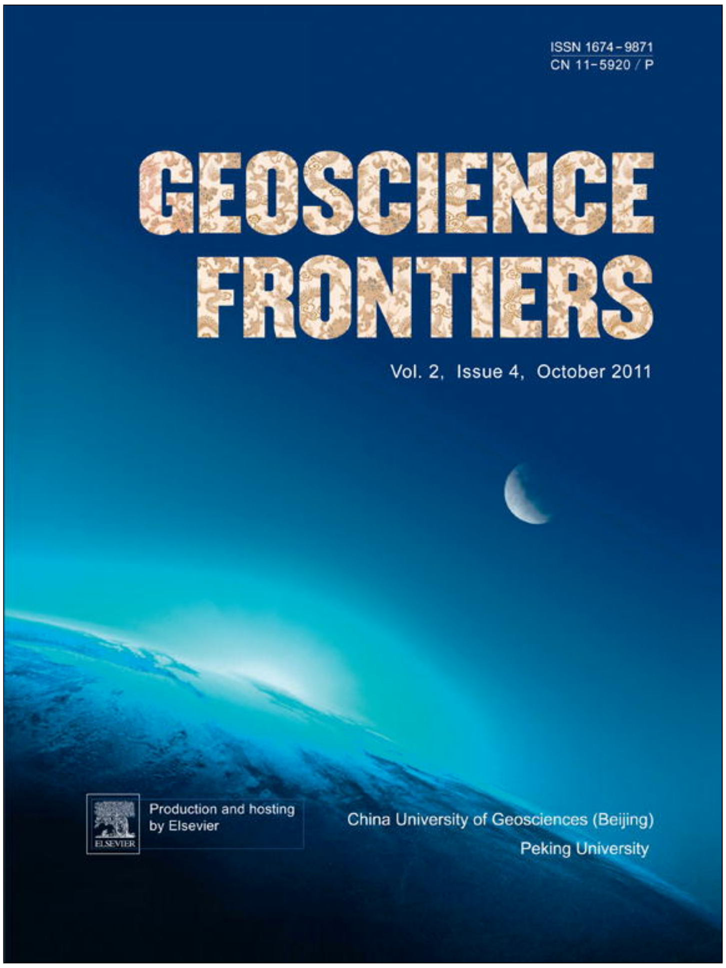
ISSN 1674-9871
CN 11-5920 / P
GEOSCIENCE FRONTIERS
Vol. 2, Issue 4, October 2011
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GEOSCIENCE FRONTIERS 2(4) (2011) 475–490

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ORIGINAL ARTICLE

# Possible markers of the Jurassic/Cretaceous boundary in the Mediterranean Tethys: A review and state of art

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Received 4 May 2011; accepted 3 August 2011
Available online 8 October 2011

**KEYWORDS**
J/K boundary;
Interregional correlation;
Biostratigraphic proxies;
Calpionellids;
Nannofossils

**Abstract** During the last decades, several integrated studies of Tethyan Jurassic/Cretaceous boundary sections from different countries were published with the objective to indicate problems for the selection of biological, chemical or physical markers suitable for identification of the Jurassic/Cretaceous boundary – the only system boundary within the Phanerozoic still not fixed by GSSP. Drawing the boundary between the Jurassic and Cretaceous systems is a matter of global scale discussions. The problem of proposing possible J/K boundary stratotypes results from lack of a global index fossils, global sea level drop, paleogeographic changes causing development of isolated facies areas, as well as from the effect of Late Cimmerian Orogeny. This contribution summarizes and comments data on J/K boundary interval obtained from several important Tethyan sections and shows still existing problems and discrepancies in its determination.

## 1. Introduction

Almost two hundreds years ago, Brogniart (1829) erected Portlandian and Purbeckian as two stages (defined only lithostratigraphically), which should mark the end of Jurassic System. The ammonite *Ammonites giganteus* was selected by d'Orbigny two decades later (1842–1851) to fix this boundary below the "Neocomian" strata. Since that time, this boundary interval became a matter of controversies (Zakharov et al., 1996; Mahoney et al., 2005; Houša et al., 2007). At the "Colloque sur la limite Jurassique Crétacé" organized in Lyon-Neuchâtel, 1973 (Thierstein, 1975), it was recommended that the J/K boundary in the Tethyan realm should coincide with the boundary between the standard Crassicollaria and Calpionella zones (Allemann et al., 1971) approximating with the ammonite Grandis-Jacobi zones. The Sűmeg Meeting of calpionellid

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Peer-review under responsibility of China University of Geosciences (Beijing).
doi:10.1016/j.gsf.2011.09.002

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specialists (Remane et al., 1986) resulted in a proposal to draw the J/K boundary line between the Crassicollaria and Calpionella zones, below the base of Beriasella Jacobi zone. This solution was equal to the variant No. 2 of the "*Colloque sur la limite Jurassique Crétacé*" in Lyon-Neuchâtel, 1973 (Thierstein, 1975).

Despite of contradicting opinions (some authors proposed to draw the boundary at the base of Subalpina zone, or even on the base of Otopeta zone), the position of the J/K boundary at the base of the ammonite Jacobi zone is accepted by majority of stratigraphers (Hoedemaeker et al., 1993; Hoedemaeker, 1995; Fig. 1). Although several zone-by zone correlations in the Tethys Realm (Tithonian and Berriasian Stages) and in the Boreal Realm (Volgian and Ryazanian Stages) have been suggested during the last half a century, none of them is unanimously accepted (Houša et al., 2007). It is correlatively one of the most difficult boundaries and one of the very last GSSP tasks to be tackled by the ICS (International Commission on Stratigraphy) and its subcommissions (Wimbledon, 2008). Detailed historical overview and recent advances in the fixing of basal Berriasian and location of the Jurassic/Cretaceous boundary were recently summarized by Wimbledon et al. (2011).

Due to scarcity of ammonites in many Tethyan Upper Jurassic and Lower Cretaceous sequences, microfossils, namely calpionellids, calcareous dinoflagellates and nannofossils (Bakalova, 1977; Borza and Michalík, 1986; Remane et al., 1986; Remane, 1986; Bucur, 1992; Reháková and Michalík, 1992; Pop, 1989, 1994; Lakova, 1994; Olóriz et al., 1995; Adatte et al., 1996) were preferentially used for biostratigraphy. Remane (1991) pointed out that none of the calpionellid zones or subzones is a total range zone and that traditional ammonite zones are loosely defined by their contents as they have no clearly cut boundaries. Therefore the 'explosion' event in abundance of small, globular *Calpionella alpina* was involved as an indicator of the J/K boundary ("Alpina acme", or "Alpina bloom" of Remane, 1985; Remane et al., 1986; Altiner and Özkan, 1991; Bucur, 1992; Lakova, 1994; Pop, 1994; Olóriz et al., 1995; Grün and Blau, 1997; Reháková and Michalík, 1997; Houša et al., 1999; Skourtsis-Coroneou and Solakius, 1999; Pszczółkowski et al., 2005; Boughdiri et al., 2006; Andreini et al., 2007; Michalík et al., 2009; Reháková et al., 2009). Moreover, Michalík et al. (2009) characterized several calpionellid diversification events: (1) the onset, diversification, and extinction of chitinoidellids (Middle Tithonian); (2) the onset, burst of diversification, extinction of crassicollarians (Late Tithonian); and (3) the onset of monospecific *Calpionella* association close to the J/K boundary.

