the Vardar Zone before the Late Cretaceous (Karamata et al., 2000; Karamata, 2006). In this area, deposition of sediments took place during the Variscan and Early Alpine evolution with obvious similarities to time-equivalent successions of the 'Bükkium' (NE Hungary), the Sana-Una terranes (NW Bosnia and Herzegovina), and even the Carnic Alps (Protić et al., 2000; Filipović et al., 2003).

3. Methods

We investigated the ammonoid occurrences of Late Viséan and Serpukhovian age based on the comprehensive database AMMON (Korn and Ilg, 2009) by means of a cluster analysis. In this analysis, we paid special attention to the two stratigraphic ages represented in the Družetić outcrop, for an integration of this occurrence in the global scale. These two time slices are:

3. 1. Early Late Viséan – this time interval is rather easy to characterise because it almost perfectly correlates with the *Entogonites* Genus Zone (Korn et al., 2007). It marks the transition from an interval with rather low ammonoid diversity (Early and Middle Viséan), which is globally represented only by a few considerably rich ammonoid occurrences (North Urals: Kusina, 1980; North England: Riley, 1996; Gourara region of Algeria: Bockwinkel et al., 2010) to the time period in which the Ammonoidea shows a rapid diversification (Late Viséan, Serpukhovian; Ruzhencev and Bogoslovskaya, 1971). For our analysis, we included only those occurrences with at least five ammonoid genera. These seven occurrences are (literature sources in brackets):

- Anti-Atlas (Korn et al., 1999; 2005)
- North England (e.g., Bisat, 1934, 1952; Riley, 1993)
- Rhenish Mountains (e.g., Nicolaus, 1963; Korn, 1988, 1990)
- Antler Foreland Basin (Korn and Titus, unpublished data)
- Alaska (Gordon, 1957)
- South Portugal (Korn, 1997a; Korn and Horn, 1997)
- Družetić (this article)

The revised spectrum of genera recorded in Družetić is composed of the following genera:

Entogonites – *E. tetragonus* (Kullmann, 1962) (very common), *E. grimmeri* (Kittl, 1904), and *E.* cf. *nasutus* (Schmidt, 1941).

Ubites (a genus newly described by Korn (in Korn et al. in press) with the new species *U. filipovici*).

Goniatites – *G. crenistriatoides* (Kullmann, 1962).

Beyrichoceras, *Bollandites*, *Prolecanites*, and an undescribed new genus with undescribed species.

The analysis is based on a very heterogeneous data set. While the north-west Serbian occurrence in Družetić is based on only one single small outcrop, some others (Anti-Atlas, Alaska, South Portugal) are based on a limited area of a few square metres, and some (North England, Rhenish Mountains) contain numerous outcrops and have a long history of investigation. For this reason, a sampling bias may influence the analysis.

Entogonites is present in all the regions except for South Portugal and serves as a good index ammonoid. It is remarkable that the genus diversity within the occurrences ranges between five and nine and that no extraordinarily rich occurrences are known.

3.2. Viséan-Serpukhovian – for our analysis we focused particularly on the latest Viséan/early Serpukhovian transition (i.e., the transition from the Brigantian into the Pendleian). This time interval is somewhat difficult to correlate on a global scale because of significant ammonoid provincialism (Korn 1997b). We included the following occurrences, all with at least seven genera:

- South Urals (Ruzhencev and Bogoslovskaya, 1971)
- Rhenish Mountains (Horn, 1960; Korn, 2006)
- British Isles (Bisat, 1950; Yates, 1962)
- American Midcontinent (e.g., Miller and Furnish, 1940; Gordon, 1965)
- Antler Foreland Basin (Youngquist, 1949; Titus, 2000)
- Béchar Basin, Algeria (Pareyn, 1961)
- Cantabrian Mountains (Kullmann, 1962; Wagner-Gentis, 1963, 1980)
- Družetić (Korn et al. in press and in this article)

