Palaeoenvironments of northwestern Bulgaria and northeastern Serbia during the Jurassic

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Abstract. Jurassic rocks in the Danube Region of northwestern Bulgaria and northeastern Serbia have been the subject of numerous earlier studies that have shown notable similarities between their sedimentary facies and depositional environments. In terms of regional palaeotectonic zonation, this area represents the westernmost parts of the Vidin Early–Middle Jurassic Complex Horst and the Mihaylovgrad Early–Middle Jurassic Graben in NW Bulgaria, as well as the easternmost part of the Lower Danubium in NE Serbia, which collectively take part of the Jurassic Moesian Platform. For compiling an overall conception of the palaeoenvironments that existed during the Jurassic, nine palaeoenvironmental sketch maps, from the Aalenian to the late Tithonian, have been composed in this study, based on reinterpretation of the data borrowed from previous literature. It became evident that the Middle Jurassic sedimentary successions of the Danube Region record an evolution from an initially isolated lacustrine–palustrine depositional setting (Aalenian) to rapidly expanding shallow to moderately deeper-marine sandy–calcareous setting (late Bajocian–early Callovian). From the middle Callovian and onwards, during the Late Jurassic, the region became an area of laterally extensive pelagic and platform carbonate deposition. This interpretation is consistent with the available earlier data, but it links the facies and their respective settings from NW Bulgaria to NE Serbia, which has not been made to date and will be of benefit for future regional correlations.

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PREFACE

In the last years of his life, Platon Tchoumatchenco focused his work on the history of the geological science. In this respect, he was able to publish a huge amount of valuable information due to his patience and attention to detail, which have always been evident in his research studies. Despite being engrossed in other matter, which is different from the interests of his earlier years, Platon Tchoumatchenco never forgot his favourite field of study, palaeoecology. I was surprised when, a few years ago, he invited me to collaborate in the preparation of an abstract on the Jurassic palaeoenvironments of the Danube Region of northwestern Bulgaria and northeastern Serbia. The abstract was a poster presentation at the International Scientific Conference “Geoparks and Modern Society”, which took place in the early autumn of 2018 in the town of Belogradchik (see Sapunov *et al.*, 2018). In this poster, Tchoumatchenco summarized his knowledge on the Jurassic geology of the Danube Region, which he had accumulated during the long years of work in the Vidin area, but also achieved as a result of his intense contacts and collaboration with colleagues from Serbia. Nine palaeoenvironmental maps were included in the poster, and the maps represented Tchoumatchenco’s ideas on the evolution of the marine environments of this area, from the Aalenian (Middle Jurassic) to the late Tithonian (Late Jurassic). However, these maps remained only on the large sheet of the poster. Platon Tchoumatchenco considered publishing them, but his sudden death in 2019 thwarted his intentions. Proceeding from the fact that the palaeoenvironmental maps were completed and also that Tchoumatchenco had started work on a preliminary manuscript, the main results of his work are presented in this paper to the attention of the geologists from both Bulgaria and Serbia. Platon Tchoumatchenco was an extraordinary palaeontologist with original conceptions, and a man who has always been devoted to science. With the publication of his latest views, I would like to express my deep respect for his great contributions to the Jurassic geology of Bulgaria and to pay tribute to his memory.

Lubomir Metodiev

INTRODUCTION

The Jurassic strata and the Jurassic development of the area of northwestern Bulgaria have been the subject of extensive studies in many publications (e.g., Bončev and Popov, 1935; Stephanov, 1961, 1966, 1972; Stephanov and Tzankov, 1970; Tchoumatchenco, 1977, 1978a–d; Sapunov *et al.*, 1988). However, the evidence contained in these papers has long been confined to the Bulgarian/Serbian state border, and what is beyond the border, in northeastern Serbia, has been known mainly from the publications of Serbian geologists (e.g., Andjelković and Petković, 1975; Andjelković *et al.* 1996; Radulović *et al.*, 1997). During the previous decade, successful correlations between the

