Integrated bio-, magnetostratigraphy and magnetic susceptibility of Upper Berriasian hemipelagic carbonates in the West Balkan Mts

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Introduction

The lower boundary of the Berriasian Stage is still not established (e.g. Wimbledon et al., 2011). Within the frame of the Berriasian Working Group (BWG) activities numerous sections are investigated using variety of stratigraphical methods for better definition of local or regional stratotypes and improvement of interregional correlations (e.g. Wimbledon et al., 2013). The studies aim also to better understanding of paleoenvironmental events in the Berriasian and recognition of important eustatic and climatic trends, as well as paleoecological turnovers.

An integrated bio- and magnetostratigraphic study of the Barlya section (West Balkan Mts) has been undertaken by a Bulgarian–Czech–Polish team in order to create a high resolution stratigraphic subdivision which might be added to database of already existing Tethyan sections.

Here we present new results of paleomagnetic, magnetic susceptibility and biostratigraphic studies of the Barlya section, embracing the Upper Berriasian up to the Berriasian/Valanginian boundary. The results from lower part of the Upper Berriasian were briefly reported at the “Geosciences 2013” conference in Sofia (Grabowski et al., 2013) and at 10th meeting of the Berriasian Working Group in Warsaw (Grabowski et al., 2014).

The Barlya section in the West Balkan Mts of Bulgaria is located at 2 km east of the Bulgarian–Serbian border (Fig.1). Continuous carbonate pelagic succession from Oxfordian to mid-Berriasian crops out. It is conformably covered by the hemipelagic clayey limestone–marl alternation of the Salash Formation (late Berriasian to Hauterivian; see Lakova et al., 2007; Lakova, Petrova, 2013). The lower part of Salash Formation, about 37-38 m thick, is the subject of this study.

Sampling and methods

The section has been measured and sampled jointly for calpionellid/calcareous dinocyst and nannofossil biostratigraphy and magnetostratigraphy. We sampled 38 m of the section which covers the transition between the Glozhene and Salash formations, as well as the lower part of the Salash Formation (Fig. 2). The samples were taken at ca. 0.5 m interval. A total number of 79 independently oriented cores were collected. The paleomagnetic experiments were carried out in the Paleomagnetic Laboratory of the Polish Geological Institute – National Research Institute in Warsaw. Mass normalized magnetic susceptibility was measured in room temperature in three positions for 79 specimens from all sampled horizons. Microfossils are studied in thin sections and smear-slides.

Calpionellid biostratigraphy

Twenty eight calpionellid species have been identified. Five calpionellid subzones have been distinguished, namely the Elliptica, Simplex, Oblonga, Murgeanui and Darderi subzones suggesting late Early and Late Berriasian and earliest Valanginian age. Calpionellid biostratigraphy follows the zonations by and Reháková, Michalík (1997) and Lakova, Petrova (2013).

