GEOLOGICA BALCANICA, 46 (2), Sofia, Nov. 2017, pp. 47–56.

Direct correlation of Tithonian/Berriasian boundary calpionellid and calcareous nannofossil events in the frame of magnetostratigraphy: new results from the West Balkan Mts, Bulgaria, and review of existing data

Iskra Lakova[1], Jacek Grabowski[2], Kristalina Stoykova[1], Silviya Petrova[1], Daniela Reháková[3], Katarzyna Sobień[2], Petr Schnabl[4]

[1] Geological Institute, Bulgarian Academy of Sciences, Acad. G. Bonchev Str., Bl. 24, 1113 Sofia, Bulgaria; e-mails: lakova@geology.bas.bg, silviya_p@geology.bas.bg, stoykova@geology.bas.bg
[2] Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warszawa, Poland, e-mails: jacek.grabowski@pgi.gov.pol, katarzyna.sobien@pgi.gov.pl
[3] Comenius University, Faculty of Natural Sciences, Department of Geology and Palaeontology, Mlynská dolina G–229, Ilkovičova 6, SK-84215 Bratislava, Slovak Republic; e-mail: daniela.rehakova@uniba.sk
[4]Institute of Geology, Academy of Sciences of the Czech Republic, v.v.l., Rozvojová, 269,165 000 Praha 6, Czech Republic; e-mail: schnabl@gli.cas.cz

(Accepted in revised form October 2017)

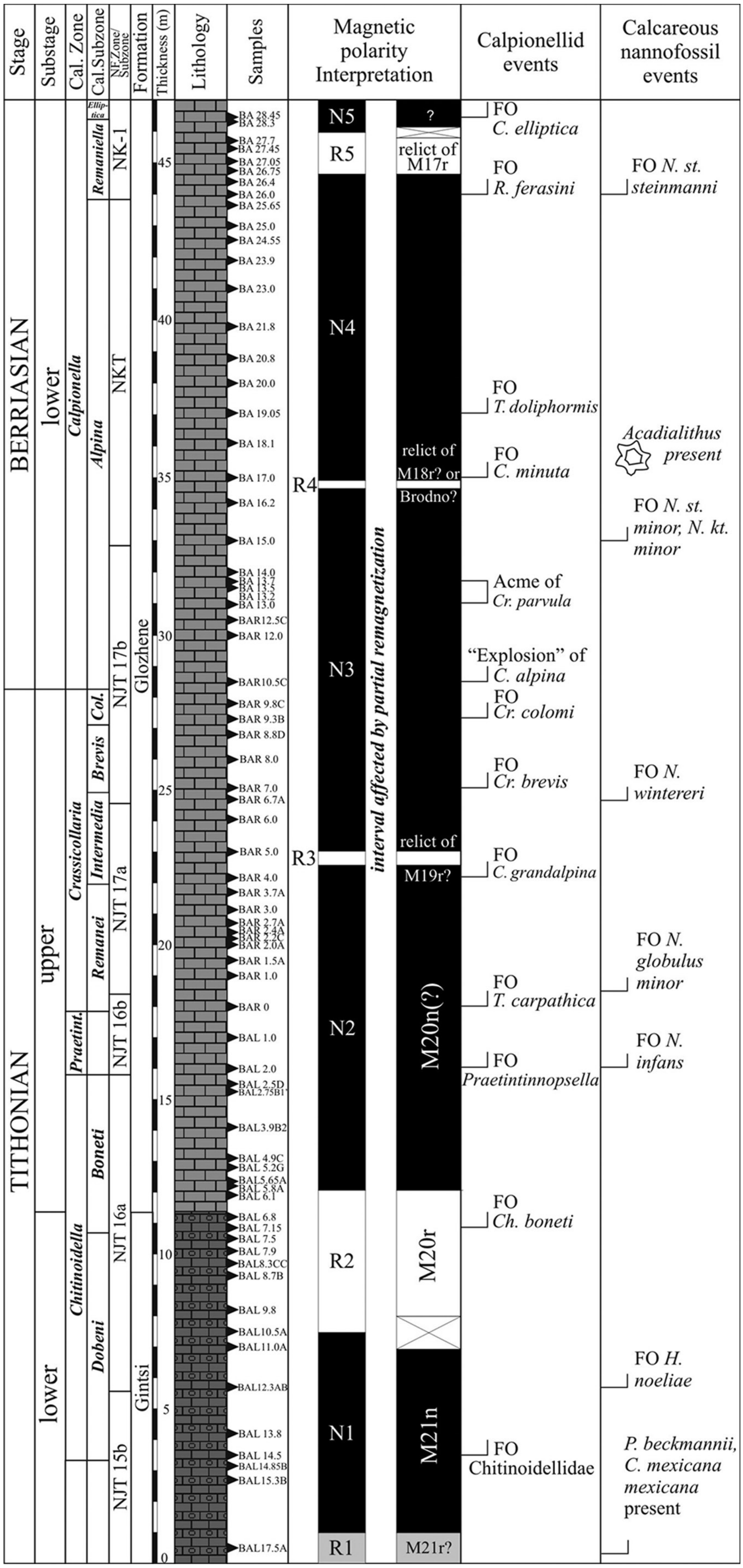
Abstract. Magnetostratigraphy, calpionellid and calcareous nannofossil biostratigraphy of the upper Tithonian and lower Berriasian of section Barlya in the West Balkan Mts are herein presented. The studied interval comprises the magnetozones from M21r to M17r, with a large interval of partial remagnetization. It has been directly correlated with a continuous succession of the calpionellid *Chitinoidella*, *Praetintinnopsella*, *Crassicollaria* and *Calpionella* zones, and with the nannofossil zones from NJT 15b to NK-1. The accumulated evidence in the last twenty years on the magnetostratigraphy, calpionellid and calcareous nannofossil biostratigraphy and events across the J/K boundary in the European Tethys has provoked the authors to plot the main micropalaeontological events against magnetostratigraphic column in order to assess the extent of diachronism of these events. Data from Slovakia, Poland, Italy, Austria, Hungary, France, Spain and Bulgaria has shown specific behaviour of different calpionellid and nannofossil events with respect to the column of the magnetic polarity chrons, which have been considered as 'isochronous' or at least less diachronous than the microfossil events. Thus, some rather consistent events have appeared, such as the first occurrences (FOs) of calpionellids *Calpionella grandalpina*, *Crassicollaria brevis*, *Calpionella minuta* and *Remaniella ferasini*, and the FOs of calcareous nannofossils *Nannoconus globulus minor*, *Hexalithus geometricus*, *Nannoconus wintereri*, *Nannoconus steinmannii minor* and *Nannoconus kamptneri minor*. The J/K boundary, as widely accepted, has been traced in section Barlya at the base of the *Calpionella alpina* Subzone.

