VOLUMINA JURASSICA, 2014, XII (1): 185–194

Berriasian bio- and magnetostratigraphy and magnetic susceptibility of the Barlya section (Western Balkan Unit, Bulgaria) – preliminary results

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Key words: Berriasian, Western Balkan, calpionellids, magnetostratigraphy, magnetic susceptibility.

Abstract. Integrated bio- and magnetostratigraphic data from the Lower to Upper Berriasian of the pelagic succession at Barlya (Western Balkan, Bulgaria) are presented. The investigated interval, 24 m thick, covers the top of the Calpionella elliptica, Calpionellopsis simplex and Calpionellopsis oblonga subzones. Magnetozones from the upper part of M17r up to M16n were identified. The boundary between the Elliptica and Simplex subzones correlates with the lower part of M16r, while the boundary between the Simplex and Oblonga subzones is situated in the lower part of M16n. The magnetic susceptibility reveals an increasing trend from the middle part of M16r which accounts for the increasing supply of fine clastic sediments to the basin.

INTRODUCTION

One of important aspects of the Berriasian Working Group (BWG) activities is documentation of well exposed sections covering the Jurassic–Cretaceous boundary interval which may serve as either local or regional stratotypes and help in interregional correlations. During the 7th BWG Meeting in Sofia in 2011, a Barlya section was presented. The section is located in the Western Balkan Mts and represents a continuous profile from the Callovian to Valanginian in open marine pelagic facies (Lakova *et al*., 2007; Lakova, Petrova, 2013). An integrated bio- and magnetostratigraphic study was undertaken by the Bulgarian-Czech-Polish team in order to create a high resolution chronostratigraphic scheme which might be added to the database of already existing sections (Michalík and Reháková, 2011; Wimbledon *et al*., 2011, 2013). Here we present preliminary results of paleomagnetic, magnetic susceptibility and microfossil studies from the Lower to Upper Berriasian part of the Barlya section, which were discussed at the 10th Meeting of the BWG in Warsaw in October 2013 and briefly reported at the "Geosciences 2013" conference in Sofia (Grabowski *et al*., 2013a).

GEOLOGICAL SETTING

The Barlya section is located at the westernmost end of the Western Balkan tectonic unit in Bulgaria (Fig. 1). To the south this unit was overthusted by the Western Srednogorie Zone. The timing of the formation of these Alpine north-vergent thrust sheets and fold structures has been estimated as Late Cretaceous and mid-Eocene (Dabovski, Zagorchev, 2009). The carbonate pelagic sedimentation in the Western Balkan Unit is of Callovian to Valanginian age (Lakova *et*

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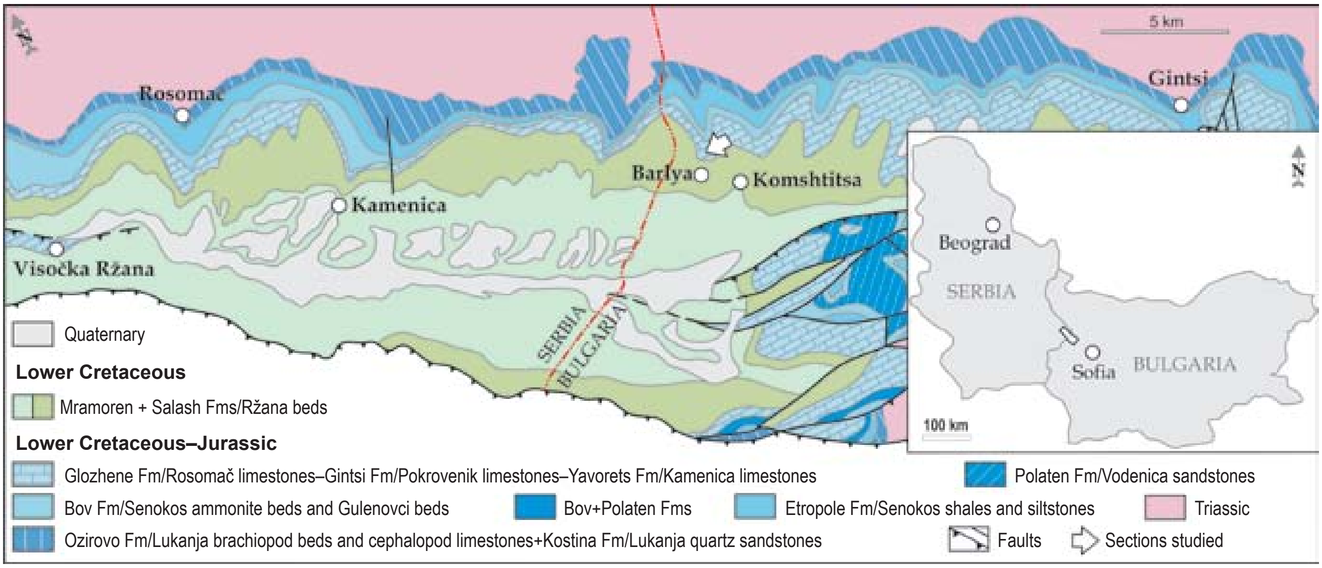