Jurassic lithostratigraphic units in NW Bulgaria and NE Serbia were made (Tchoumatchenco *et al.*, 2006a, 2006b, 2008, 2010a, 2010b, 2011). A result of this is that correlations between the Bulgarian and Serbian Jurassic lithostratigraphic successions have now attained the highest levels of reliability and detail. The present work is an attempt to continue the latest correlation efforts by extending the available Jurassic palaeoenvironmental sketch maps for NW Bulgaria (Sapunov *et al.*, 1988) up to the Danube Region in NE Serbia. The maps put forward in this study reflect the Jurassic depositional environments, based on the data borrowed from previous literature for the Jurassic strata cropping out in two areas: Montana–Belogradchik–Vidin (NW Bulgaria) and Knjaževac–Kučaj–Miroč–Donji Milanovac (NE Serbia) (Fig. 1). These areas have shown that they have common features regarding the Jurassic successions. However, there are also local specifics that prevent the correlation. The latter were not taken into account herein and will need to be considered carefully elsewhere. Nevertheless, there are sufficient features in the sedimentary record that allowed a clear picture of the depositional environments of the two regions to be drawn.

JURASSIC PALAEOENVIRONMENTS

During the Early–Middle Jurassic, the area of northwestern Bulgaria took part of the Vidin Early–Middle Jurassic Complex Horst (Sapunov *et al.*, 1988). The latter palaeotectonic unit is a southern extension of the Lower Danubicum from NE Serbia (see Kräutner and Krstić, 2003), and these equivalent units were developed after the Old Cimmerian Orogeny on the territory of present-day NW Bulgaria and NE Serbia. The Vidin Jurassic Horst was limited from the west by the Izdremets Jurassic Graben (the southern prolongation of the Infra-Getic in East Serbia *sensu* Tchoumatchenco *et al.*, 2011), and from the SSE by the Mihaylovgrad Early–Middle Jurassic Graben, respectively (Sapunov *et al.*, 1988). The Vidin Horst and the Mihaylovgrad Graben, as well as the Lower Danubicum, took part of the Jurassic Moesian Platform, on which various depositional environments were developed. However, in the Mihaylovgrad Graben, the marine sedimentation started at the late Hettangian, whereas the Vidin Horst represented a dryland, composed of diverse Paleozoic and Triassic rocks, in conditions of erosion and denudation. The latter environments persisted throughout the Early Jurassic, both in NW Bulgaria and NE Serbia.

Fig. 1. a) Location sketch map of the area of this study; b) Outcrops (blue) and subcrops (light blue) of the Jurassic rocks in the Danube River region of NW Bulgaria and NE Serbia (modified from Tchoumatchenco *et al.*, 2011). Abbreviations: LD – Lower Danubicum; VH – Vidin Horst; MG – Mihaylovgrad Graben.

Middle Jurassic palaeoenvironments

In latest Toarcian–earliest Aalenian times, a lacustrine to palustrine deposition started in separate locations to the northwest and southeast of the present-day town of Belogradchik and in the Miroč Mt (Fig. 2a). Heterogranular oligomict sandstones, conglomerates, clays and coal-bearing shales, sporadically containing Cycadophyta and referred to the Vrashka Chuka Formation, were deposited (Sapunov *et al.*, 1988). The first marine shallow sublittoral environments, with sandy-pebbly bottom and agitated water, were imposed, into a narrow strip with NW–SE trend, on the southern and central part of the Vidin Horst, in which the oligomict sandstones and conglomerates of the Kichera Formation and the Staro Selo Clastites were accumulated (Tchoumatchenco *et al.*, 2011). Poor fossil assemblages of bivalves and less common brachiopods (often fragmented), as well as poorly preserved single ammonites and belemnites, occur as extreme rarities in the clastic rocks. This style of deposition continued until the end of the Aalenian, but with reduction and liquidation of the continental and gradual expansion of the marine environments (see Fig. 2b). Generally, the shallow sublittoral environments existed on the Vidin Horst up to the end of the late Bajocian (see Tchoumatchenco, 1977; 1978a; Sapunov *et al.*, 1988). However, at the end of the early Bajocian, thin “tongues” of sandy limestones to calcareous sandstones, referred to the Polaten Formation, were formed into narrow areas to the east and the south of Belogradchik Town. Equivalent strata, called Štubic Clastites, were accumulated into separate localities to the south of the town of Donji Milanovac (Tchoumatchenco *et al.*, 2011). These sediments were deposited in shallow to moderately-deep sublittoral environments with calcareous bottom and agitated water. In both NW Bulgaria and NE Serbia, the rocks recording the latter environments have preserved diverse brachiopod faunas (Tchoumatchenco, 1977, 1978d). It seems that, towards the end of the Bajocian, the terrigenous-carbonate sedimentation significantly widened its range (see Fig. 2c).