*Conusphaera* and *Polycostella* proliferate in the Early Tithonian and are not useful species for the J/K boundary (see Bralower et al., 1989; Casellato, 2010; Tremolada et al., 2006). Otherwise mid-Tithonian is characterized by a speciation event which provides several FOs that could be useful for the boundary: among the others four FOs (*Nannoconus wintereri*, *Cruciellipsis cuvillieri*, *Nannoconus steinmanni minor*, *Nannoconus camptneri minor*) were chosen and proposed as useful datums for J/K boundary interval (see Wimbledon et al., 2011).

Potential of calcareous dinoflagellates in determination of the J/K boundary was considered by Řehánek (1992). The FO of *Stomiospaherina proxima* Řehánek, regarded by him as an appropriate marker in defining of the boundary, was fixed by Ivanova in Lakova et al. (1999) and Reháková (2000a) within Late Tithonian Crassicollaria zone.

The J/K boundary interval was characterized by eustatic oscillations of the sea level (Haq et al., 1987). Reháková (2000b) studied the radiation and stagnation in calpionellid and calcareous dinoflagellate evolution and interpreted monospecific *C. alpina* association as reflection of environmental instability related to eustatic lowering of the sea level.

Oxygen isotope data supported by nannoplankton ecology data indicate a slight cooling (Price, 1999) after a generally warm climate (14–20 °C, Gröcke et al., 2003) during Late Jurassic, followed by gradual temperature increase (and by decrease of latitudinal climatic gradients, cf. Žák et al., 2010) around the J/K boundary. The overall low $\delta^{13}$C characterizing the uppermost Jurassic have been related to a global increase in continental weathering and/or to upwelling of cooler oceanic water enriched in oxidized organic carbon. Similarly, increase in strontium isotopes ratio may result from either a decrease of mid-oceanic spreading and/or from an increasing weathering rate (Gröcke et al., 2003).

Clay mineral content (Dorset Purbeck Limestone and Wealden Group) shows that semi-arid climate prevailed during Late Tithonian and earliest Berriasian followed by humidization (Schnyder et al., 2006).

Magnetostratigraphy was successfully used across the boundary interval. Marine sections in the Tethyan region offer good correlation possibilities at the Jurassic/Cretaceous (J/K) boundary interval because of established (micro- and nanno-) bio-, chemo-, and magneto- stratigraphy (Channell et al., 1982; Lowrie and Channell, 1984; Ogg and Lowrie, 1986; Channell and Grandesso, 1987; Bralower et al., 1989; Ogg et al., 1991). Magnetic polarity zones are relatively easy to be identified, due to specific pattern of two long normal magnetozones (M20n and M19n), containing short reversed polarity subzones (M20n1r and M19n1r), named as the Kysuca- and the Brodno Subzone, respectively by Houša et al. (1996, 1999). Tethyan calpionellid and nannoplankton zonations were calibrated with magnetic reversals (Bralower et al., 1989; Casellato et al., 2009; Channell et al., 2010; Lukeneder et al., 2010; Pruner et al., 2010).

According to a tentative proposal of the Berriasian Working Group at the International Subcomission on Cretaceous Stratigraphy (ISCS) lead by Dr. W.A.P. Wimbledon, potential primary markers of the J/K boundary are: (1) the base of the Calpionella zone–Alpina Subzone characterized by an "explosion" of small, globular *C. alpina*; (2) FADs of *Nannoconnus steinmannii minor* and *Nannoconus kamptneri minor*; and (3) the base of M18r magnetozone. Several secondary supporting markers were also suggested (see Wimbledon et al., 2011, for details).

In this paper, we are giving a short survey of several important Tethyan sections with comments on potential J/K boundary.

## 2. Tethyan J/K sections

Integrated study of the J/K boundary in northeastern Mexico (Adatte et al., 1994, 1996) concerning microfacies, clay minerals mineralogy, calpionellids and ammonites enabled precise trans-Atlantic correlations. The J/K boundary was not strictly recognized because typical Mediterranean fauna of Upper Tithonian mostly miss in the sections studied (Puerto Piñones, Sierra Jabali, Iturbide, and San Pedro del Gallo sections, northeastern Mexico; Guapotec, Tehepican I, II, and Mazatepec sections, central–eastern Mexico). Sporadic calpionellids and endemic ammonite taxa characterized the lower part of Calpionella zone; Mediterranean ammonite taxa and calpionellid-rich facies appeared only during Late Berriasian.

Two sections (PR-01, PR-06), situated in the Sierra de los Organos, on the south-facing slope of the Sierra del Infierno belonging to the Proto-Caribbean Basin, Western Cuba were studied