Lakova, I., Grabowski, J., Stoykova, K., Petrova, S., Reháková, D., Sobień, K., Schnabl, P. 2017. Direct correlation of Tithonian/Berriasian boundary calpionellid and calcareous nannofossil events in the frame of magnetostratigraphy: new results from the West Balkan Mts, Bulgaria, and review of existing data. *Geologica Balcanica* 46 (2), 47–56.

Keywords: calpionellids, calcareous nannofossils, magnetostratigraphy, J/K boundary, West Balkan Mts, Bulgaria, Tethyan Realm.

INTRODUCTION

The present micropalaeontological study of the calpionellid (Iskra Lakova and Silviya Petrova) and calcareous nannofossil (Kristalina Stoykova) vertical distribution and recognition of certain events is restricted to the upper Tithonian and lower Berriasian (from the base of the *Chitinoidella* Zone to the base of the *Elliptica* Subzone of the *Calpionella* Zone) (Fig. 1). Actually, the lowermost part of the studied interval in section Barlya, *i.e.*, the *Dobeni* Subzone of the *Chitinoidella* Zone, should be assigned to the topmost lower Tithonian (see Benzaggagh *et al*., 2010; Gradstein *et al*., 2012). The calpionellid and nannofossil events have been directly confronted to magnetostratigraphy (Jacek Grabowski, Katarzyna Sobień, and Petr Schnabl). The plotting of calpionellid events versus magnetostratigraphy (Iskra Lakova and Daniela Re-


Stage
Substage
Cal. Zone
Cal.Subzone
NF.Zone/Subzone
Formation
Thickness (m)
Lithology
Samples
Magnetic polarity Interpretation
Calpionellid events
Calcareous nannofossil events
BERRIASIAN
TITHONIAN
lower
upper
lower
Calpionella
Crassicollaria
Chitinoidella
Elliptica
Remaniella
Alpina
Col.
Brevis
Intermedia
Remanei
Praetint.
Boneti
Dobeni
NK-1
NKT
NJT 17b
NJT 17a
NJT 16b
NJT 16a
NJT 15b
Glozhene
Gintsi
N5
R5
N4
R4
N3
R3
N2
R2
N1
R1
?
relict of M17r
relict of M18r? or Brodno?
relict of M19r?
M20n(?)
M20r
M21n
M21r?
interval affected by partial remagnetization
FO C. elliptica
FO R. ferasini
FO T. doliphormis
FO C. minuta
Acme of Cr. parvula
"Explosion" of C. alpina
FO Cr. colomi
FO Cr. brevis
FO C. grandalpina
FO T. carpathica
FO Praetintinnopsella
FO Ch. boneti
FO Chitinoidellidae
FO N. st. steinmanni
Acadialithus present
FO N. st. minor, N. kt. minor
FO N. wintereri
FO N. globulus minor
FO N. infans
FO H. noeliae
P. beckmannii, C. mexicana mexicana present