The extension of the marine terrigenous-carbonate sedimentation on the Vidin Horst continued until the middle Bathonian and was associated with the deepening of the basin, resulting in both an increase in the carbonate component and the formation of deeper-marine depositional environments. During the mid-late Bathonian and the early Callovian, clayey-calcareous muddy sea bottoms were imposed (see Fig. 3a, b). The latter environments resulted in the accumulation of marl-limestone de-

Fig. 2. Palaeoenvironmental sketch maps of NW Bulgaria and NE Serbia: a) for the beginning of the Aalenian; b) for the end of the Aalenian; c) for the late Bajocian. Presumable environments: 1) dryland in conditions of erosion and denudation; 2) continental environments; 3) shallow sublittoral environments with sandy bottom and agitated water; 4) shallow to deep sublittoral environments with calcareous bottom and agitated water; 5) deep sublittoral environments with muddy bottom and slightly agitated water; 6) palaeofaults. *Abbreviations:* LD – Lower Danubium; VH – Vidin Horst; MG – Mihaylovgrad Graben.

Fig. 3. Palaeoenvironmental sketch maps of NW Bulgaria and NE Serbia: *a*) for the middle Bathonian; *b*) for the late Bathonian. Presumable environments: 1) shallow to deep sublittoral environments with calcareous bottom and agitated water; 2) deep sublittoral environments with muddy bottom and slightly agitated water; 3) shallow to deep sublittoral environments with calcareous bottom and agitated water; 4) shallow sublittoral environments with calcareous bottom and agitated water; 5) littoral and sublittoral environments with strong bottom currents (areas of non-deposition and submarine washout); 6) palaeofaults. *Abbreviations:* LD – Lower Danubicum; VH – Vidin Horst; MG – Mihaylovgrad Graben.

posits, referred to the Bov Formation in NW Bulgaria (Sapunov *et al.*, 1988), and called “*Posidonia*” beds in NE Serbia (Tchoumatchenco *et al.*, 2011). At that time, several normal regional faults, with E–W trends, were presumably also present and two areas of reduced sedimentary influx, resulting from non-deposition or submarine washout, were developed. In these areas of littoral and sublittoral

Fig. 4. Palaeoenvironmental sketch maps of NW Bulgaria and NE Serbia: *a*) for the early Callovian; *b*) for the middle Callovian. Presumable environments: 1) deep sublittoral environments with muddy bottom and slightly agitated water; 2) sublittoral and shallow epibathyal environments with calcareous bottom and slightly agitated water; 3) shallow sublittoral environments with sandy bottom and agitated water; 4) moderately deep sublittoral environments with calcareous bottom and slightly to moderately agitated water; 5) shallow sublittoral environments with calcareous bottom and agitated water; 6) palaeofaults. *Abbreviations:* LD – Lower Danubicum; VH – Vidin Horst; MG – Mihaylovgrad Graben.

environments with strong bottom currents, highly condensed fossil localities have been preserved. For instance, from such fossil sites are the Bathonian ammonites previously studied by Stephanov (1966, 1972), as well as the classical locality to the north of Belogradchik, in which Bončev and Popov (1935) proved for the first time the presence of the Callovian in Bulgaria. Similar depositional environments

have been recorded in the Bujkovo Sandstones in NE Serbia. In the early Callovian, however, a small sector of NE Serbia became an area of deposition of thick-bedded and ferruginized bioclastic limestones, referred to the Rgotina/Gulenovtsi Beds (Tchoumatchenco *et al.*, 2011). These sediments were accumulated into shallow to moderately-deep sublittoral environments with calcareous bottom and slightly agitated to moderately agitated water.