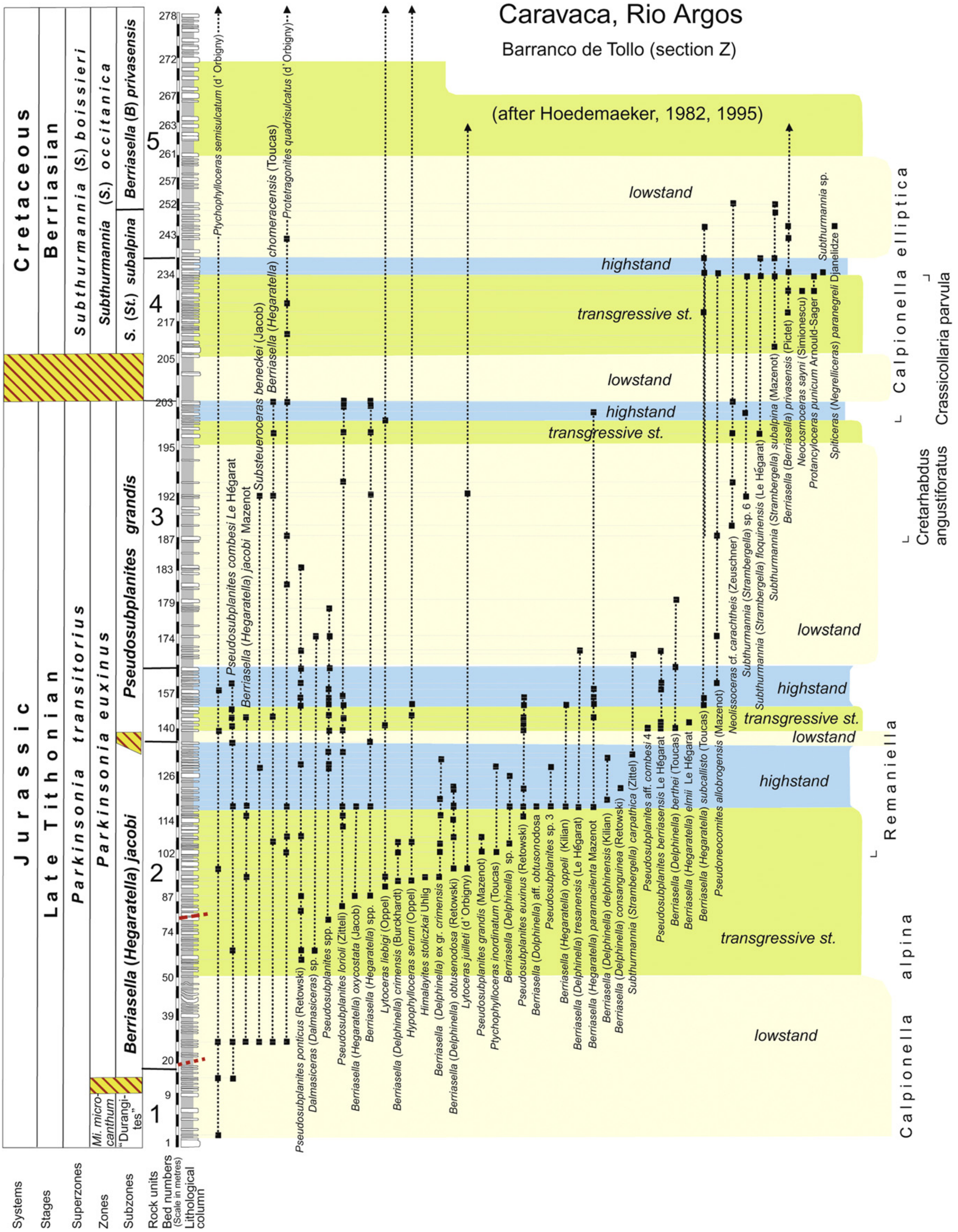

**Figure 1** Distribution of ammonites in the frame of sequence stratigraphy of the Barranco de Tollo section, Rio Argos near Caravaca, provincia Murcia, Spain (after Hoedemaeker, 1982, 1995).

in details to document the position of the Tithonian–Berriasian boundary in the Guasasa Formation (Pszczółkowski and Myczyński, 2004; Pszczółkowski et al., 2005). The authors situated the J/K boundary inside the El Americano Member, characterizing it by a transition between the Crassicollaria intermedia Subzone (correlatable with the Nannoconus wintereri Subzone sensu Pszczółkowski and Myczyński, 2004) and the Calpionella alpina Subzone (correlatable with the N. steinmannii minor Subzone and the N. steinmannii steinmannii zone, sensu Bralower et al., 1989). Proto-Caribbean Basins with dysaerobic to anaerobic regime were inhabited by rich radiolarian fauna, which allowed to Jud (1994) to determine the D2 radiolarian zone.

Presence of calpionellids in the Nova Scotia offshore (Jansa et al., 1980) in the Western North Atlantic was introduced as the evidence of warm Tethyan oceanic waters which penetrated into juvenile Atlantic between North America, Iberia and Africa. Ascoli et al. (1984) studying 28 borehole sections in a 2300 km transect along the North American Atlantic margin across the Baltimore Canyon Trough, Georges Bank Basin, Scotia Basin and eastern New Foundland Basin were studied by Ascoli et al. (1984) to revise microfossil (benthic foraminifer-, ostracod- and calpionellid) integrated biozonation of the Jurassic/Cretaceous strata. The J/K boundary was recognized in five boreholes (COST G-2, Mohican I-100, Puffin B-90, Moheida P-15, Bonnition H-32) supported by relative abundance and morphological change of *C. alpina* tests. It has to be noted that the boundary drawn on the base of calpionellid indexes (sensu Ascoli et al., l.c) does not fit with the one according to foraminifers and ostracods (being situated lower, cf. Jansa et al., l.c.).

Calpionellids from basinal (Miravetes section) and swell facies (Cañada Lengua sections) from the Rio Argos valley near Caravaca (Subbetic zone, Spain) were studied by Allemann et al. (1975). Although he concluded that the Tithonian–Berriasian boundary cannot be fixed with calpionellids in these areas, he placed it within

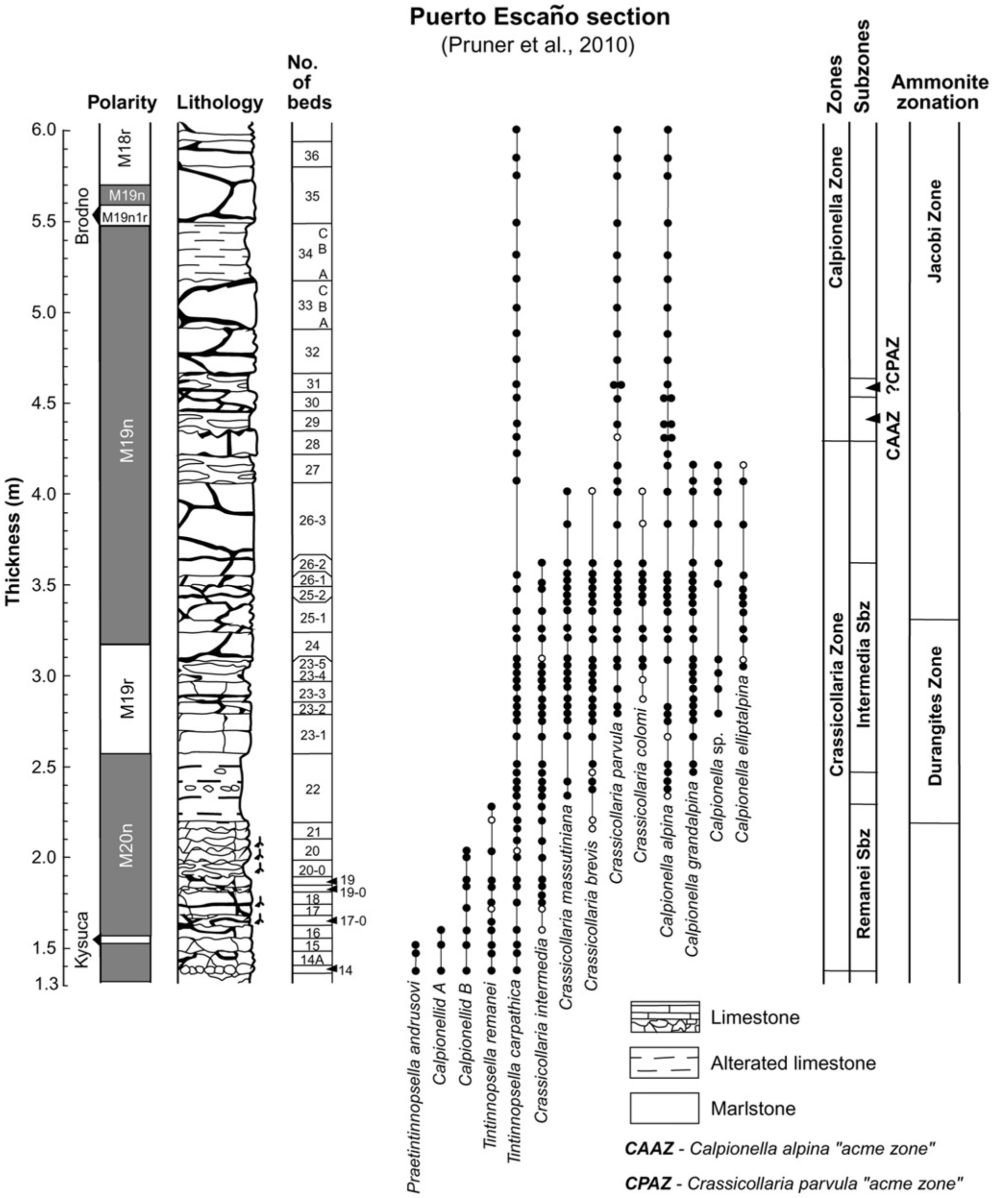

**Figure 2** Puerto Escaño section, Spain: comparison of magneto- and microbiostratigraphy (after Pruner et al., 2010).

the upper part of the Calpionella alpina zone (boundary interval of Jacobi−Euxina ammonite zones). According to most recent revision of calpionellid associations (Jamrichová and Reháková, unpublished) from the Rio Argos Z-section (Fig. 1), the base of the Alpina Subzone of the Calpionella zone (approximating the plausible J/K level) is situated much higher than previously identified by Allemann et al. (1975). Crassicollaria zone partially covers also the ammonite Jacobi zone, similarly to the situation in the Puerto Escaño section (Pruner et al., 2010).

