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Paleomagnetism and integrated stratigraphy of the Upper Berriasian hemipelagic succession in the Barlya section Western Balkan, Bulgaria: Implications for lithogenic input and paleoredox variations

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ABSTRACT

A continuous Late Berriasian sedimentary and stratigraphic record is here presented from a hemipelagic succession from the Western Balkan (Barlya section, Bulgaria). The section, 39-m-thick, was stratigraphically calibrated using a variety of methods: biostratigraphy (calpionellids, calcareous nannofossils and calcareous dinocysts), magnetostratigraphy and carbon isotope stratigraphy. Additionally, chemostratigraphy and rock magnetic stratigraphy were applied in order to identify major paleoenvironmental changes: lithogenic input and paleoredox variations. Polarity zones from M17r to M14r were identified from the uppermost Lower Berriasian up to the Berriasian/Valanginian boundary (*Elliptica* to *Darderi* calpionellid subzones and NK-1 to NK-3 nannofossil zones). Late Berriasian calcareous dinocyst zones of *Stomiosphaerina proxima*, *Stomiosphaera wanneri* and *Colomisphaera conferta* were correlated with magnetostratigraphy for the first time. A carbon isotope profile correlates very well with the δ^{13}C records from SE France and the Western Atlantic, documenting some well-resolved minima and maxima in a generally decreasing trend. Magnetic susceptibility (MS) reveals a very good positive correlation with lithogenic elements (e.g., Al, Ti, Zr, Th and others) and is regarded as a reliable proxy of detrital input. Influx of fine grained terrigenous material increases in the Upper Berriasian up to the Berriasian/Valanginian boundary. A prominent MS increase takes place in the lowermost part of polarity zone M16n (close to the *Simplex*/*Oblonga* subzonal boundary). The MS event can be traced in the Central Carpathian, Apennine and SE France sections, exactly in the same stratigraphic position. It is coeval with an important climatic turnover in Western Tethys; however, it might have been strengthened by a general regression and regional tectonic events in the Carpatho–Balkan area. Two oxygen deficient intervals were documented: the first in the Lower Berriasian (M17r to M16r); the second one in the uppermost Upper Berriasian up to the boundary with Valanginian (M15r to M14r). Both intervals correlate with an elevated sea-level in the Western Tethys.

1. Introduction

Paleoenvironmental changes in the Late Berriasian and around Berriasian/Valanginian boundary are usually treated as a prelude to a well-known paleoceanographic perturbations in the Late Valanginian, manifested by an important δ^{13}C positive anomaly (known as "Weissert event", see e.g. Channell et al., 1993; Bornemann and Mutterlose, 2008; Föllmi, 2012; Morales et al., 2013). Late Berriasian and earliest Valanginian are characterized by general climatic warming and a trend towards more humid conditions (Föllmi, 2012). The δ^{13}C record from pelagic carbonates reveals a decreasing trend, which reflects widespread oligotrophization of oceanic waters (Weissert and Channell, 1989). On the other hand, periodic increase of surface water nutrient availability and organic carbon burial were matched with positive δ^{13}C excursions around the Early/Late Berriasian boundary and in the latest Berriasian (Emmanuel and Renard, 1993; Bornemann and Mutterlose, 2008; Morales et al., 2013). An important climate change from arid to humid mode took place around the Early/Late Berriasian boundary

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(e.g. Deconinck, 1993; Schnyder et al., 2006), accompanied by an increased lithogenic input in the western Tethyan basins (Morales et al., 2013; Grabowski and Sobień, 2015). It was recently noted that the lithogenic input in the Berriasian basinal facies of Tethys is faithfully recorded by magnetic susceptibility (MS) fluctuations (Lukeneder et al., 2010; Grabowski et al., 2013) and correlates well with major transgressive-regressive cycles (Hardenbol et al., 1998; Ogg and Hinnov, 2012).

Magnetostratigraphy in the Late Berriasian offers excellent possibilities for correlation and the evaluation of the synchronicity biotic and paleoenvironmental changes (e.g. Ogg et al., 1991). Unfortunately, there are very few sections (Southern Alps – Xausa, SE France – Berrias and Western Atlantic – DSDP sites 534A, 535 and 603B) where a high resolution Late Berriasian paleoenvironmental record (most often nannofossils and $\delta^{13}C$) has been directly correlated with Global Polarity Time Scale (GPTS; Gradstein et al., 2012; Bornemann and Mutterlose, 2008; Emmanuel and Renard, 1993; Weissert and Channell, 1989).

The aim of this study is to investigate multiple stratigraphic proxies in the well-exposed hemipelagic Barlya section (Western Balkan, Bulgaria; Lakova et al., 1999), and to present an integrated chronostratigraphic framework for dating and global correlation of numerous Late Berriasian paleoenvironmental events. We utilize calpionellids, calcareous nannofossils and calcareous dinocysts as well as magneto- and rock magnetic stratigraphy, carbon isotope stratigraphy and elemental chemostratigraphy. Relative lithogenic input and paleoredox proxies are evaluated, correlated with other sections from the Western Tethys and compared to the eustatic sea-level and climatic changes.

2. Geological setting

The Lower Cretaceous deposits in Bulgaria (Fig. 1a, b) are generally thought to be formed into a broad epicontinental basin, located on the northern border of the ocean of Tethys (Peri-Tethys), and developed on the European fragment of the Eurasian plate (Nikolov, 1987; Nikolov and Tzankov, 1997). The Bulgarian Early Cretaceous basin was an asymmetric, back-arc type, superimposed upon thin continental crust, at the southern periphery of the Moesian microplate (Nikolov et al., 2007; Nikolov and Minkovska, 2012).