Fig. 1. Simplified geological map of the Western Balkan Unit (after Petrova *et al.*, 2012, modified)

al., 2007). The Upper Tithonian and Berriasian interval consists of the Glozhene and Salash formations. The boundary between the two formations coincides with the boundary between the Lower and Upper Berriasian (Lakova *et al.*, 2007). They are favourable for palaeomagnetic studies since the stratigraphic succession is continuous, without hiatuses, slumps, breccia levels or faults. The chosen part of the lower part of the Salash Formation is characterized by an alternation of thin-bedded clayey limestones and micritic limestones. In the upper part of the interval studied marls replace the micritic limestones.

SAMPLING AND METHODS

We sampled *ca*. 24 m of the section which covers the transition between the Glozhene Fm. and the Salash Fm. as well as the lower part of the Salash Fm. The samples were taken in *ca*. 0.5 m interval, a total number of 51 independently oriented cores was collected. The palaeomagnetic experiments were carried out in the Palaeomagnetic Laboratory of the Polish Geological Institute – National Research Institute in Warsaw. Natural remanent magnetisation (NRM) was measured with a JR-6A spinner magnetometer (AGICO, Brno; noise level 10^{-5} A/m). 33 specimens were demagnetised thermally using the non-magnetic MMTD oven (Magnetic Measurements, UK, rest field <10 nT). NRM measurements and demagnetisation experiments were carried in the magnetically shielded space (a low-field cage, Magnetic Measurements, UK, which reduces the ambient geomagnetic field by about 95%). Magnetic susceptibility was monitored with a KLY-2 bridge (AGICO, Brno; sensitivity 10^{-8} SI units) after each thermal demagnetization step. Characteristic components of the magnetization were calculated using REMASOFT software (Chadima, Hrouda, 2006). Bulk magnetic susceptibility was measured at room temperature in three positions for 51 specimens from all sampled horizons and mass normalized.

Biostratigraphic investigations of calpionellids were undertaken in thin-sections prepared from the palaeomagnetic samples. A total of 24 thin-sections were studied under a transmitted light microscope. The average sampling interval for biostratigraphy is 1.0 m.

RESULTS

BIOSTRATIGRAPHY

On total 25 calpionellid species are identified. A range-chart of calpionellids is shown in Figure 2. Three calpionellid subzones have been distinguished, namely the Elliptica, Simplex and Oblonga subzones, that suggest a late Early to Late (but not latest) Berriasian age of the section studied in the lower part of the Salash Formation. The biostratigraphy