←

Fig. 1. The upper Tithonian and lower Berriasian of section Barlya: magnetostratigraphy, calpionellid events and biostratigraphy, and calcareous nannofossil events and biostratigraphy (calpionellid zonation scheme according to Reháková and Michalík, 1997; Pop, 1997; and Lakova and Petrova, 2013; nannofossil zonation scheme according to Casellato, 2010). Black – normal polarity; white – reversed polarity; grey – reversed polarity interpreted from great circle demagnetization paths.

háková) and the nannofossil events versus magnetostratigraphy (Kristalina Stoykova) of practically all published sections across the Tithonian/Berriasian boundary seem very promising for estimation of how consistent and reliable for distant correlation the main microfossil events are. Since this review is restricted to the European Tethys, remote localities with magneto- and calpionellid biostratigraphy such as that in Argentina (Kietzmann, 2017; Iglesia Llanos *et al.*, 2017) still remain outside the geographic scope of this account.

The Upper Berriasian part of section Barlya has already been published, involving palaeomagnetism, calpionellid and nannofossil biostratigraphy (Grabowski *et al.*, 2016). The last reviews of the microfossil biostratigraphy and/or magnetostratigraphy (Michalík and Reháková, 2011; Grabowski, 2011) of the Jurassic/Cretaceous (J/K) boundary strata were followed by study of additional sections in the European Tethys, which deserve to be incorporated in the present review. The purposes of this publication are: 1) to present new results on the direct calibration of magnetostratigraphy and calpionellid and calcareous nannofossil biostratigraphy of the upper Tithonian and lower Berriasian in the continuous section Barlya in the West Balkan Mts in Bulgaria; and 2) to determine the extent of diachroneity and dispersion of certain key calpionellid and nannofossil events with respect to magnetostratigraphy.

MATERIAL AND METHODS

A total of 160 oriented cores were drilled from the Tithonian–lower Berriasian interval of the Barlya section. Sampling resolution was between 0.1 m and 0.5 m. One to three standard palaeomagnetic specimens (25.4 mm diameter, 22 mm length) were prepared from each core. The palaeomagnetic experiments were carried out in the Paleomagnetic Laboratories of the Institute of Geology (Academy of Sciences of the Czech Republic, Pruhonice, Prague) and in the Polish Geological Institute–National Research Institute (PGI-NRI) in Warsaw. Palaeomagnetic procedure in the Pruhonice Laboratory included a progressive thermal (TH) demagnetization, using the MAVACS (Magnetic Vacuum Control System). The natural remanent magnetization (NRM) was measured, using the 2G Superconducting Rock Magnetometer 755 (2G SRM). The magnetic susceptibility (χ) was measured with AGICO KLF–4A Automatic Magnetic Susceptibility Meter after each demagnetizing step. NRM in the laboratory of PGI-NRI was measured with a JR-6A spinner magnetometer (AGICO, Brno; noise level 10^{-5} A/m). Samples were demagnetised thermally, using the non-magnetic MMTD oven (Magnetic Measurements, UK, rest field <10 nT). NRM measurements and demagnetization experiments were carried out 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 magnetization were calculated, using REMASOFT software (Chadima and Hrouda, 2006). Despite the different measurement and demagnetization equipment, the results from both laboratories were fully concordant. Although calpionellid and nannofossil stratigraphy of the Barlya section had been studied before (*e.g.*, Lakova *et al.*, 1999), new sampling and biostratigraphic studies were integrated with the palaeomagnetic investigations presented in this study.

Widely accepted processing of samples (*i.e.*, smear-slides for nannofossils and thin-section observations for calpionellids) was performed, followed by application of classical biostratigraphic methods for detection of bio-events.

RESULTS OF SECTION BARLYA

Palaeomagnetic results

NRM intensities were quite strong, usually exceeding 10^{-3} A/m. Most of the samples revealed presence of three components of magnetization: A, B and C, with well-separated unblocking temperature spectra (Fig. 2). Component A, with unblocking temperatures between 100 °C and 250 °C, is virtually identical with the present-day geomagnetic field direction (in present-day coordinates). Component B reveals exclusively reversed polarity and it is unblocked between 250 °C and 350–400 °C. The hardest, predominantly