Puerto Escaño section, southern Spain (Fig. 2) exposes basinal limestone sequence belonging to Crassicollaria−Calpionella zones. Tavera et al. (1994) considered several possibilities of the boundary drawing: (1) interval of "relative explosion" of *C. alpina* (characterized by a sudden decrease of Crassicollaria, but *C. alpina* does not yet display the change toward small spherical forms); (2) the overlying strata where small isometric forms of *C. alpina* coeval with *Crassicollaria parvula* and *Crassicollaria brevis* are present; (3) the interval of a complete disappearance of the Crassicollaria

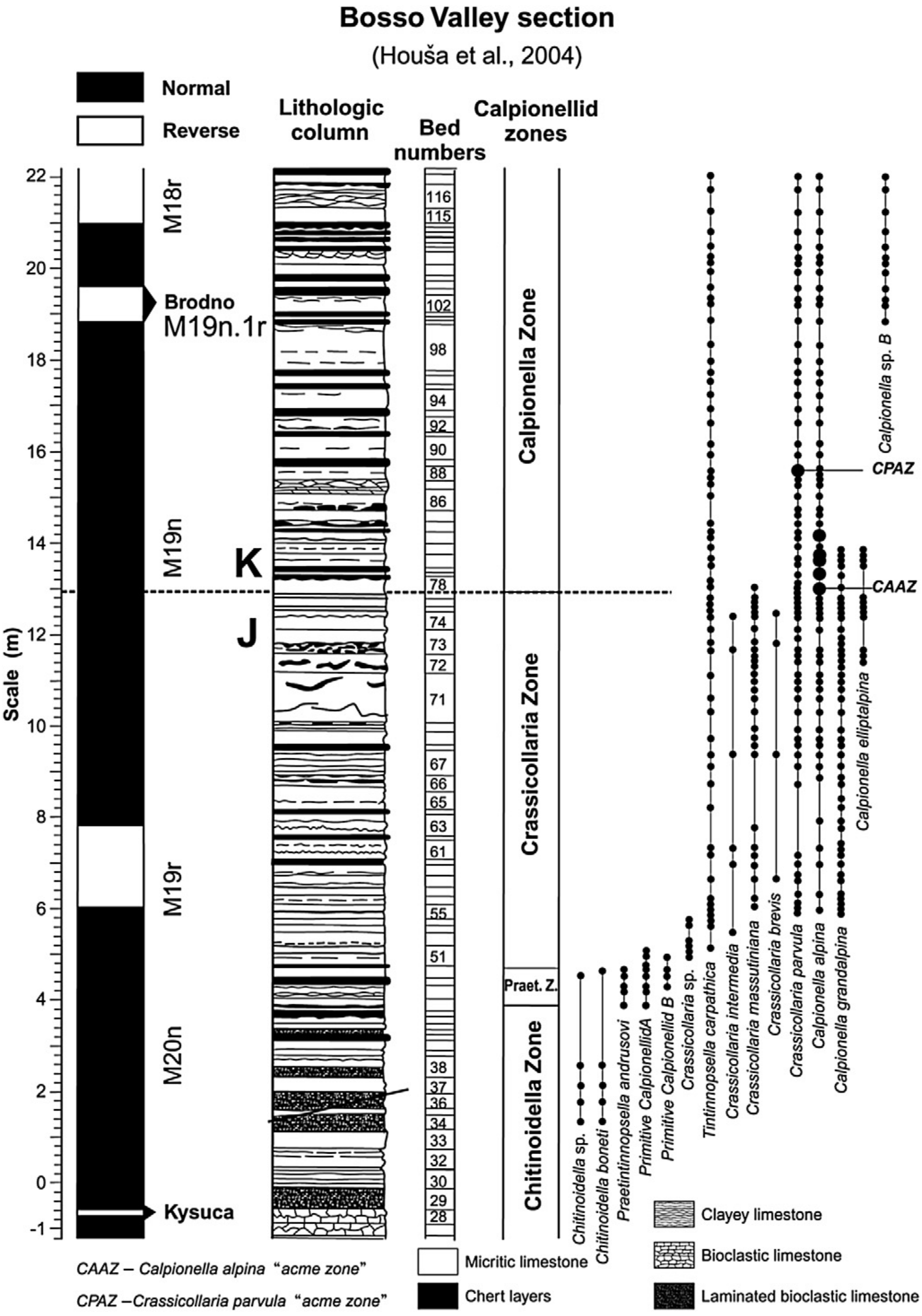

**Figure 3** Val Bosso section in the Umbria-Marche area of the Central Italy, comparison of magneto- and calpionellid biostratigraphy (after Houša et al., 2004).

species inside the Calpionella zone. This interval was regarded as the J/K boundary.

In a more detailed and integrated (ammonites, calpionellids, magnetostratigraphy) study, Pruner et al. (2010) approximate the boundary between the Crassicollaria and Calpionella zones. According to these authors, the mass occurrence of *C. alpina* should be considered as indicating the epibole for this species (CAAZ; see Fig. 2) which is overlied by the interval with abundant occurrence of