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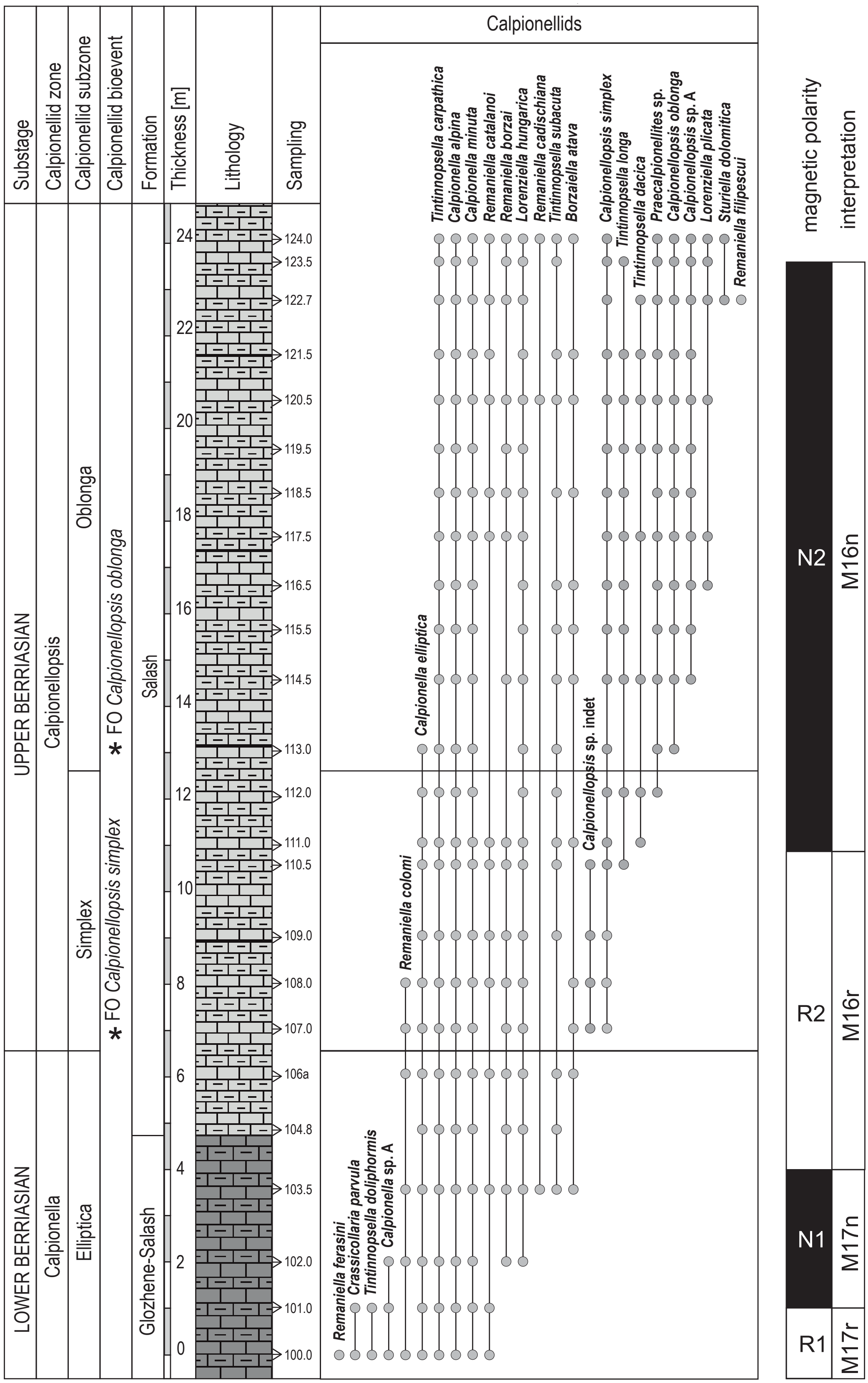
Fig. 2. Calpionellid biostratigraphy and magnetostratigraphy of the Lower to Upper Berriasian part of the Barlya section

Details of magnetostratigraphic interpretation are presented in the Figure 5. Black – normal polarity, white – reversed polarity



Substage
Calpionellid zone
Calpionellid subzone
Calpionellid bioevent
Formation
Thickness [m]
Lithology
Sampling
Calpionellids
LOWER BERRIASIAN
UPPER BERRIASIAN
Calpionella
Calpionellopsis
Elliptica
Simplex
Oblonga
* FO Calpionellopsis simplex
* FO Calpionellopsis oblonga
Glozhene-Salash
Salash
0
2
4
6
8
10
12
14
16
18
20
22
24
100.0
101.0
102.0
103.5
104.8
106a
107.0
108.0
109.0
110.5
111.0
112.0
113.0
114.5
115.5
116.5
117.5
118.5
119.5
120.5
121.5
122.7
123.5
124.0
Remaniella ferasini
Crassicollaria parvula
Tintinnopsella doliphormis
Calpionella sp. A
Remaniella colomi
Calpionella elliptica
Tintinnopsella carpathica
Calpionella alpina
Calpionella minuta
Remaniella catalanoi
Remaniella borzai
Lorenziella hungarica
Remaniella cadischiana
Tintinnopsella subacuta
Borzaiella atava
Calpionellopsis sp. indet
Calpionellopsis simplex
Tintinnopsella longa
Tintinnopsella dacica
Praecalpionellites sp.
Calpionellopsis oblonga
Calpionellopsis sp. A
Lorenziella plicata
Sturiella dolomitica
Remaniella filipescui
magnetic polarity
interpretation
R1
N1
R2
N2
M17r
M17n
M16r
M16n

follows the calpionellid zonations by Pop (1994), Reháková and Michalík (1997).