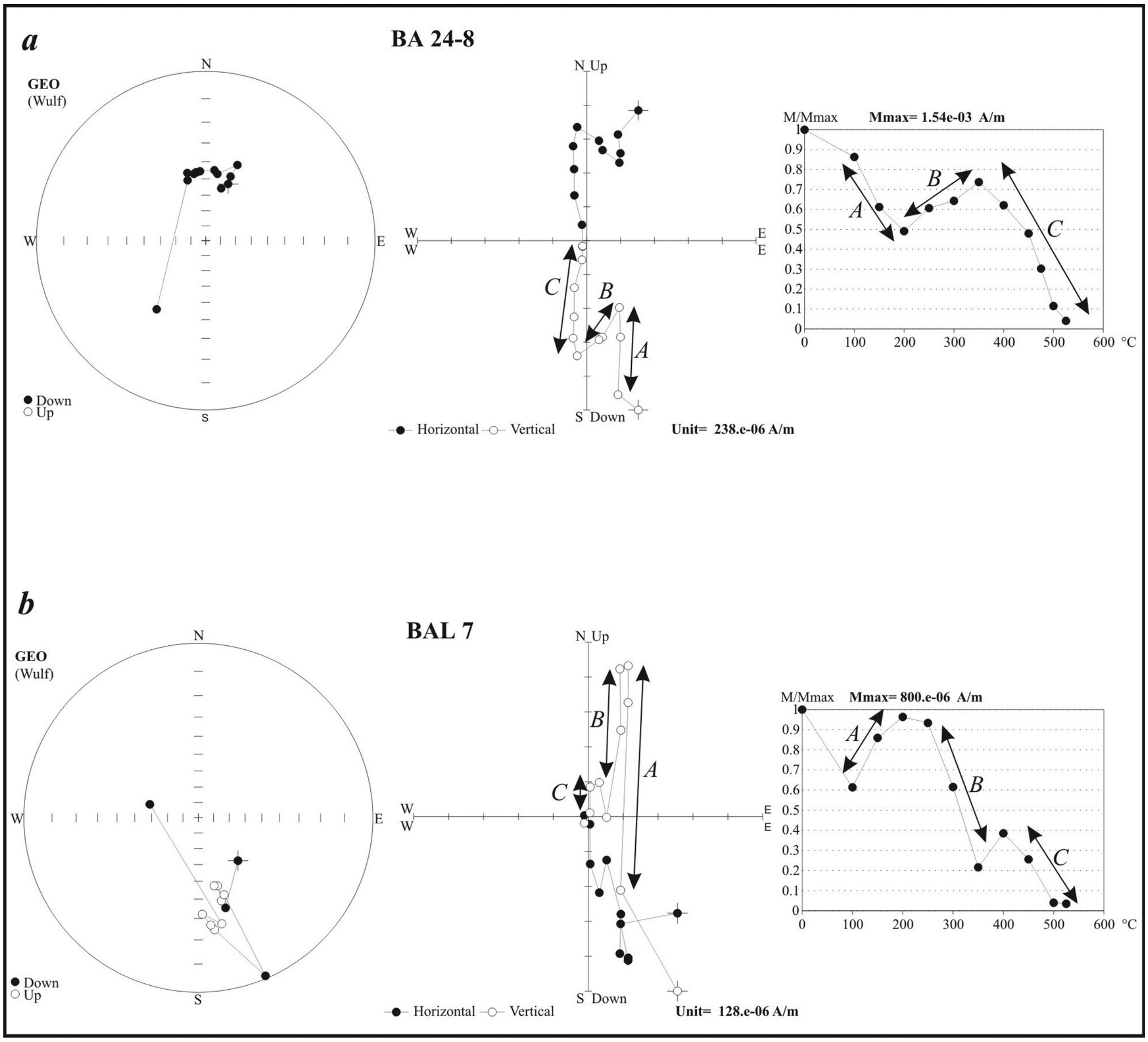


Fig. 2. Thermal demagnetization of typical specimens with normal and reversed component C. *a*) sample BA 24-8. Interval N4, *Alpina* Subzone; *b*) sample BAL 7, interval R2 (M20r?), *Dobeni* Subzone. Left – stereographic projection of demagnetization path; middle – orthogonal projection; right – NRM decay during thermal treatment. A, B and C components indicated. All projections are in geographic (*in situ*) coordinates.

normal, polarity component C is demagnetized between 400 °C and 525 °C.

A relatively long interval of reversed polarity is observed between samples BAL 10.5A and BAL 6.1 in the *Chitinoidella* Zone (interval R2, see Fig. 2b). Short and very short reversed polarity intervals occur between samples BAL 17.3 and BAL 17.15 (below the *Chitinoidella* Zone, interval R1), BAR 4.7 to BAR 4.8 (interval R3, *Intermedia* Subzone), in sample BA 16.8 (interval R4, middle part of the *Alpina* Subzone) and in the topmost part of the section between samples BA 26.75 and BA 27.90 (interval R5, *Remaniella* Subzone).

Calpionellid biostratigraphy

Upper Tithonian

The succession of Tithonian chitinoidellid and calpionellid events involves, from bottom to top, the FOs of Chitinoidellidae, *Chitinoidella boneti*, *Praetintinnopsella andrusovi*, Calpionellidae (namely *Tintinnopsella carpathica/Tintinnopsella remanei*), *Calpionella grandalpina*, *Crassicollaria brevis* and *Crassicollaria colomi*, as well as the last occurrence (LO) of *Calpionella elliptalpina*. In the upper part of the *Crassicollaria* Zone, crassicollarians show significant decline.