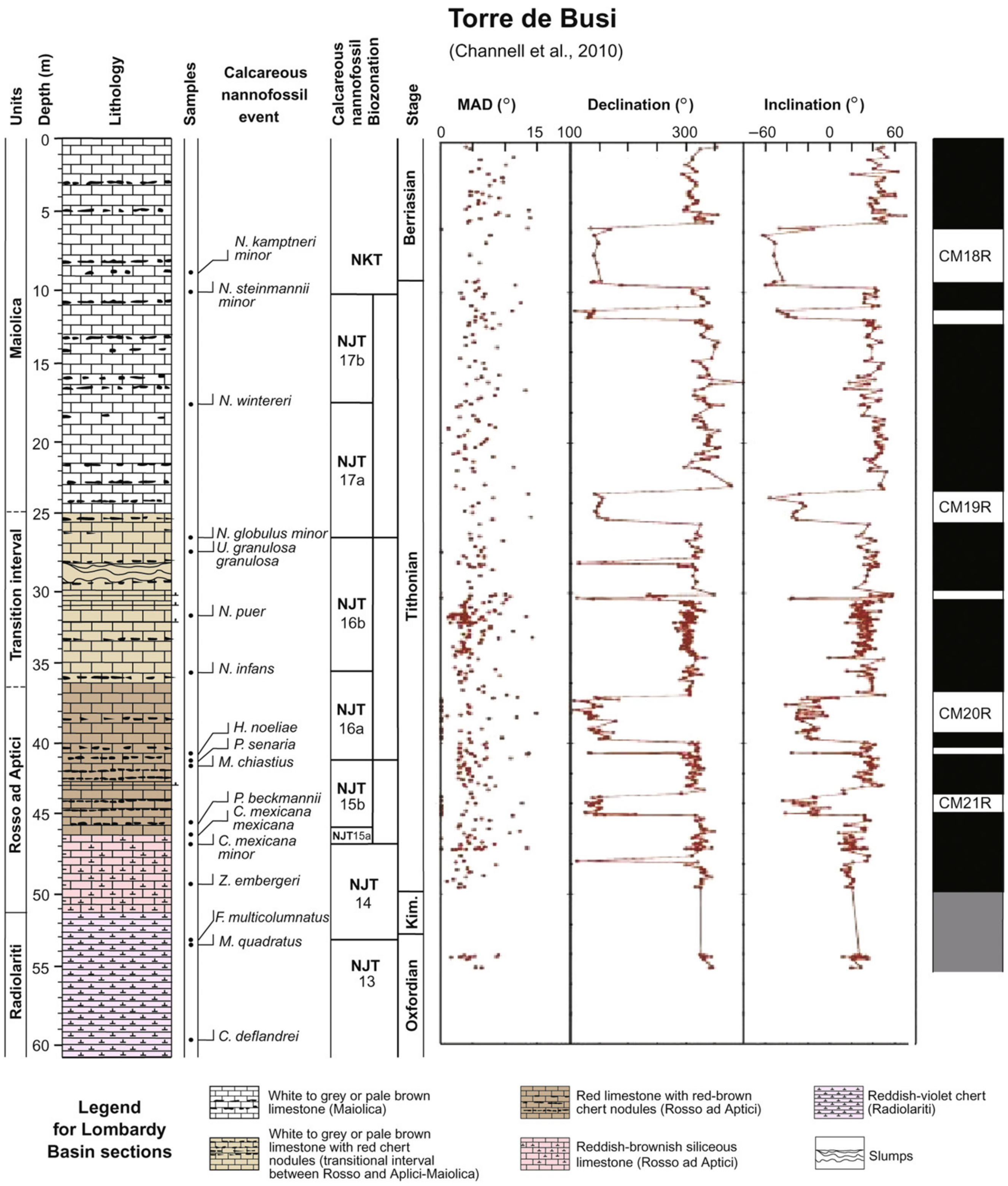

**Figure 4** Torre de Busi section from Southern Alps, Northern Italy: magneto-nanno- and calpionellid biostratigraphy (after Casellato, 2010; Channell et al., 2010).

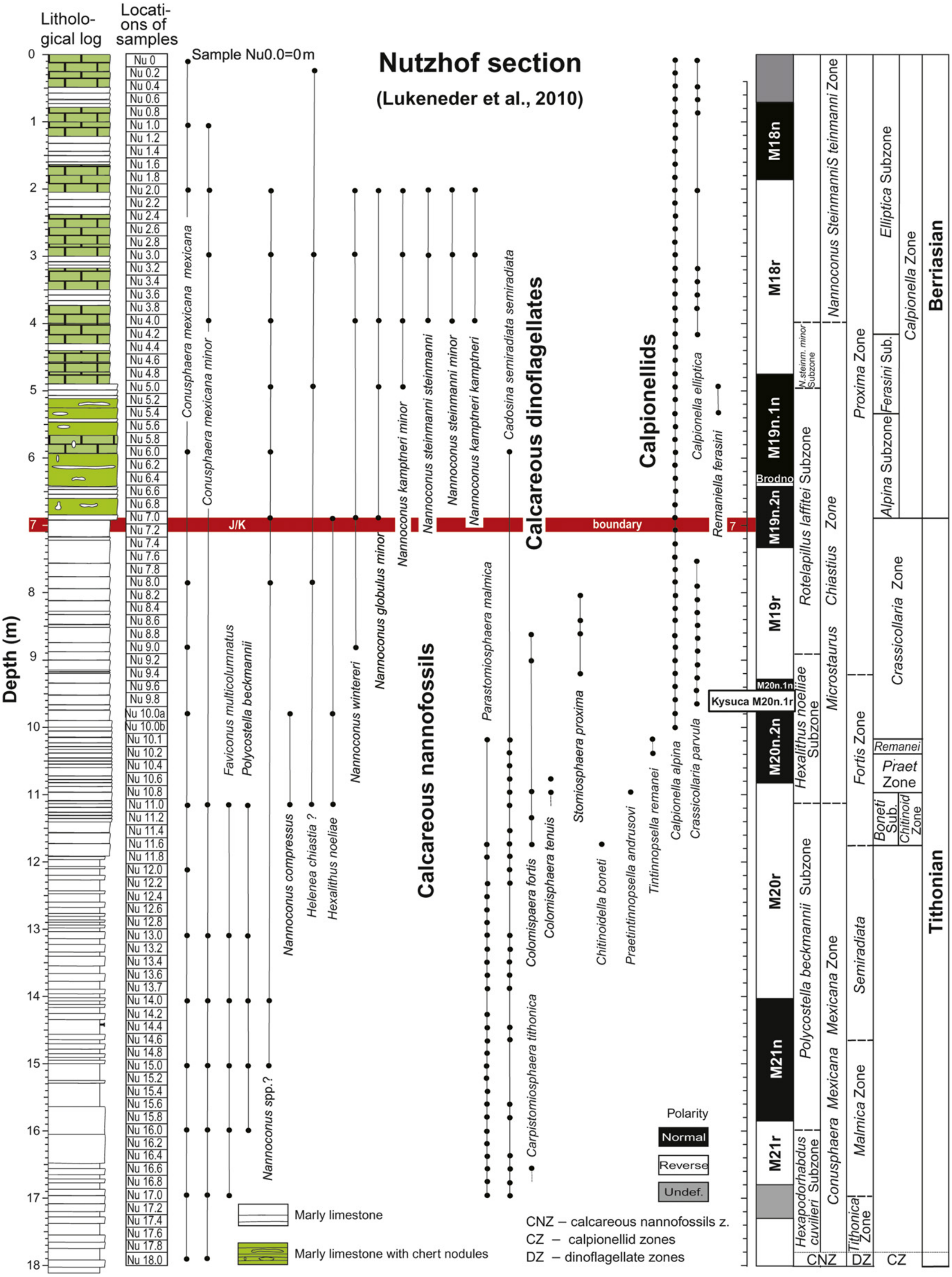

**Figure 5** Nutzhof section of the Gresten Klippenbelt, Northern Calcareous Alps, Austria: microbiostratigraphy and magnetostratigraphy (after Lukeneder et al., 2010).