Elliptica Subzone. This covers the lowermost 6 m of the section studied representing 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, the latter being a transitional form between *Calpionella alpina* and *Calpionella elliptica*. 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 Remane (1971)'s C Zone. It should be stressed that the bases of the Elliptica Subzone and the C Zone do not coincide, the former being below the latter. The FO of *L. hungarica* within the Elliptica Subzone proves the inconsistency of this event as a marker of the latest Berriasian D3 (Hungarica) Subzone. *Remaniella cadischiana*'s FO has been recorded at level 103. Pszczółkowski (in Grabowski, Pszczółkowski, 2006) used the FO of *R. cadischiana* to define the base of the Cadischiana = C Zone between the Elliptica and Simplex subzones. The association of the Elliptica Subzone includes also *Remaniella colomi*, *R. catalanoi*, *R. borzai* and *Tintinnopsella subacuta*. The lower boundary of the Elliptica Subzone has been found in a neighbouring section that is to be published.

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

Oblonga Subzone. The topmost interval of the section, *ca*. 10 m thick, from samples 114.5 to 124.0 belongs to the Oblonga Subzone of the Calpionellopsis Zone. *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 and Petrova (2013) accompanies *Calpionellopsis oblonga*. *Calpionellopsis simplex* and *Lorenziella hungarica* are common. *Lorenziella plicata* appears close to the base of the Oblonga Subzone, and *Remaniella filipescui* and *Sturiella dolomitica* appear at the top of the section studied. Representatives of the genus *Praecalpionellites* also occur but they differ from *Praecalpionellites murgeanui*, the index species of the overlying uppermost Berriasian calpionellid subzone.

PALEOMAGNETISM

NRM intensities fluctuated between 1.25 and $13.2 \cdot 10^{-4}$ A/m. Most of the samples revealed three components of the NRM (see Table 1): A, B and C with well separated unblocking temperature spectra (Fig. 3). Component A, with unblocking temperatures between 100 and 250°C is virtually identical with the present day geomagnetic field direction (in present day coordinates, see Fig. 4A). Component B reveals exclusively reversed polarity and it is unblocked between 250 and 350–400°C. The hardest, double polarity component C is demagnetized between 400 and 525°C. The declinations of both B and C components do not deviate significantly from the present day north (Fig. 4B, C). Component B is interpreted as secondary because of its persistent

Table 1

Characteristic NRM components from the Barlya section

Component	D/I	α_{95}	k	Dc/Ic	α_{95}	k	N/N_o
A	12/67	7.6	17.8	63/86	7.8	16.8	22/25
B	174/-23	9.7	12.9	172/-44	10.0	12.3	19/25
Cn	5/38	7.6	26.2	4/58	6.5	36.s0	15/25
Cr	170/-25	15.7	15.7	166/-45	14.3	18.7	7/22
Cn+r	0/34	7.4	18.3	358/55	6.6	23.0	22/25

D/I (Dc/Ic) – declination and inclination of the magnetization component before (after) tectonic correction; α_{95}, k – Fisher statistics parameters; N/N_o – number of samples used for calculation of mean direction/number of samples studied