The following zones have been documented (Fig. 1): *Chitinoidella* (with *Dobeni* and *Boneti* subzones), *Praetintinnopsella* and *Crassicollaria* (with *Remanei*, *Intermedia*, *Brevis* and *Colomi* subzones).

Lower Berriasian

The base of the *Calpionella* Zone is herein considered as the base of the Berriasian, *i.e.*, the J/K boundary. The early Berriasian calpionellid events began with the "explosion" of the small spherical *Calpionella alpina*, followed by acme of *Crassicollaria parvula* and the successive FOs of *Calpionella minuta*, *Tintinnopsella doliphormis*, *Remaniella ferasini* and *Calpionella elliptica*. These calpionellid events were used for determination of the base of the *Alpina*, *Remaniella* and *Elliptica* subzones of the *Calpionella* Zone. The acme of *Crassicollaria parvula* and the FOs of *Calpionella minuta* and *Tintinnopsella doliphormis* appear as auxiliary events that help informal subdivision of the *Alpina* Subzone.

Calcareous nannofossil biostratigraphy

The succession of calcareous nannofossil events includes widely recorded FOs in the Tethys, such as that of *Hexalithus noeliae*, *Nannoconus infans*, *Nannoconus globulus minor*, *Nannoconus wintereri*, the coeval FOs of *Nannoconus steinmannii minor* and *Nannoconus kamptneri minor*, and the FO of *Nannoconus steinmannii steinmannii*. These events define, in ascending order, Casellato's (2010) nannofossil (sub) zones NJT 16a, NJT 16b, NJT 17a, NJT 17b, NKT and NK-1. The base of the *Calpionella* Zone is within nannofossil subzone NJT 17b (Fig. 1). It is worth mentioning the occurrence of the newly described genus *Acadialithus* (*Acadialithus dennei*) in zone NKT (samples BAL 17 and BAL 19.10). *Hexalithus geometricus*, a species somewhat neglected so far, is of interest since it shows very consistent FO in different Tethyan sections and appears quite close to the base of the *Calpionella* Zone.

DISCUSSION AND REVIEW OF RECENT DATA

Interpretation of magnetostratigraphy

Component A is interpreted as recent viscuous remanent magnetization. Component B has already been documented in the upper Berriasian part of the Barlya section (Grabowski *et al*., 2016) and interpreted as a pre-folding overprint. The nature of component C is not clear. The succession of normal and reversed intervals of component C can hardly be correlated with the reference Global Polarity Time Scale for the Tithonian–early Berriasian (Gradstein *et al*., 2012). Although normal polarity regime of the geomagnetic field indeed prevailed in the late Tithonian–early Berriasian transition (for review: Ogg *et al*., 1991; Grabowski, 2011), the position of reversed polarity magnetozones and magnetosubzones is well constrained to calpionellid stratigraphy. Between the base of the *Chitinoidella* Zone and the base of the *Elliptica* Subzone, six reversed polarity intervals should be expected: M20r, M20n1r, M19r, M19n1r (Brodno), M18r and M17r. Relatively long reversed interval R2 with the FO of *Chitinoidella boneti* might be interpreted as M20r, since the *Dobeni/Boneti* subzonal boundary is typically situated in this magnetozone (*e.g.*, Ogg *et al.,* 1991; Michalík *et al*., 2009; Grabowski *et al.,* 2010a, b). However, the other five reversed magnetozones could hardly be identified. The thin reversed interval R3 (just above the FO of *Calpionella grandalpina*) might be interpreted as M19r (see, *e.g*., Michalík *et al*., 2009, 2016). The reversed interval R4, below the FO of *Calpionella minuta*, might be either M19n1r (Brodno) or M18r (see, *e.g.,* Pruner *et al*., 2010). Both of these intervals are extremely thin. That stays in contrast with typical development of these magnetozones. Usually, even in condensed sections, with sedimentation rate of 1–4 m/Myr, the M19r and M18r have been well recorded and thin reversed magnetosubzones have been documented as well (Michalík *et al.*, 2009; Pruner *et al.*, 2010; Grabowski *et al.*, 2010a). Surprisingly, the base of the *Elliptica* Subzone in section Barlya falls in the normal polarity interval N5, which is not typical since this bioevent usually occurs in the long reversed polarity magnetozone M17r (Channell and Grandesso, 1987; Grabowski and Pszczółkowski, 2006; Michalík *et al*., 2016). These observations indicate that the magnetostratigraphic record in the Barlya section is either incomplete (lacking large parts of reversed magnetozones) or the section has been partially remagnetized. As the Barlya section is excellently exposed, with very gentle tectonic deformations (monoclinal dip, no internal faults or overthrusts) and no visible sedimentary breaks (breccia levels, hardground horizons), the remagnetization hypothesis seems more likely. Remagnetization must have been not complete, and that is why the "relicts" of reversed magnetozones were preserved. The question why the Tithonian–lower Berriasian part of the Barlya section is partially remagnetized whilst in the upper Berriasian interval primary magnetization was preserved (Grabowski *et al.*, 2016) cannot be answered for the time being. Further investigations will focus on comparison of rock magnetic properties of both remagnetized and unremagnetized parts of the section and constraining the timing and origin of the remagnetization event.