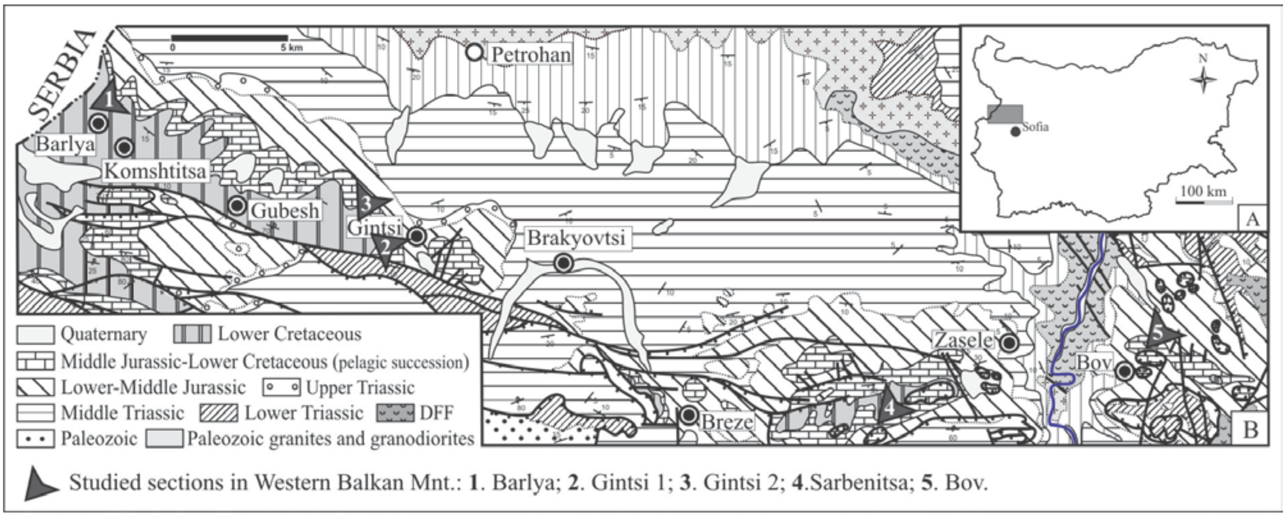

Fig.1. Geological scetch map of the West Balkan Mts (after Lakova, Petrova, 2013).

Elliptica Subzone. It covers the lowermost 6 m of the studied section that represents a fast lithological transition between the Glozhene and Salash formations. The index-species *Calpionella elliptica* occurs throughout the subzone. Four calpionellid species that are abundant in the underlaying Alpina and Remaniella subzones disappeared in the Elliptica Subzone. These are: *Remaniella ferasini*, *Crassicollaria parvula*, *Tintinnopsella doliphormis* and *Calpionella* sp. A. Of interest is the level of sample 102 with the first mass occurrence of the large variety of *Tintinnopsella carpathica* and the first occurrence (FO) of *Lorenziella hungarica*. The former bioevent indicates the base of C Zone. The bases of Elliptica Subzone and C Zone do not coincide, the former being below the latter. The FOs of *Remaniella cadischiana, Borzaiella atava* and *Tintinnopsella subacuta* are recorded at level 103.5. Grabowski, Pszczółkowski (2006) used the FO of *R. cadischiana* to define the base of Cadischiana Subzone between the Elliptica and Simplex subzones. At Barlya section, both the FO of *R. cadishiana* and the mass occurrence of large *T. carpathica* are within the M17n magnetic chron. The association of Elliptica Subzone includes also *Remaniella colomi*, *R. catalanoi* and *R. borzai*. The lower boundary of this subzone has been found in a neighboring section that is to be published.

Simplex Subzone. It covers an interval of ca. 6 m thickness. The base is defined at the FO of *Calpionellopsis simplex*. *Remaniella colomi* and *Calpionella elliptica* that are characteristic of lower stratigraphic levels still persist. *Remaniella catalanoi*, *Remaniella borzai* and *Remaniella cadischiana* from the Elliptica Subzone occur in the Simplex Subzone, too. *Tintinnopsella longa* and *Tintinnopsella dacica* made their FOs. *Tintinnopsella carpathica* and *Tintinnopsella subacuta* are very abundant. The FO of *Calpionellopsis simplex* is within M16r.

Oblonga Subzone. An interval, 14-15 m thick, belongs to the Oblonga Subzone. *Calpionellopsis oblonga* is the most abundant species. The association is rich in species of the genera *Tintinnopsella* and *Remaniella* already mentioned in the Simplex Subzone. A smaller form of *Calpionellopsis* designated as "*Calpionellopsis* sp. A" in Lakova, Petrova (2013) accompanies *Calpionellopsis oblonga*. *Calpionellopsis simplex* and *Lorenziella hungarica* are common. *Calpionella elliptica's* LO is in the lowest part of this subzone. *Lorenziella plicata* appeared above the base of Oblonga Subzone, and *Sturiella dolomitica* and *Remaniella filipescui* – in higher levels within this subzone. The FO of *Calpionellopsis oblonga* is within the M16n magnetic chron.

Murgeanui Subzone. It covers a 3 m thick interval. *Praecalpionellites murgeanui*, *Praecalpionellites siriniaensis* and *Praecalpionellites hillebrandti* are characteristic species. Other species within this subzone are *Tintinnopsella carpathica*, *T. longa*, *T. subacuta*, *Calpionellopsis oblonga*, *Lorenziella hungarica*, *L. plicata*, *Remaniella cadishiana* and *R. filipescui*.