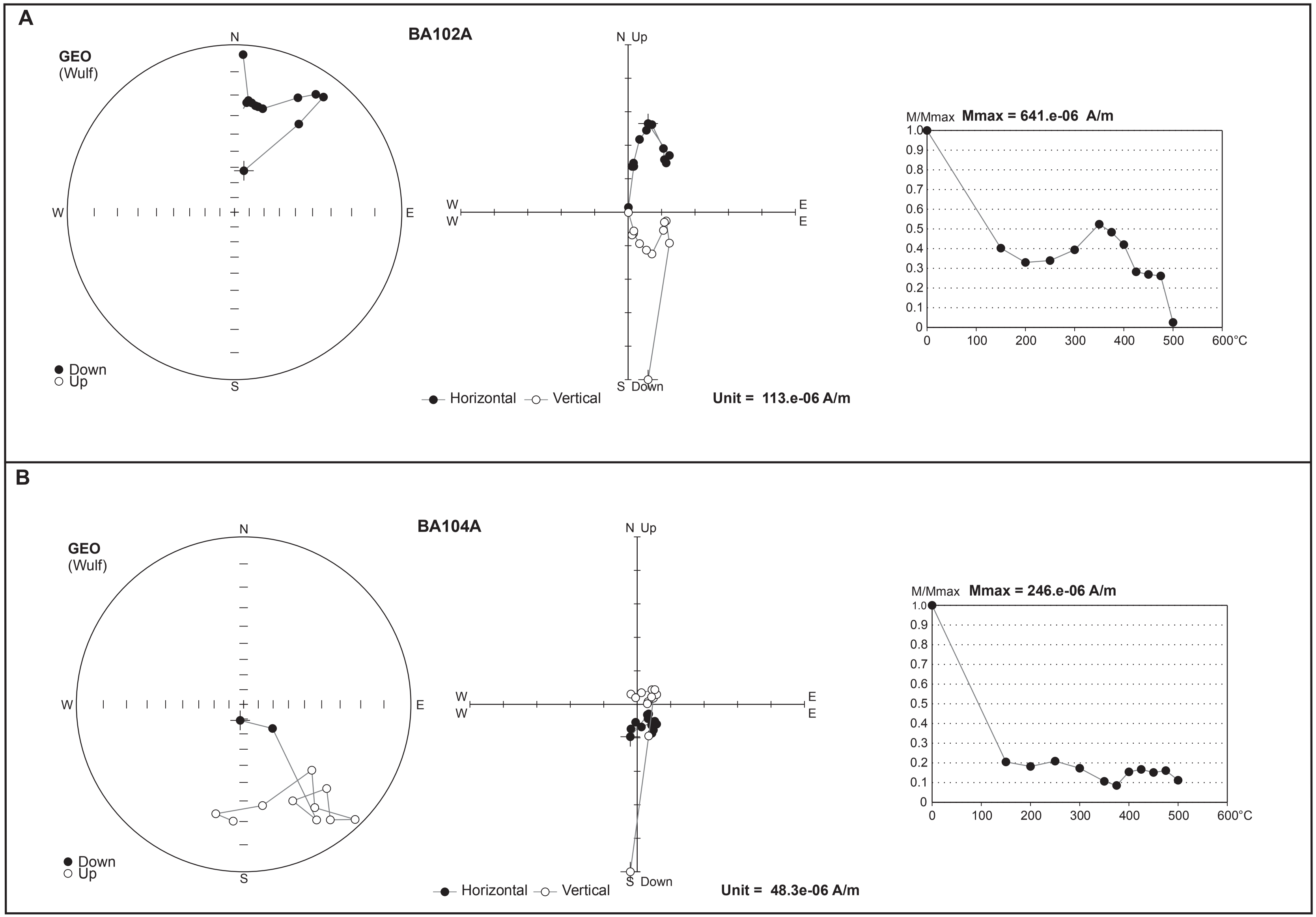


Fig. 3. Thermal demagnetization of typical specimens. Left – stereographic projection of demagnetization path; middle – orthogonal projection; right – NRM decay during thermal treatment. Stereographic and orthogonal projections before tectonic correction

A – specimen BA 102A, Elliptica Subzone, normal polarity of component C, magnetozone N1 (M17n). **B** – specimen BA 104A, Elliptica Subzone (uppermost part), reversed polarity of component C, magnetozone R2 (M16r)