The ammonoid fauna from Družetić requires revision, but at the moment it is possible to identify the following genera in the fauna:

Irinoceras – I. stevanovici (Kullmann, 1962).
Dombarites – D. wocklumerioides (Kullmann, 1962) and possibly also *D. serbicus* (Kullmann, 1962).
Rhymmoceras – R. gracilentum Ruzhencev, 1958.
Glaphyrites – G. europaeus (Kullmann, 1962).
Pachylyroceras with an undescribed species.
Dombarocanites – D. chancharensis Ruzhencev, 1949.
Uralopronorites – U. mirus Ruzhencev, 1947.

Some of the determinations have to be confirmed after revision of the fauna. "*Eoasianites europaeus* Kullmann, 1962", for instance was assigned to *Glaphyrites* by Ruzhencev and Bogoslovskaya (1971, p. 37), but the occurrence in Družetić appears to be stratigraphically too old for this genus.

In contrast to the early Late Viséan occurrences, the genus richness differs markedly between the analysed regions, with the South Urals occupying an outstanding position with 27 genera, followed by the Béchar Basin in Algeria with 13 genera.

The cluster analysis was performed using Ward's linkage method, because this is only little sensitive for samples of different size.

4. Results and discussion

4.1. Early Late Viséan

For the early Late Viséan, three major provinces of occurrences of ammonoid genera can be separated (Figs. 1, 2):
(1) An eastern North American province (including Alaska and the Antler Foreland Basin).
(2) A North Variscan province (Central Europe, British Isles, Portugal), and
(3) A South Variscan/ North Gondwanan province with the Anti-Atlas and the Jadar Block.

The analysis is not very stable because of the low number of co-occurring ammonoid genera and their rather cosmopolitan distribution pattern. *Goniatites*, for instance has an almost global distribution and *Entogonites* has been reported from Alaska, Utah, Ireland, England, Germany, Poland, the Czech Republic, Bosnia and Herzegovina, Serbia, and Morocco (Fig. 1). It means that correspondence of these shelf areas must have existed in this time interval. Even more, the presence of the species *Entogonites grimmeri* (Kittl, 1904) at Prača near Sarajevo, Družetić in north-western Serbia, the Rhenish Mountains, and the British Isles suggests that the occurrences on the Balkan Peninsula were rather closely connected with the Rhenohercynian Basin. This pattern indicates that a closed Variscan land barrier had not been established in early Late Viséan times.

Fig. 1. Palaeogeographic map for the North Atlantic region of the early Late Viséan (after Scotese 1997; image (modified) by Ron Blakey, Flagstaff, Arizona, showing the distribution of the genera *Entogonites* and *Goniatites*. [AK – Alaska; YU – Yukon; NV – Nevada; UT – Utah; OK – Oklahoma; AR – Arkansas; MM – Moroccan Meseta; SP – South Portugal; IR – Ireland; BE – Belgium; RM – Rhenish Mountains; GB – England; MS – Moravia and Silesia; HC – Holy Cross Mountains; SU – South Urals; NU – North Urals; CM – Cantabrian Mountains; AA – Anti–Atlas; SV – Saoura Valley; BO – Bosnia and Herzegovina; JB – Jadar Block].

4.2. Early Serpukhovian

The distribution is different in the early Serpukhovian. Two major realms can be separated, both with two provinces (Figs. 3, 4):
(1) A south-eastern realm includes (1a) a Uralian-North Gondwanan province (including the South Urals and the Béchar Basin of Algeria) and (1b) a South Variscan province (Cantabrian Mountains and the Jadar Block).
(2) A north-western realm is composed of (2a) a North Variscan province (Central Europe, British Isles) and (2b) a North American province (American Midcontinent and Antler Foreland Basin).