Darderi Subzone. The FO of *Calpionellites darderi* in the level 136.6 marks the base of this subzone and the base of Valanginian. It shares almost the same longer-ranging species from the Oblonga Subzone. The base of Darderi Subzone is in M14r.

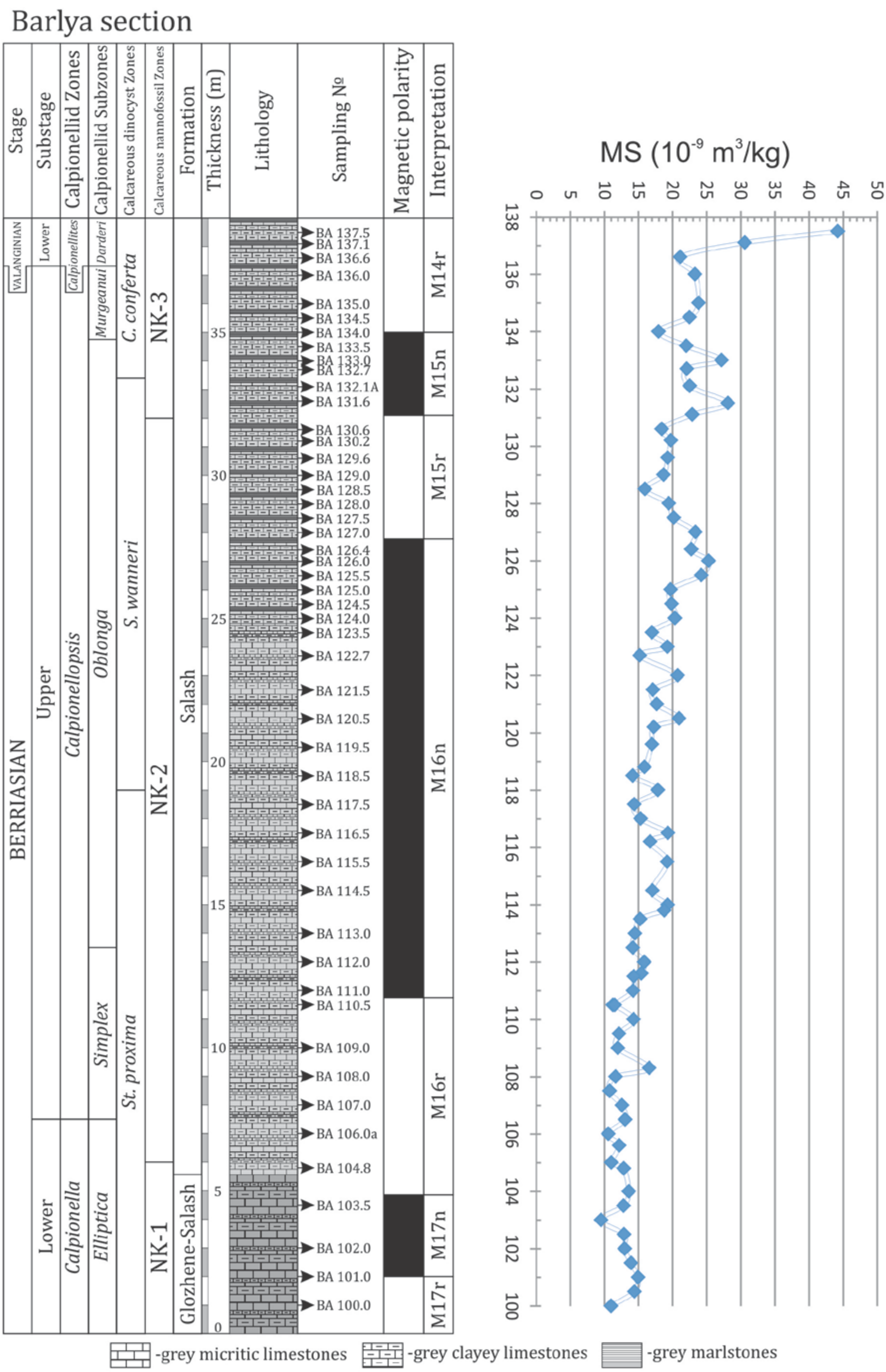

Fig. 2. Bio-, magneto- and chronostratigraphy and magnetic susceptibility of the Salash Formation (Barlya section).