Calpionellid events and magnetostratigraphy

Correlation of calpionellid events with respect to magnetostratigraphy in previously studied coeval sections in the Carpathians in Slovakia (Houša *et al*., 1999; Grabowski *et al*., 2010b; Michalík *et al*., 2009,

2016) and Poland (Grabowski and Pszczółkowski, 2006; Grabowski *et al*., 2013), in the Transdanubian Range in Hungary (Grabowski *et al*., 2010a), as well as in France (Wimbledon *et al*., 2013), Spain (Pruner *et al*., 2010), Italy (Houša *et al*., 1999; Channell and Grandesso, 1987) and Austria (Lukeneder *et al*., 2010) is shown in Table 1 and Fig. 3. Each calpionellid event exhibits different extent of dispersion. Even dispersed, the calpionellid events are restricted to one certain normal or reverse magnetic polarity chron. These are as follows (from top to bottom):

1. FO of *Calpionella elliptica* – within M17r;
2. FO of *Remaneilla ferasini* – M18n;
3. FOs of *Tintinnopsella doliphormis* and *Calpionella minuta* – also within M18n;
4. Acme of *Crassicollaria parvula* – M19n2n, below the Brodno subchron (M19n1r);
5. "explosion of *Calpionella alpina*" – M19n2n to M19n1n (base of Berriasian);
6. FOs of *Crassicollaria colomi* and *Crassicollaria brevis* – lower half of M19n2n;
7. FOs of *Calpionella grandalpina*/*Calpionella alpina* – upper half of M20n to M19r;
8. FOs of *Tintinnopsella carpathica/Tintinnopsella remanei* – upper half of M20n, above or below the Kysuca subchron;
9. FO of *Praetintinnopsella andrusovi* – normally in M20n;
10. FO of *Chitinoidella boneti* – normally within M20r (base of upper Tithonian);
11. FO of Chitinoidellidae – M21r (the upper part of lower Tithonian).

Calcareous nannofossil events and magnetostratigraphy

The nannofossil events recognized in the Barlya section have been compared with previous nannofos-