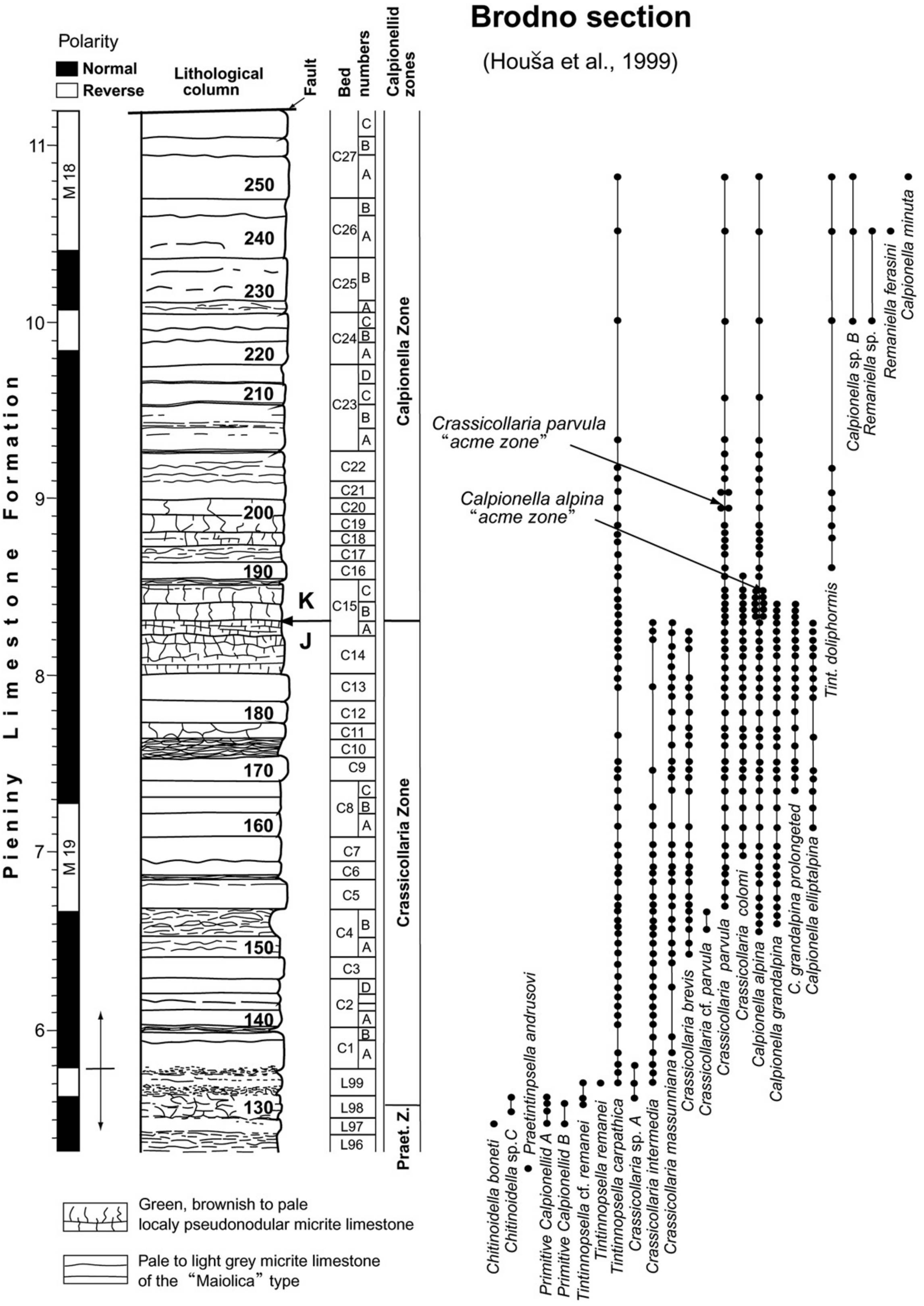

**Figure 6** Brodno section in the Kysuca Gate near Žilina, Western Carpathians, Slovakia: correlation of magneto and calpionellid microbiostratigraphy (after Houša et al., 1996, 1999).

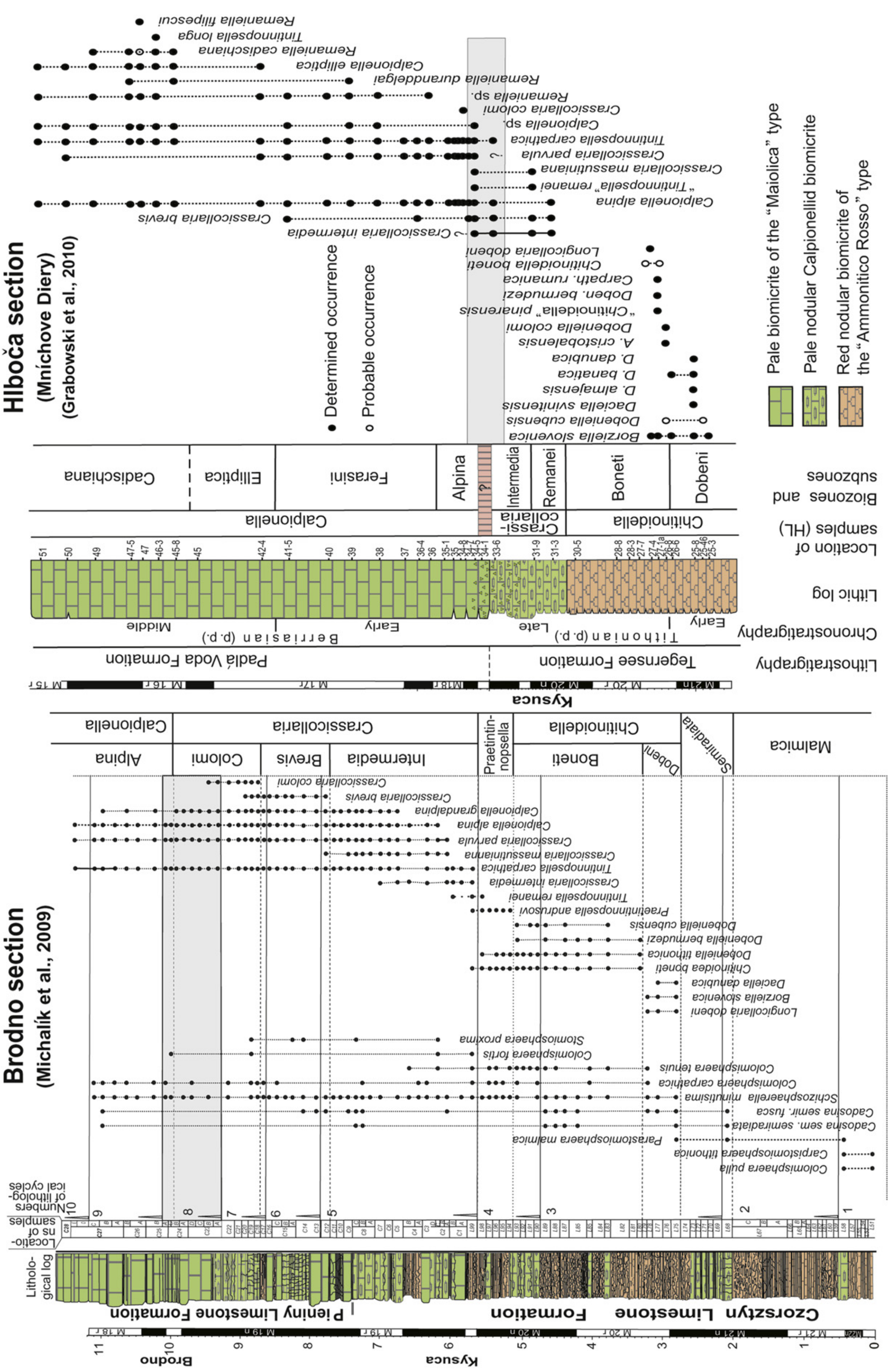

**Figure 7** Correlation of the Brodno and Hlboča sections, Western Carpathians, Slovakia on the base of magneto- and microbiostratigraphy (Michalík et al., 1990b, 2009; Grabowski et al., 2010a, b).