Calcareous dinoflagellate cyst biostratigraphy

***St. proxima* Zone.** In the Glozhene-Salash sediments the relatively longer-ranging zone *Stomiosphaerina proxima* was established. Within the scope of this zone a bloom of the species *Crustocadosina semiradiata olzae* and *Crustocadosina fusca cieszynica* has been witnessed. The association is represented by *Colomisphaera tenuis, C. fortis, C. fusca fusca, C. semiradiata semiradiata, Stomiosphaera moluccana* and *Colomisphaera carpathica.*
***St. wanneri* Zone.** The FO of the index-species *Stomiosphaera wanneri* marks the base of this zone, and the FO of *Colomisphaera conferta* – its top. Other species found within this zone are from the precedent one. The FOs of the species *Cadosina minuta* and *Colomisphaera heliosphaera* are registered in the Wanneri Zone.
***C. conferta* Zone.** In the upper portions of the section the lower part of the *Colomisphaera conferta* Zone was established. In the upper part, reduction in the number of calcareous dinocysts was observed.

Calcareous nannofossil biostratigraphy

A total of 33 calcareous nannofossil species from the Upper Berriasian interval have been determined. Preservation of the nannofossils throughout the studied interval is generally poor to moderate, improving up section. Tethyan nannofossil zonation for the Lower and Upper Berriasian is applied, consisting of N. steinmanni steinmanni (NK-1), C. angustiforatus (NK-2) and C. oblongata (NK-3) Zones (Bralower et al., 1989, Bown et al., 1998).
N. steinmanni steinmanni (NK-1) Zone. It is documented in the lowermost 5.5 m of the studied section, covering the whole M17 and the lower part of M16r magnetic chrons. The nannofossil associations include dissolution-resistant coccoliths from the genera *Watznaueria*, *Cyclagelosphaera* and *Zeugrhabdotus*, as well as *Assipetra infracretacea.*
C. angustiforatus (NK-2) Zone. The base of the zone is traced by the FO of the index-species. Within this zone an overall increase of nannofossil diversity and abundance is recorded, resulting in rich documented nannofossil associations. However, the nannoconids become somewhat less abundant than below. The important components of nannofossil association include *Assipetra infracretacea, Cyclagelosphaera margerelii, Cretarhabdus octofenestratus, Lithraphidites* spp.
C. oblongata (NK-3) Zone. It covers the uppermost 6.5 m of the section. Its base is defined at the FO of *C. oblongata* in the level 131.00 m, roughly coinciding with M15r-M15n magnetic polarity chron boundary. The nannoconids are important component, but do not dominate nannofossil associations. Other significant species in this interval include *Cruciellipsis cuvillieri, Rucinolithus spp., Lithraphidites carniolensis, Rhagodiscus* spp., *Calcicalathina oblongata.*

Magnetostratigraphy

Details of thermal demagnetization were presented in Grabowski et al. (2014) and are only briefly reported here. The structure of magnetization was similar in the entire section of the Upper Berriasian limetsones of Salash Formation. Three components of magnetization were revealed. A post-folding component A of normal polarity was interpreted as recent viscuous remanent magnetization. An ubiquituous pre-folding to early synfolding component B of reversed polarity is an overprint acquired most probably between Late Cretaceous and Eocene. A component C of mixed polarity is regarded as primary.

Magnetozones between the uppermost part of M17r and M14r have been identified in the section. Boundaries between calpionellid zones are situated in the following magnetozones: Elliptica/Simplex – in M16r, Simplex/Oblonga – in the lower part of M16n, Oblonga/Murgeanui – at the top of M15n, and Murgeanui/Darderi (Berriasian/Valanginian boundary) – in the lower part of M14r. Our data confirm the position of the currently accepted Berriasian/Valanginian boundary in M14r (Gradstein et al., 2012). It corresponds to data from other Tethyan sections situated in the Trento Plateau (Capriolo, Xausa, Val de Mis – see Channell et al. (1987), Channell, Grandesso (1987), and in the Sub-Betic zone, south-eastern Spain (Caravaca, Cehegin) – see Ogg et al. (1988), Aguado et al. (2000).