From the middle Callovian to the end of the Jurassic, the area of both NW Bulgaria and NE Serbia became a field of extensive carbonate deposition. Initially, micritic and partly intraclastic-bioclastic limestones, *i.e.*, the Yavorets Formation and the Vidlič Limestones (*pars.*), were deposited in deep sublittoral to shallow epibathyal environments with calcareous bottom and slightly agitated water (Fig. 4a). Bioclastic, bioconstructed and micritic limestones (locally with secondary dolostones), referred to the Slivnitsa Formation in NW Bulgaria and to the Basara Limestones in NE Serbia, were also deposited in a shallow sublittoral environment with calcareous bottom and agitated water (Fig. 4b).

Late Jurassic palaeoenvironments

From the late Oxfordian to the early Tithonian, in both NW Bulgaria and NE Serbia, carbonate deposition in deep sublittoral to shallow epibathyal environments, with calcareous bottom and slightly agitated water, continued to exist (see Fig. 5a, b). Near the town of Vidin and in the Donji Milanovac–Miroč area, bioclastic, bioconstructed and micritic limestones continued to accumulate in shallow sublittoral environments. In the area of the town of Belogradchik, however, in a deep sublittoral to moderately deep epibathyal environments with calcareous bottom and slightly agitated water, nodular limestones of the pelagic facies “*Ammonitico rosso*” were deposited. During the middle and the late Tithonian, micritic and partly lithoclastic limestones (Glozhene Formation, type *Majolica*) were deposited in deep sublittoral to shallow epibathyal environments with calcareous bottom and slightly agitated water. In NE Serbia, reefal limestones, as well as thick-bedded micritic limestones, were deposited in shallow sublittoral environments with calcareous bottom and agitated water. These sediments were referred to the Crni Vrh Limestones, which are analogous to the Slivnitsa Formation in Bulgaria (Tchoumatchenco *et al.*, 2011). In the vicinity of Donji Milanovac Town, nodular limestones of “*Ammonitico rosso*” facies were accumulated between the *Majolica*-type sediments and the reefal limestones.

Fig. 5. Palaeoenvironmental sketch maps of NW Bulgaria and NE Serbia: a) for the late Oxfordian–early Tithonian; b) for the late Tithonian. Presumable environments: 1) deep sublittoral to moderately deep epibathyal environments with calcareous bottom and slightly agitated water; 2) sublittoral and shallow epibathyal environments with calcareous bottom and slightly agitated water; 3) shallow sublittoral environments with sandy bottom and agitated water; 4) moderately deep sublittoral environments with calcareous bottom and slightly to moderately agitated water; 5) shallow sublittoral environments with calcareous bottom and agitated water; 6) palaeofaults. *Abbreviations:* LD – Lower Danubicum; VH – Vidin Horst; MG – Mihajlovgrad Graben.

CONCLUSION

The Middle Jurassic sedimentary successions of the Danube Region in NW Bulgaria and NE Serbia record an evolution from an initially isolated lacustrine-palustrine depositional setting (Aalenian) to rapidly expanding shallow to moderately deeper-marine sandy and carbonate setting (late Bajocian–early

Callovian). This style of deposition supports the idea of a delayed Jurassic marine transgression in both NW Bulgaria and NE Serbia, which is a conspicuous feature that has rarely been taken into account before. From the middle Callovian and onwards, during the Late Jurassic, the region under consideration herein became an area of laterally extensive and thick pelagic and platform carbonate deposition. Therefore, a clear transition from a depositional stage, with differential subsidence rates and formation of horst-and-

graben structures and a wide variability of sedimentary facies (Middle Jurassic), to a depositional stage, with a stable carbonate regime and relatively uniform topography (Late Jurassic) can be assumed.

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