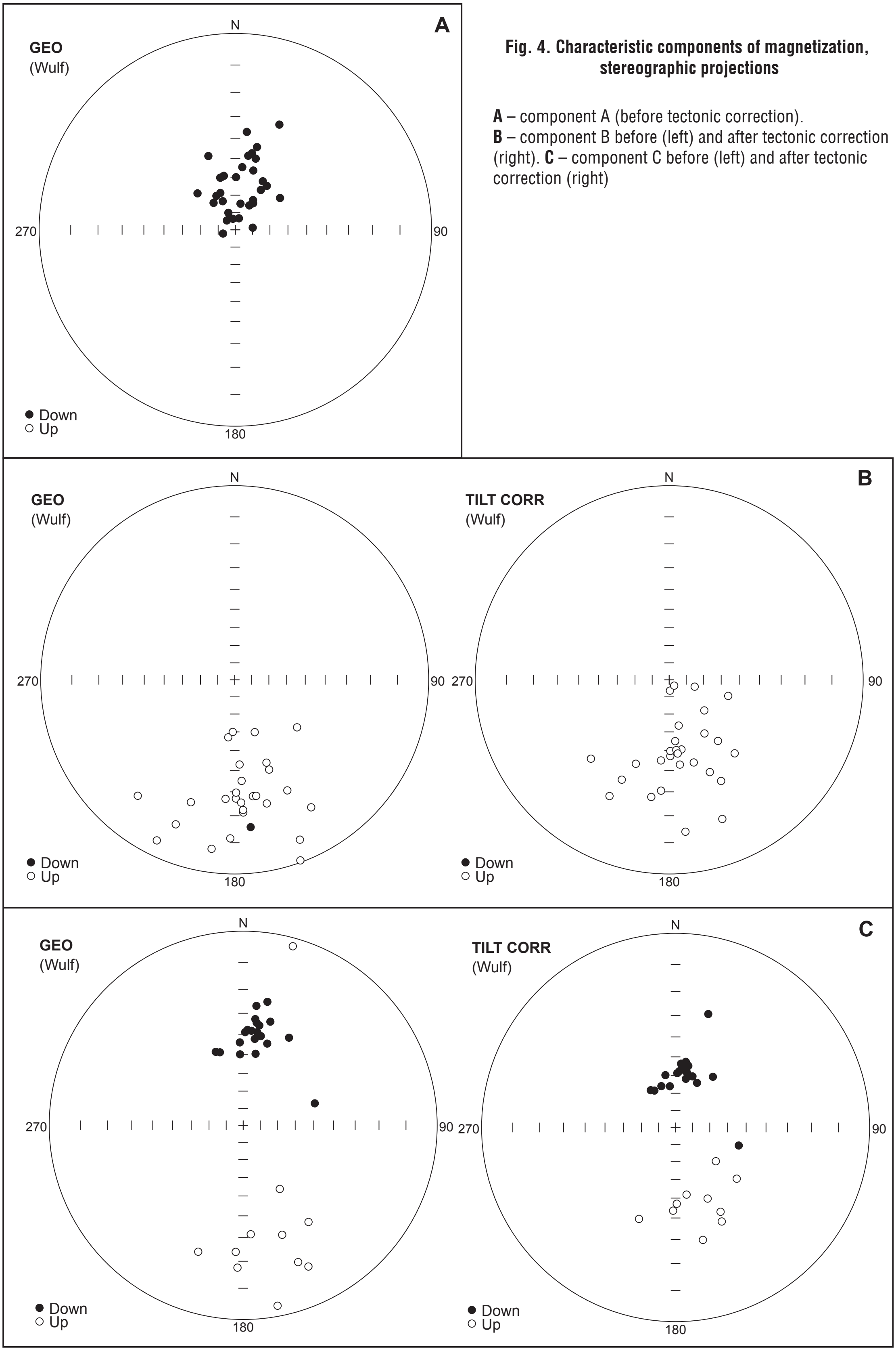


Fig. 4. Characteristic components of magnetization, stereographic projections

A – component A (before tectonic correction).
B – component B before (left) and after tectonic correction (right). **C** – component C before (left) and after tectonic correction (right)