Two major depositional areas can be distinguished in Bulgaria in the Berriasian from south to north, containing contrasting lithologies and development: southern and northern. The southern area was a trough, with NE-SW to E-W trends and asymmetric passive margins, an active tectonic regime and almost equal rates of subsidence and sedimentary filling of the basin. It is known as the "Nish-Troyan geosynclinal flysch depression" (Nachev, 1969) or the "Peri-Moesian marginal flysch basin" (Nikolov and Tzankov, 1997, see Fig. 1c). The trough was filled up by terrigenous basinal sediments, with a more or less pronounced turbiditic character. The northern depositional area was located on the Moesian platform. It was more stable and extensive, occupied by shelf sediments. The Moesian platform is covered by thick Upper Jurassic–Lower Cretaceous shelf marly-carbonate and carbonate rocks. In northwestern Bulgaria, the lateral transition between the trough and the Moesian platform is characterized by the presence of a few outer-shelf subbasins (Glozhene and Salash formations; see Fig. 1c; Minkovska et al., 2002; Nikolov et al., 2007; Nikolov and Minkovska, 2012) and small carbonate Bahamian-type "islands" (Brestnitsa and Slivnitsa formations; see Fig. 1c; Minkovska et al., 2002; Nikolov et al., 2007; Nikolov and Minkovska, 2012). The most important source of terrigenous material during the Early Cretaceous was the Thracian massif ("Thracian Island" in Nikolov and Tzankov, 1997). It was located south of the southern passive margin of the Peri-Moesian trough (Fig. 1c; see Minkovska et al., 2002; Nikolov et al., 2007; Nikolov and Minkovska, 2012). The Mesozoic succession of the Western Balkan was folded and thrusted during the Eocene (Jordanova et al., 2001; Vangelov et al., 2013).

The Barlya section is located at the northern end of the village of Barlya (Sofia District), about 1.5 km east of the Bulgarian–Serbian state border (Fig. 1b; 43°06′29″ N; 22°59′21″ E). The section occupies part of WNW-ESE trending monocline of thick Mesozoic rocks that composes the southwest end of the Western Balkan tectonic unit (Fig. 1a, b). This unit was overthrusted from the south by the Western Srednogorie Zone. Both Western Balkan and Western Srednogorie units represent Alpine north-verging thrust sheets and fold structures that were formed after Late Cretaceous compression and mid-Eocene inversion of the Balkan Orogen (Dabovski and Zagorchev, 2009). The Barlya section represents a sequence-slice of thick and continuous carbonate pelagic sediments that is typical for the Western Balkan Unit, and has total a chronostratigraphic extent from the Callovian to the Valanginian (Lakova et al., 2007). Hitherto, this section has been repeatedly studied with emphasis on the biostratigraphy of various fossil groups (e.g. calpionellids, calcareous dinocysts, calcareous nannofossils, ammonites), but also for its sedimentology and microfacies (e.g. Lakova et al., 1999; Lakova et al., 2007; Lakova and Petrova, 2013; Petrova, 2009; Petrova et al., 2012). The stratigraphic succession does not contain hiatuses, slumps or breccia levels and therefore has been found to be favourable for paleomagnetic studies (Grabowski et al., 2014).

The Berriasian interval of the Barlya section includes the Glozhene Formation (Upper Tithonian–Lower Berriasian) and the Salash Formation (Upper Berriasian–Hauterivian). We studied a 39-m-thick part of the section referrable to the lithological transition between the Glozhene and Salash formations and the lower part of Salash Formation (Fig. 2). Almost 5 m of this transition are characterized by an alternation by thick-bedded to thin-bedded micritic limestones with gray chert nodules and thin-bedded marly limestones (samples BA 100.0–BA 103.5). The rest of the succession (34-m-thick) is represented by alternating thin-bedded micritic limestones and marly limestones (samples BA 104.8–BA 124), which gradually pass upwards to alternating marls and marly limestones (samples BA 124.5–BA 137.5).

3. Methods

3.1. Biostratigraphy

This study was carried out on 49 samples distributed throughout the 39-m-thick Barlya section. Sampling intervals vary from nearly 1 m (samples BA 100.0–BA 122.7) to 0.5 m (samples BA 123.5–BA 137.5). Thin sections for the study of calpionellids and calcareous dinocysts were prepared in the Polish Geological Institute, Warsaw, from drill cores, collected for magnetostratigraphic study (Section 3.2). The determination of calpionellids and calcareous dinocysts was performed in the Geological Institute, Sofia, under transmitted light microscopes: Jenaval (for calpionellids) and Amplival (for calcareous dinoflagellate cysts study). Thin sections are stored in the Department of Paleontology, Stratigraphy and Sedimentology (Geological Institute, Sofia, Bulgaria). The smear-slides for calcareous nannofossil study were prepared using the standard preparation technique of Bown and Young (1998) applied to small rock chips from the same magnetostratigraphy drill cores as for the other studies. They were analyzed in the Bulgarian Geological Institute, Sofia, using Zeiss polarised light microscope Axioskop 40Pol with ProgRes® Capture Pro digital camera. Observations and paleontological identifications were carried out with an immersion objective (100×) at magnifications of 1000×. A minimum of 300 fields of view per sample were examined. The set of smear-slides is kept at the Geological Institute in Sofia, Department of Geocollections as item (BNM/2013/KS001).

3.2. Paleo- and rock magnetism

A total number of 77 stratigraphic horizons were sampled for magnetostratigraphic study, samples numbered from BA 99.8 to BA 138. Samples were taken using either gasoline or electrically powered drills with a mean sampling resolution of c. 0.5 m.

Standard cylindrical specimens (2.2 cm high and 2.5 cm in diameter) were prepared from drill cores. Usually, at least two twin specimens