Magnetic susceptibility

Magnetic susceptibility (MS) reflects detrital influx of fine clay particles which is evidenced from good correlation between MS and K and Th from the gamma ray spectroscopy, as well as other detrital elements (Al. Ti, Zr). MS reveals a well defined increasing trend starting in the lower part of M16n, close to the

Simplex/Oblonga boundary. The highest MS values are observed already in the Lower Valanginian in M14r. The trend correlates well with the sea-level regression curve which culminates in the Early Valanginian (Haq, 2014). Small variations on the MS curve might reflect short term sea-level changes. However, increase of terrigenous influx might be partially related also to the climate humidity increase which is well documented in the Western Tethys area in the Late Berriasian and Early Valanginian (Morales et al., 2013), as well as local/regional tectonic events (Grabowski, Sobień, 2015).

Similar MS patterns have been observed between the Barlya section and sections from the deep water Križna succession in the Tatra Mts (Grabowski, Sobień, 2015). Significant positive MS shift takes place in the lower part of M16n in both areas which indicates increase of supply of fine clay particles. It should be noted that similar phenomena are reported also from other sections in the West Balkan Mts in Bulgaria and Serbia. The onset of siliciclastic sedimentation (Cherni Osam Formation) is observed at the beginning of the Late Berriasian (Simplex Subzone) in the Sarbenitsa and Bov sections of the West Balkan (Petrova, 2010). This corresponds exactly to MS event recorded in Križna succession and Barlya section. The beginning of marly sedimentation in the Rosomač section (eastern Serbia, Stara Planina–Poreč Zone) is apparently older and falls in the late Early Berriasian. The bottom of Ržana Beds is correlated with Remaniella Subzone (Petrova et al., 2012). The isochronism and nature of the Berriasian clastic events should be further verified by integrated bio-, magnetostratigraphic and MS studies.

Conclusions

The lower part of the hemipelagic limestone-marl succession (Salash Formation) in the West Balkan Mts is of late Early and Late Berriasian and earliest Valanginian age. The calpionellid subzones Elliptica, Simplex, Oblonga, Murgeanui and Darderi have been directly correlated to a succession of magnetozones from M17r to M14r. The calcareous dinocyst zones Proxima, Wanneri and Conferta, as well as calcareous nannofossil zones NK-1, NK-2 and NK-3 have also been determined. Magnetic susceptibility that reflects detrital influx of fine clayey particles shows positive shifts in the lower part of M16n close to the Simplex/Oblonga boundary, as well as in M14r in the lowermost Valanginian. Increasing trends in the magnetic susceptibility are interpreted as being related to sea-level regression and/or climate humidity increase.

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Интегрирана био-, магнитостратиграфия и магнитна възприемчивост на горнобериаски хемипелагични карбонатни скали в Западна Стара планина

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Представят се нови резултати от биостратиграфски и палеомагнитни изследвания, както и за магнитна възприемчивост на горнобериаски хемипелагични карбонатни скали от Западна Стара планина. Изследвана е алтернация на глинести варовици и мергели от най-долната част на Салашката свита в разреза при с. Бърля. Представя се директна корелация на магнитострафска последователност от M17r до M14r с установените зонални схеми по калпионелиди, варовити диноцисти и варовит нанопланктон. Определена е границата между бериаския и валанжинския етаж в основата на калпионелидната зона Darderi в магнитозона M14r. В бериаския етаж е налице последователност от калпионелидните подзони Elliptica, Simplex, Oblonga и Murgeanui паралелно с диноцистните зони Proxima, Wanneri и Conferta и с нанофосилните зони NK–1, NK–2 и NK–3. Магнитната възприемчивост, която отразява детритния привнос на фини глинести частици, показва тенденция към нарастване на стойностите в долната част на M16n близо до границата на подзоните Simplex и Oblonga, както и в M14r в най-долния валанжин. Интервалите на високи стойности на магнитната възприемчивост вероятно са свързани с периоди на понижаване на морското ниво и регресия и/или на хумиден климат и интензивно изветряне.