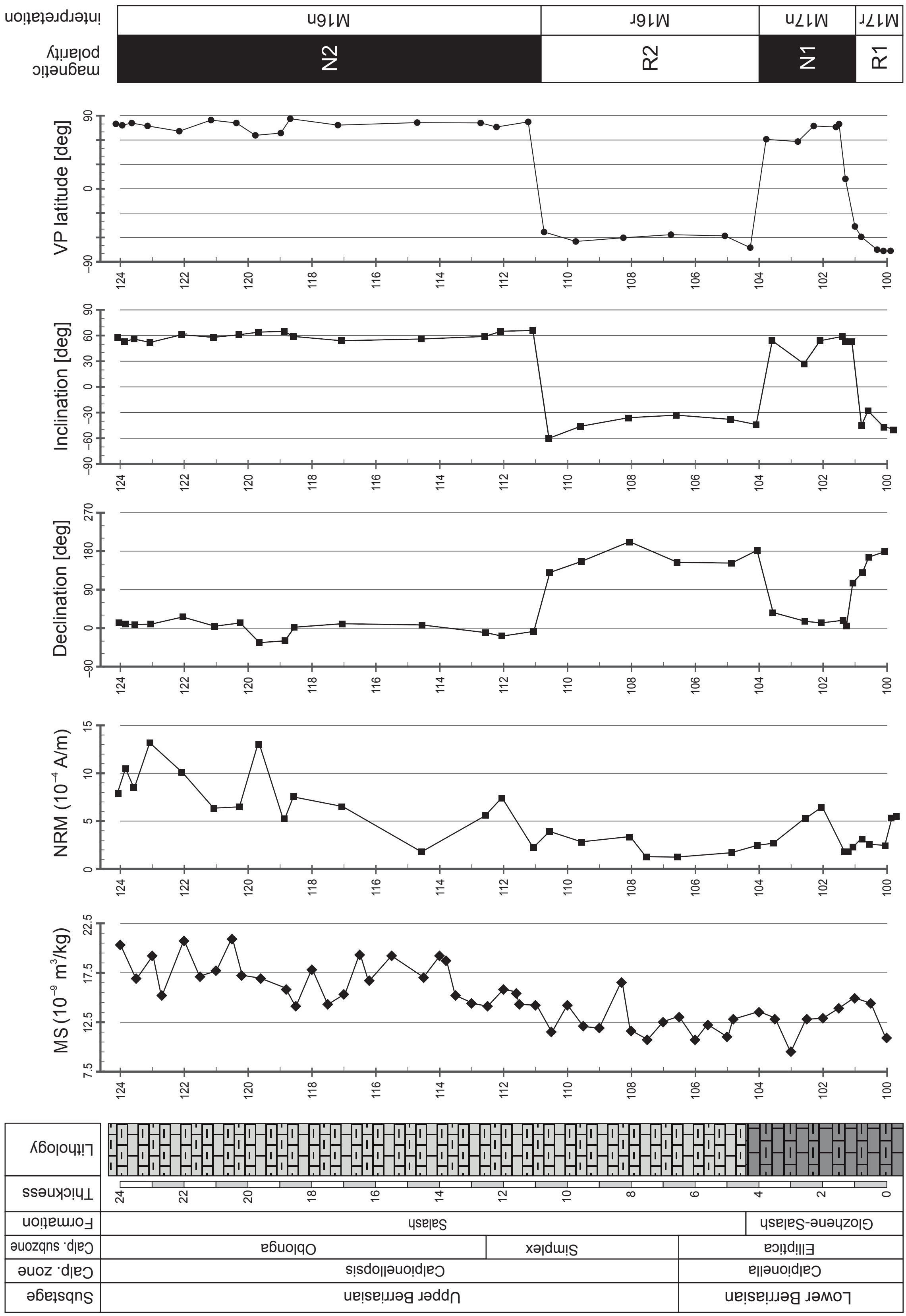


Fig. 5. Magnetic susceptibility, natural remanent magnetization, magnetic declination and inclination of the component C, VGP latitudes and magnetostratigraphic interpretation

reversed polarity. It was acquired most probably between the Late Cretaceous and the Eocene and its inclination (Table 1) accounts rather for a prefolding or early synfolding origin. Unblocking temperature spectra indicate that the carrier of component B might be an iron sulphide, while component C is most likely carried by magnetite. Further rock magnetic investigations are in progress. Component C is interpreted as primary and used for the construction of the magnetostratigraphic log.