The analysis is rather robust because of the high number of ammonoid genera (in total 40) and the limited palaeogeographic range of many of them. The strict separation of the two realms, visible in high distance values (Fig. 4) is caused by a partly endemic evolution in the various palaeogeographic regions including limited exchange of faunal elements. The evolution of the important family Goniatitidae, for instance, was truncated in the North Variscan province in the mid-Brigantian (with *Lusitanoceras* being the last representative). Occurrences in North America show very few descendents of the Goniatitidae up to horizons near the Viséan-Serpukhovian boundary. In the Urals, the goniatitid descendents are the predominant elements of the faunas on both sides of the Viséan-Serpukhovian boundary; they belong to at least seven genera (*Hypergoniatites*, *Neogoniatites*, *Dombarites*, *Deleshumardites*, *Proshumardites*, *Platygoniatites* and *Delepinoceras*) with numerous species. In the absolute numbers of specimens they outnumber the other co-occurring taxa. Occurrences in the Béchar Basin of Algeria, the Cantabrian Mountains, and in Družetić are similar in this respect. Similarly, the family Neoglyphioceratidae becomes extinct much earlier (mid-Brigantian) in the North Variscan province, but survives with numerous descendents in the Uralian-North Gondwanan province. This pattern is contrasting the evolution of the Girtyoceratids (genera *Girtyoceras*, *Edmooroceras*, *Tumulites*, *Eumorphoceras*), which are well-represented in the North Variscan and North American provinces, but are a lot less common in the other regions.

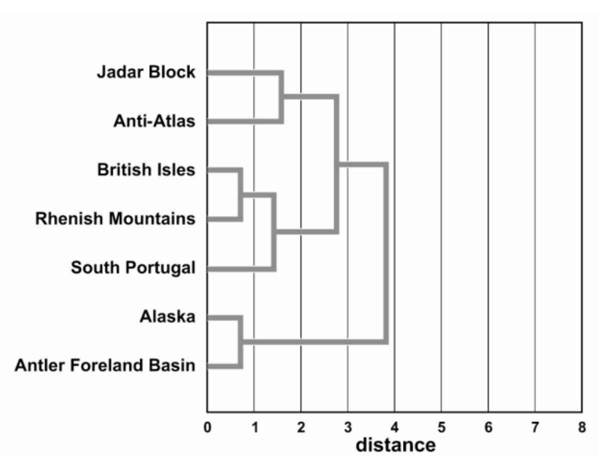

Fig. 2. Dendrogram of a hierarchical cluster analysis using Ward's linkage algorithm for the early Late Viséan ammonoid occurrences.

5. Conclusion

It can be concluded that the single ammonoid occurrence in Družetić indicates, for the early Late Viséan and early Serpukhovian, close relationships to other South Variscan-North Gondwanan occurrences. While for the early Late Viséan correspondence of the ammonoid faunas with the occurrences in Central Europe, the British Isles, as well as North America (Utah, Alaska) can be postulated, clear separation took place until the early Serpukhovian, for which the spectrum of genera suggests a South Variscan position of the Jadar Block.