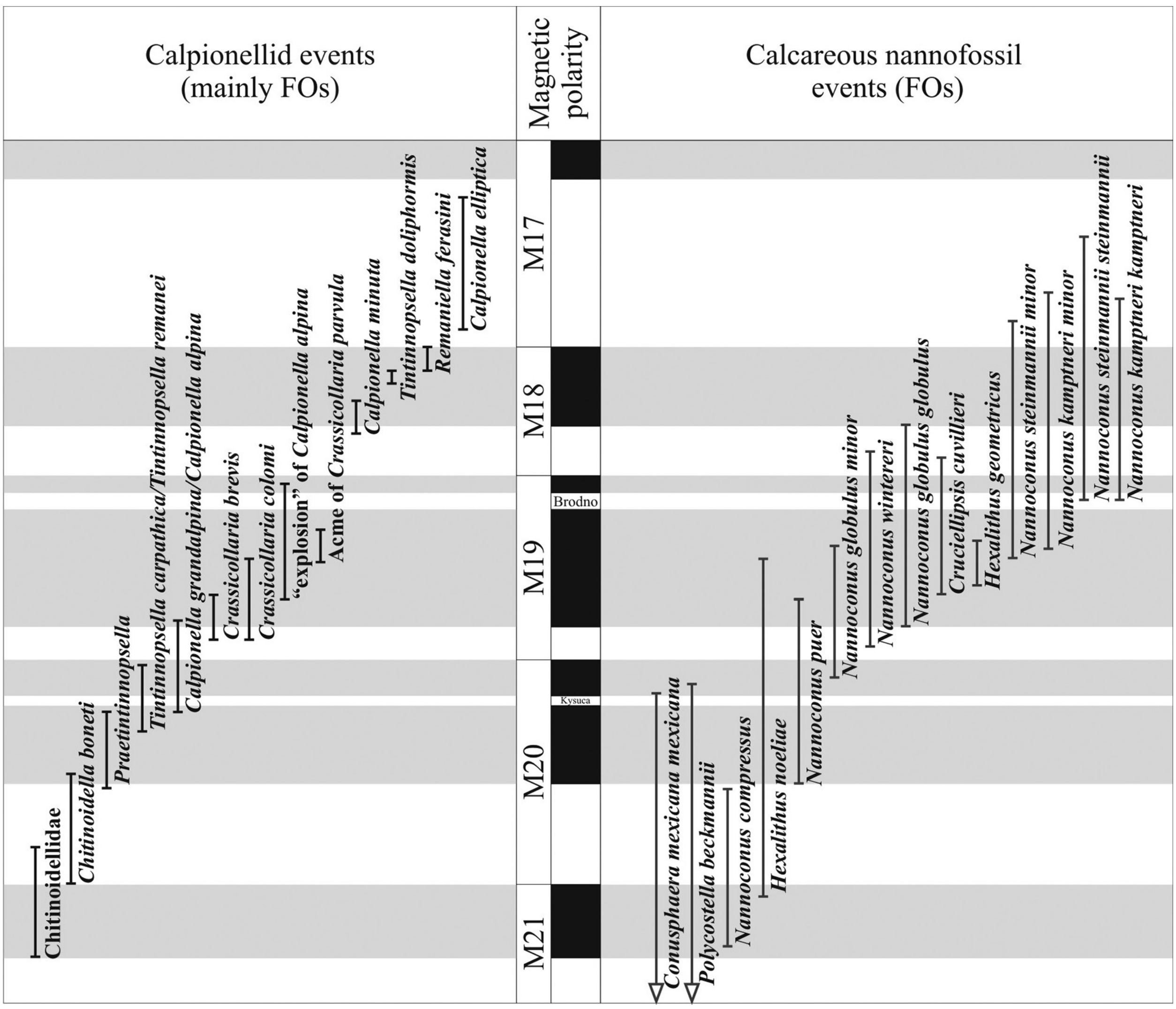


Fig. 3. Selected calpionellid and calcareous nannofossil events from the Tithonian/Berriasian boundary interval, directly correlated to magnetostratigraphy (for sources see references in Tables 1, 2).

Table 1
List of sections across the J/K boundary with direct correlation between magnetostratigraphy and calpionellid zones/subzones

Country	Section	Thickness (m)	Succession characteristics	Calpionellid Zones (Subzones)	Magnetozones	Magnetozone – J/K boundary	References
Austria	Nutzhof	11.8	condensed	*Chitinoidella* (*Boneti*)–*Calpionella* (*Elliptica*)	M20r–M18n	M19n2n	Lukeneder *et al*. (2010)
Bulgaria	Barlya	47	normal	*Chitinoidella* (*Dobeni*)–*Calpionella* (*Elliptica*)	M21r–M17r	M19n (?)	this study
France	Le Chouet	23	condensed	*Chitinoidella*–*Calpionella* (*Alpina*)	M20n–M19n	M19n2n	Wimbledon *et al*. (2013)
Hungary	Lókút	13	condensed	*Chitinoidella* (*Dobeni*)–*Calpionella* (*Alpina*)	M21r–M18r	M19n2n	Grabowski *et al*. (2010a)
Italy	Bosso Valley	26	normal	*Chitinoidella*–*Calpionella* (*Remaniella*)	M20n–M17r	M19n	Houša *et al*. (2004)
	Valle del Mis	35	normal	*Chitinoidella*–*Calpionella* (*Elliptica*)	M20r–M17r	M19n	Channell and Grandesso (1987)
	Frisoni	27	condensed		M21n–M17r	M19n	
	Xausa	13	condensed		M21r–M17r	M19n	
Poland	Pośrednie III	25	fault	*Chitinoidella*–*Calpionella* (*Elliptica*)	M20r–M17r	M19n	Grabowski and Pszczółkowski (2006); Grabowski *et al*. (2013)
Spain	Puerto Escaño	7.5	condensed	*Chitinoidella*–*Calpionella* (*Doliphormis*)	M20r–M18n	M19n	Pruner *et al*. (2010)
Slovakia	Brodno	9	condensed	*Chitinoidella* (*Dobeni*)–*Calpionella*	M20r–M18r	M19n	Houša *et al*. (1999)
				Chitinoidella (*Dobeni*)–*Calpionella* (*Alpina*)	M21n–M18r	Brodno	Michalík *et al*. (2009)
	Hlboča	20	breccia	*Chitinoidella* (*Dobeni*)–*Calpionella* (*Elliptica*)	M21n–M17r	M20n/M19r	Grabowski *et al*. (2010b)
	Strapkova	50	normal	*Chitinoidella*–*Calpionella* (*Elliptica*)	M19n–M17r	M19n2n	Michalík *et al*. (2016)

Table 2
List of sections across the J/K boundary with direct correlation between magnetostratigraphy and nannofossil zones/subzones