*Crassicollaria parvula* (CPAZ; see Fig. 2), also identified at Brodno, Bosso and Puerto Escaño (Houša et al., 1999; Houša et al., 2004). Nevertheless, recent revision of J/K boundary interval of the Puerto Escaño section has shown that the boundary sensu Pruner et al. (2010) was located in a brecciated layer (sample 28) in which abundant crassicollarians were derived by erosion of underlying strata. Clast-bearing calpionellid biomicrites were documented in several Upper Jurassic and Lower Cretaceous (Lower Berriasian) formations in areas affected by extensional pulses and subsequent synsedimentary erosion of basement (Michalík et al., 1990b, 1995; Grabowski et al., 2010a, b).

Boughdiri et al. (2006) analyzed Jurassic/Cretaceous calpionellid associations in correlation with the ammonite distribution in the Jebels Amar and Jédidi sections in Tunisian North Atlas Mountains. They correlated equivalent successions within the Maghrebide Range and stressed their West-Tethyan affinity. The J/K boundary coincided with relative high frequencies of small *C. alpina* corresponding with the limit between Durangites and Euxinus ammonite zones.

Andreini et al. (2007) revisited calpionellid bio-chronostratigraphy of the Jurassic/Cretaceous sequence of Guidaloca and Diesi sections in the Western Sicily (Italy). Thirteen calpionellid assemblages have been recognized on the basis of their vertical distribution; the fifth assemblage was characterized by an explosion of *C. alpina*.

Detailed magnetostratigraphic and micropaleontological study of the J/K boundary interval in the Bosso Valley section (Umbria–Marche area, Central Italy; Fig. 3) was performed by Houša et al. (2004). The pronounced increase in abundance of *C. alpina* documented at the base of Calpionella zone was accepted as the J/K boundary indicator.

Casellato (2010) and Channell et al. (2010) performed integrated bio- and magneto- stratigraphy across the J/K boundary in the Torre de Busi section, Southern Alps, Northern Italy (Fig. 4). They recognized Crassicollaria and Calpionella zones, CM19 and CM18 polarity chrons, the FOs of *N. wintereri* and *C. cuvillieri* (correlated with the middle part of CM19n); and the FOs of *N. steinmanni minor* and *N. camptneri minor* (at the top of CM19n). The "explosive" onset of small, globular *C. alpina* has been recognized in the uppermost part of the CM19n.

Channell et al. (2010) suggest that the J/K boundary is correlatable with the onset of the CM18r and with the FO of *N. steinmanni minor.*

The boundary interval in hemipelagic sequence of the Blassenstein Formation of the Nutzhof section of the Gresten Klippenbelt (Ultrahelvetic paleogeographic realm) contains relatively rich microplankton (calpionellids, dinoflagellates and nannofossils; Lukeneder et al., 2010; Fig. 5). The magnetostratigraphic log of the Nutzhof section includes the M21r to the M17r magnetozones including the Kysuca (M20r) and the Brodno (M19r) subzones. The main lithological change was observed within the Late Tithonian *Crassicollaria* zone (M20n Chron), whereas the J/K boundary was supposed at the *Crassicollaria*–*Calpionella* boundary (situated within M19n.2n Chron).

The Hlboča section in central Western Carpathians (Vysoká Unit of the Krížna Nappe; Grabowski et al., 2010a) is an example of near-slope sedimentation. Upper Tithonian Rosso Ammonitico

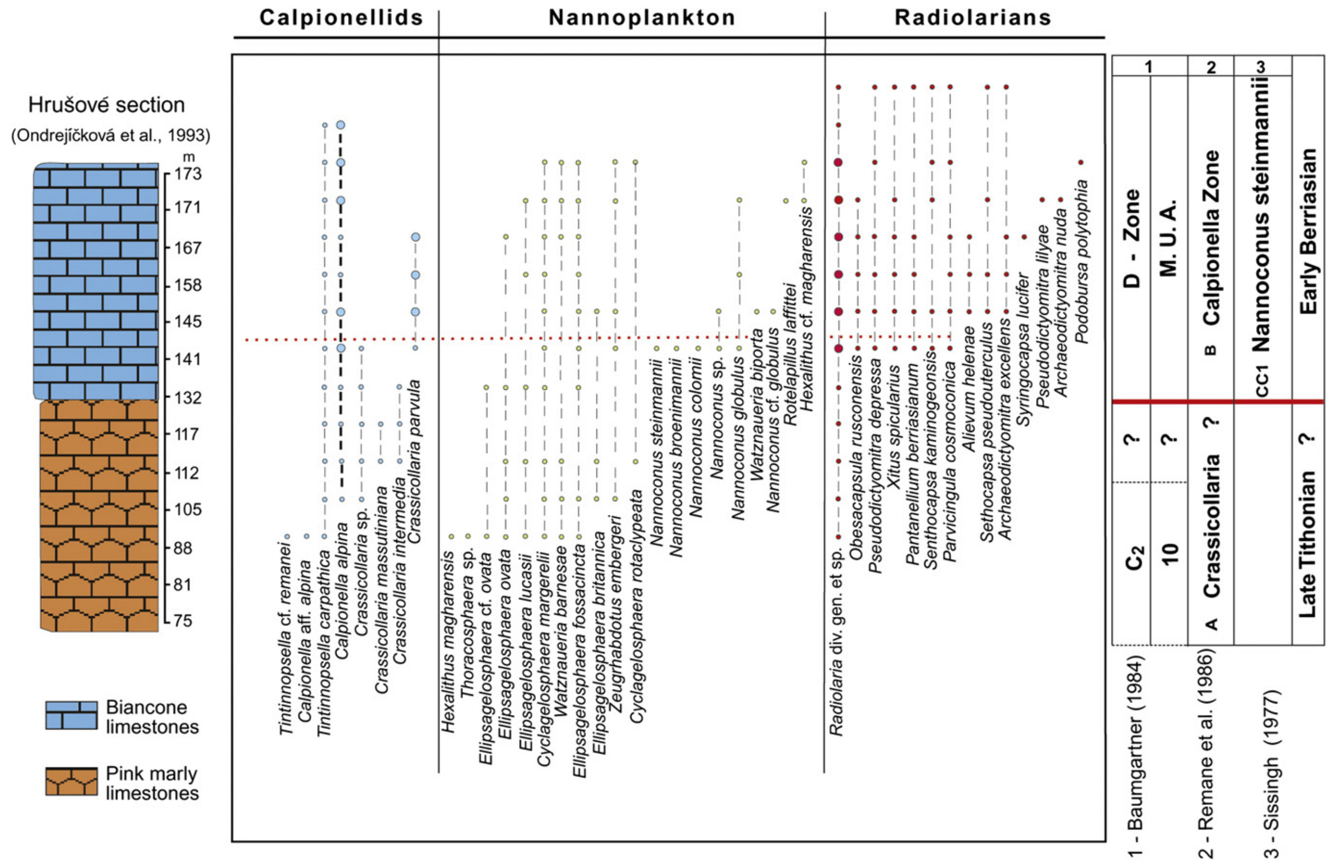

**Figure 8** Hrušové section near Nové Mesto nad Váhom, Western Carpathians, Slovakia: correlation of radiolarian, calpionellid and nannofossil microbiostratigraphy (after Ondrejíčková et al., 1993).