MAGNETOSTRATIGRAPHY AND MAGNETIC SUSCEPTIBILITY

Two reversed (R1 and R2) and two normal (N1 and N2) magnetozones were revealed (Figs 2, 5). A long normal magnetozone N2 is interpreted as M16n. It covers the upper part of the Simplex Subzone and the Oblonga Subzone. It conforms well to the position of that magnetozone in the Vocontian Basin (Berrias section, Galbrun, 1985), Tatra Mts (Rówienka section, Grabowski, Pszczółkowski, 2006) and Southern Alps (Channell, Grandesso, 1987). Magnetozone R2, interpreted as M16r, is spread between the upper part of the Elliptica Subzone and lower part of the Simplex Subzone. Normal magnetozone N1 corresponds to M17n and occurs entirely within the Elliptica Subzone. The lowermost reversed polarity interval (R1) is interpreted as a topmost part of M17r (still in the Elliptica Subzone).

The magnetic susceptibility reveals a slightly decreasing trend through the Elliptica Subzone up to the lower part of the Simplex Subzone, middle part of M16r (Fig. 5). Then a gentle increase is observed in the Simplex Subzone, whereas a more pronounced increase takes place in the lowermost part of the Oblonga Subzone (lower part of M16n).

DISCUSSION

The Lower to Upper Berriasian transition in the Barlya section correlates well with the coeval interval in the Križna unit in the Tatra Mts (Fig. 6) and the Western Tethyan realm (Ogg *et al.*, 1991). The boundary between the C and D calpionellid zones (defined as the Elliptica/Simplex boundary in Barlya and as the Cadischiana/Simplex boundary in the Tatra Mts), falls within the M16r magnetozone, and the Simplex/Oblonga boundary occurs in the lower part of M16n (see also Ogg *et al.*, 1991; Grabowski, Pszczółkowski, 2006). The sedimentation rates at Barlya reveal an increasing trend, from 7.7 m/My in M17n to 12.2 m/My in M16r

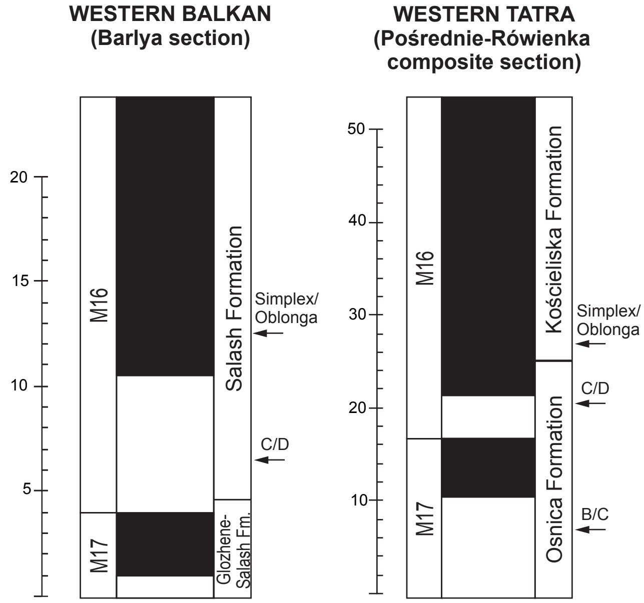


Fig. 6. Correlation of the Lower to Upper Berriasian intervals from the Western Balkan (this work) and Tatra Mts (Western Carpathians, Poland, after Grabowski, Pszczółkowski, 2006)

Note the similar stratigraphic positions of calpionellid subzones and magnetic polarity chron boundaries. C/D, B/C explained in the text

and at least 10.8 m/My in M16n (using the Ogg, 2012 timescale). Similar MS patterns are also observed between the Bulgarian and Polish sections. A large positive MS shift takes place in the lower part of M16n in both sections, which indicates an increase of supply of fine clay particles. The event was recently interpreted by Grabowski *et al.* (2013b) as related to sea-level fall in the Late Berriasian (Hardenbol *et al*., 1998) and it coincided with a period of important humidity increase in the Western Tethys and adjacent areas (Schnyder *et al*., 2009 and references therein).

Acknowledgements. The paper profited from the critical remarks of the journal referees: Cristina Casellato and Jaume Dinares-Turell. Investigations were financially supported by the project DEC-2011/03/B/ST10/05256 of the National Science Centre, Poland. Thanks are due to Platon Tchoumatchenco, Kristalina Stoykova, Tadeusz Sztyrak and Stanislav Šlechta for field assistance, Agnieszka Bagnicka (AGH, Cracow) and Beata Dąbrowska (University of Warsaw) for carrying out palaeomagnetic measurements.

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