Country (Site)	Section	Thickness (m)	Succession characteristics	Nannofossil Zones (Subzones)	Magnetozones	Magnetozone – J/K boundary	References
Austria	Nutzhof	11.8	condensed	NJT 15a–NK-1	M20r–M18n	M19n2n	Lukeneder *et al*. (2010)
Bulgaria	Barlya	47	normal	NJT 15b–NK-1	M21r–M17r	M19n (?)	this study
France	Le Chouet	23	condensed	NJT 16b–NKT	M20n–M19n	M19n2n	Wimbledon *et al*. (2013)
Hungary	Lókút	13	condensed	NJT 16b–NKT	M21r–M18r	M19n2n	Grabowski *et al*. (2017)
Italy	Torre de' Busi Colme di Vignola Frisoni Foza A	60 20 25 35	normal condensed condensed condensed	NJT 13–NKT NJT 13–NK1 NJT 15–NKT NJT 14–NK-2	M22n–M18n M21r–M17r M22r–M17r M22r–M16r	M19n M19n/M18r M19n/M18r M19n/M18r	Casellato (2010) Casellato (2010) Casellato (2010) Casellato (2010)
Spain	Puerto Escaño	7.5	condensed	NJT 15–NK-1	M20r–M18n	M19n	Svobodová and Košťák (2016)
Slovakia	Brodno Hlboča Strapkova	9 20 50	condensed breccia normal	NJ-20–NJK ? No zones	M21n–M18r M21n–M17r M19n–M17r	Brodno M20n/M19r M19n2n	Michalík *et al*. (2009) Grabowski *et al*. (2010b) Michalík *et al*. (2016)
Atlantic Ocean	DSDP 534 A	50	normal	NJK-C–NK-1	M19n–M17n	M19n	Bralower *et al*. (1989)

sil–magnetostratigraphy relationships mainly in Italy (Casellato, 2010; Channell *et al.*, 2010), as well as in Spain (Svobodová and Košťák, 2016), Austria (Lukeneder *et al.*, 2010), Slovakia (Michalík *et al.*, 2009, 2016), France (Wimbledon *et al.*, 2013) and Hungary (Grabowski *et al.*, 2017) (see Table 2).

A comprehensive review of the available data on nannofossil and magnetostratigraphy correlation has clearly shown two distinct groups of nannofossil taxa: the first one, with rather scattered and diachronous FOs, and the second one, which displays more or less consistent FO record amongst different sections (Fig. 3). The first group includes *Conusphaera mexicana mexicana, Polycostella beckmannii, Hexalithus noeliae* and *Nannoconus compressus*. These taxa's FOs demonstrate diachroneity in the Tethyan realm, and therefore could hardly be used for precise correlation.

The second group includes *Nannoconus globulus minor, Hexalithus geometricus, N. globulus globulus, N. wintereri, Cruciellipsis cuvillieri, N. steinmannii minor* and *N. kamptneri minor*. Overall, their FOs fall within the long M19n chron. The FO of *Hexalithus geometricus* seems a fairly consistent bioevent at the middle of the M19n2n subchron and thus of potentially high relevance for detailed correlation(s). The FOs of *N. steinmannii minor* and *N. kamptneri minor,* commonly used for biostratigraphic zonation, appear concentrated within the upper part of the M19n and in the M18r chrons. It is worth noting that the next two evolving species in the early Berriasian, *N. steinmannii steinmannii* and *N. kamptneri kamptneri*, show relatively dispersed FOs within M19n1r–M17r chrons, which could be due to various reasons: preservation problems, problematic bio-magnetostratigraphy calibrations or simple diachroneity.

CONCLUSIONS

In the Barlya section (West Balkan Mts, Bulgaria), the direct correlation of magnetostratigraphy and microbiostratigraphy has revealed the presence of magnetic polarity chrons from M21r to M17r in the upper Tithonian and lower Berriasian, as well as a number of correlative calpionellid and calcareous nannofossil events/biohorizons. A large interval of normal polarity between M20r and M17r appears to be partly remagnetized, and only two thin reversed intervals could be interpreted as remnants of M19r and M18r or Brodno. This large remagnetized interval extends from the base *Boneti* Subzone to the base *Elliptica* Subzone.

The calpionellid *Chitinoidella*, *Praetintinnopsella*, *Crassicollaria* and *Calpionella* zones and their subzones have been correlated to the magnetostratigraphy and to the calcareous nannofossil (sub)zones NJT 15b, NJT 16a, NJT 16b, NJT 17a, NJT 17b, NKT and NK-1. The base of the Berriasian is traced at the base of the *Calpionella alpina* Subzone within nannofossil subzone NJT 17b.

A review of the available data of joint magneto- and biostratigraphy on calpionellids and calcareous nannofossils across the J/K transition in the European Tethys shows here for the first time the extent of diachroneity of all major calpionellid and nannofossil events with respect to magnetostratigraphy. Thus, the main calpionellid events show dispersals in different sections within one certain normal or reversed magnetic polarity chron. The nannofossil events show grouping into two clusters: the first one is with considerable dispersal, and the second one is quite concentrated in restricted polarity chron interval, consistent and therefore recommendable for distant correlations.

Acknowledgements

The work on this publication has been supported by the Bulgarian Science Fund (contract DNTS Slovakia 01/9) and the Slovakian Research and Development Agency under the contract APVV-14-0118. Investigations of Jacek Grabowski and Kristalina Stoykova were financially supported by the project DEC-2011/03B/ST10/05256 of the National Science Centre, Poland. Petr Schnabl was funded by Czech science foundation project no: 16-09979S.

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