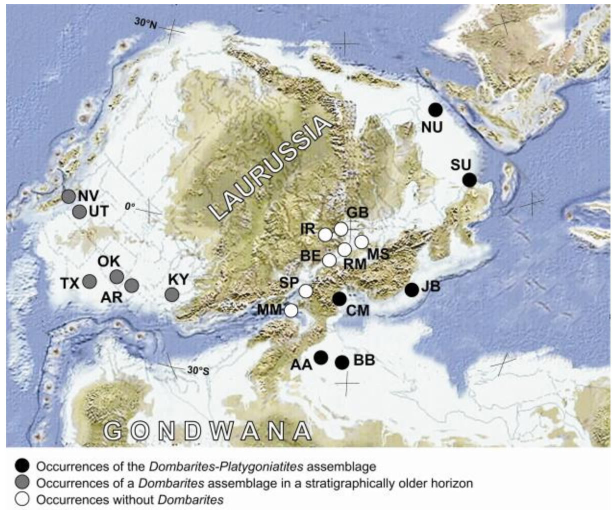

Fig. 3. Palaeogeographic map for the North Atlantic region of the Viséan-Serpukhovian boundary, after Scotese 1997; image (modified) by Ron Blakey, Flagstaff, Arizona. [NV – Nevada; UT – Utah; TX – Texas; OK – Oklahoma; AR – Arkansas; KY – Kentucky; MM – Moroccan Meseta; SP – South Portugal; IR – Ireland; BE – Belgium; RM – Rhenish Mountains; GB – England; MS – Moravia and Silesia; SU – South Urals; NU – North Urals; CM – Cantabrian Mountains; AA – Anti–Atlas; BB – Béchar Basin; JB – Jadar Block].

This interpretation is based on the presence of distinct genera (i.e., *Dombarites*, *Pachylyroceras*, *Rhymmoceras*) in the assemblage from Družetić and the absence of others (i.e., *Edmooroceras*, *Tumulites*), which are to be expected in faunas of this age. Not a single genus from Družetić is known from North Variscan time equivalent strata, but some of them (*Dombarites*, *Ophilyroceras*, *Rhymmoceras*) are characteristic elements in the occurrences of the South Urals and the Cantabrian Mountains.

It means that the generally increasing provincialism of the Early Carboniferous ammonoid faunas can also be observed in the single outcrop in Družetić. Here the stratigraphically older horizon (early Late Viséan) still contains some cosmopolitan elements, but in the younger horizon (with the turn into the Serpukhovian) it becomes separated from the North Variscan province and clearly belongs to the south-eastern biogeographic realm.

According to the ammonoid records, the palaeogeographic position of the Jadar Block at the southern flank of the Variscan would be the most likely situation. As Filipović et al. (2003) have pointed out, there exists a close resemblance between the Jadar Block, the Bükk (north-eastern Hungary), and the Carnic Alps (Austria, Italy) in terms of the sedimentological development during the Late Carboniferous and Permian. Unfortunately, there are no Viséan and Serpukhovian ammonoid faunas known from the Bükk and the Carnic Alps, and hence a direct comparison with the Jadar Block is not possible in this respect.

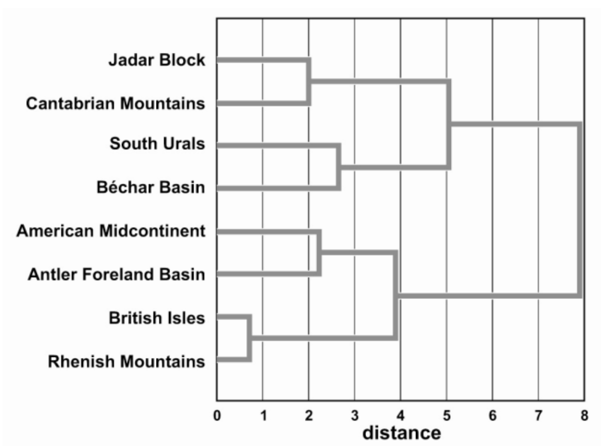

Fig. 4. Dendrogram of a hierarchical cluster analysis using Ward's linkage algorithm for the ammonoid occurrences at the Viséan-Serpukhovian boundary.

The ammonoid results confirm the palaeogeographic reconstruction by Stampfli and Borel (2002) and Stampfli and Kozur (2006), who placed these terranes in a position adjacent to the southern margin of Laurussia. However, these authors postulated a wide (more than 1,000 km) Early Carboniferous (~340 Ma) Palaeotethys Ocean, which was closed until the Bashkirian. Ammonoid relationships between the South Variscan and North Gondwanan shelves, however suggest that such a wide ocean is very unlikely and that at least the western end of the Palaeotethys (north-western Africa) had to be much narrower to allow faunal exchanges between South Variscan and North Gondwanan shelves during the Late Viséan and Serpukhovian.

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