facies contains indicators of slope transport (Michalík et al., 1990b). The most apparent synsedimentary breccia layer occurs near the J/K boundary containing clasts from both uppermost Crassicollaria and lowermost Alpina zones. M21n to M20n magnetozones were identified, including reversed Kysuca (M20n1r) Subzone. Breccia horizons embraced M19r and most of M19n magnetozones. Sedimentation rate was somewhat slower than in the Nutzhof section at M19, while in M20 higher rates were indicated in the Hlboča section. The section yielded good correlation between record of microplankton distribution, C and O isotopes and magnetic properties of the rocks as well.

The Brodno section (Houša et al., 1996; Michalík et al., 2009; Fig. 6) is the most detailed J/K West Carpathian section. It is situated in the Pieniny Klippen Belt, in a unit with the most intricated structure. The sequence is represented with Tithonian Rosso Ammonitico facies, followed by uppermost Tithonian to Barremian Maiolica limestone facies. The section does not contain well-preserved ammonoids, but microfossils, C and O isotopes and magnetic polarity are well studied. Thus the magnetostratigraphical record of the J/K boundary interval has been correlated with micropaleontological data. According to Houša et al. (l.c.), the base of the standard Crassicollaria zone is within the middle part of M20n magnetozone, whereas the base of standard Calpionella zone (i.e. supposed Jurassic/Cretaceous boundary) lies in younger part of the lower half of the M19n magnetozone (in the Brodno section between BC-15A and BC-15B beds).

Michalík et al. (2009) correlated the distribution of calpionellids and nannofossils. The J/K boundary was approximated between the Crassicollaria and Calpionella zones indicated by morphological change of *C. alpina* tests. On the base of nannofossils distribution the FO of *N. wintereri* together with small nannoconids occurs at the base of the NJKc zone. The FO of *Nannoconus steinmanni minor* at its top was selected for location of the Tithonian/Berriasian boundary. Stable isotopes ($\delta^{18}$O, $\delta^{13}$C) curves point to late Tithonian cooling followed by slight warming at the J/K boundary, where either volcanic activity or impact event could be indicated by raised content of Ni and Sb (Mizera and Řanda, 2009).

Michalík et al. (l.c.; Fig. 7) put the base of Crassicollaria zone higher than Houša et al. (1996). It should coincide with the Kysuca reverse magnetic Subzone; while the onset of Alpina Subzone of the Calpionella zone (J/K boundary interval) should be situated close to the Brodno reverse magnetic Subzone.

In the Strážovce section (Zliechov Basin, the Krížna Nappe), the J/K boundary was put between the Crassicollaria and Calpionella zone by Borza et al. (1980), Michalík et al. (1990a), close to the lithological boundary between shaly Jasenina- and "biancone" Osnica Limestone formations. All the sequence was affected by Turonian (?) remagnetization (Grabowski et al., 2009) during nappe transport.

Hrušové (Ondrejíčková et al., 1993; Fig. 8) section belongs to the southernmost part of the West Carpathian nappe system. It yielded well-preserved association of calpionellids, nannofossils and

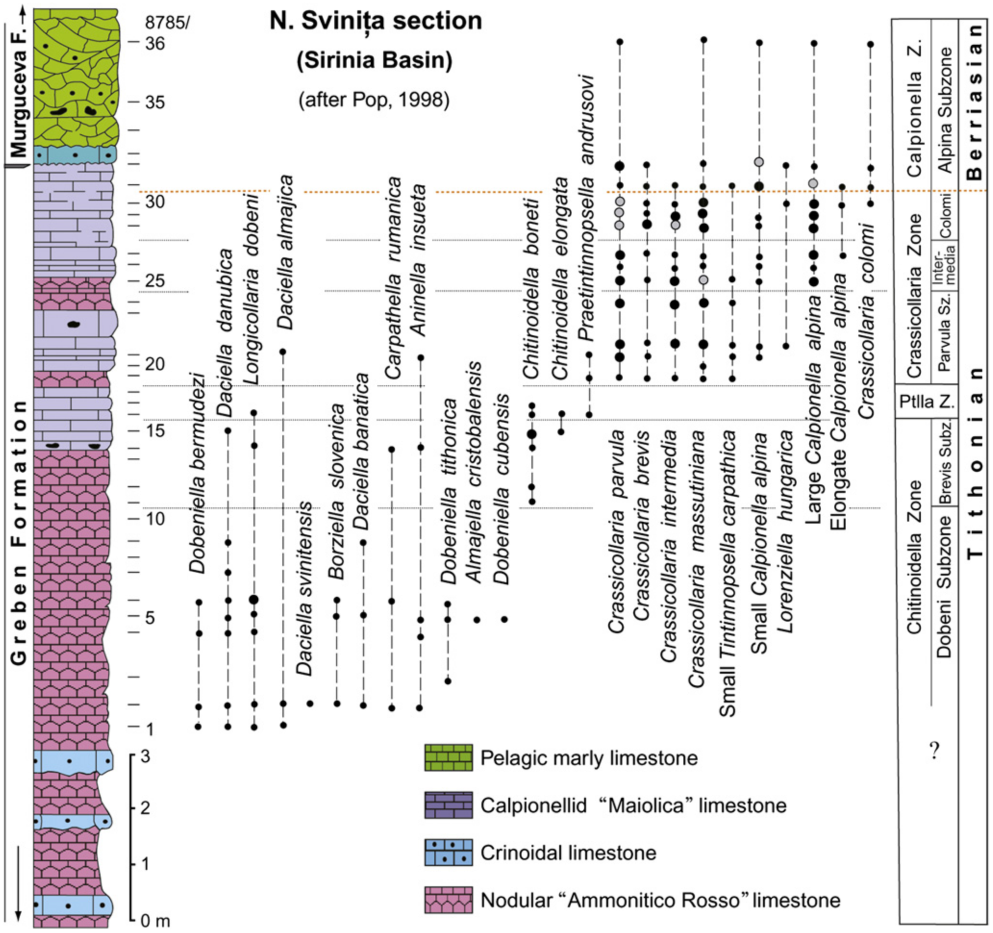

**Figure 9** N. Sviniţa section (Sirinia Basin) in Romania: calpionellid biostratigraphy (after Pop, 1989).

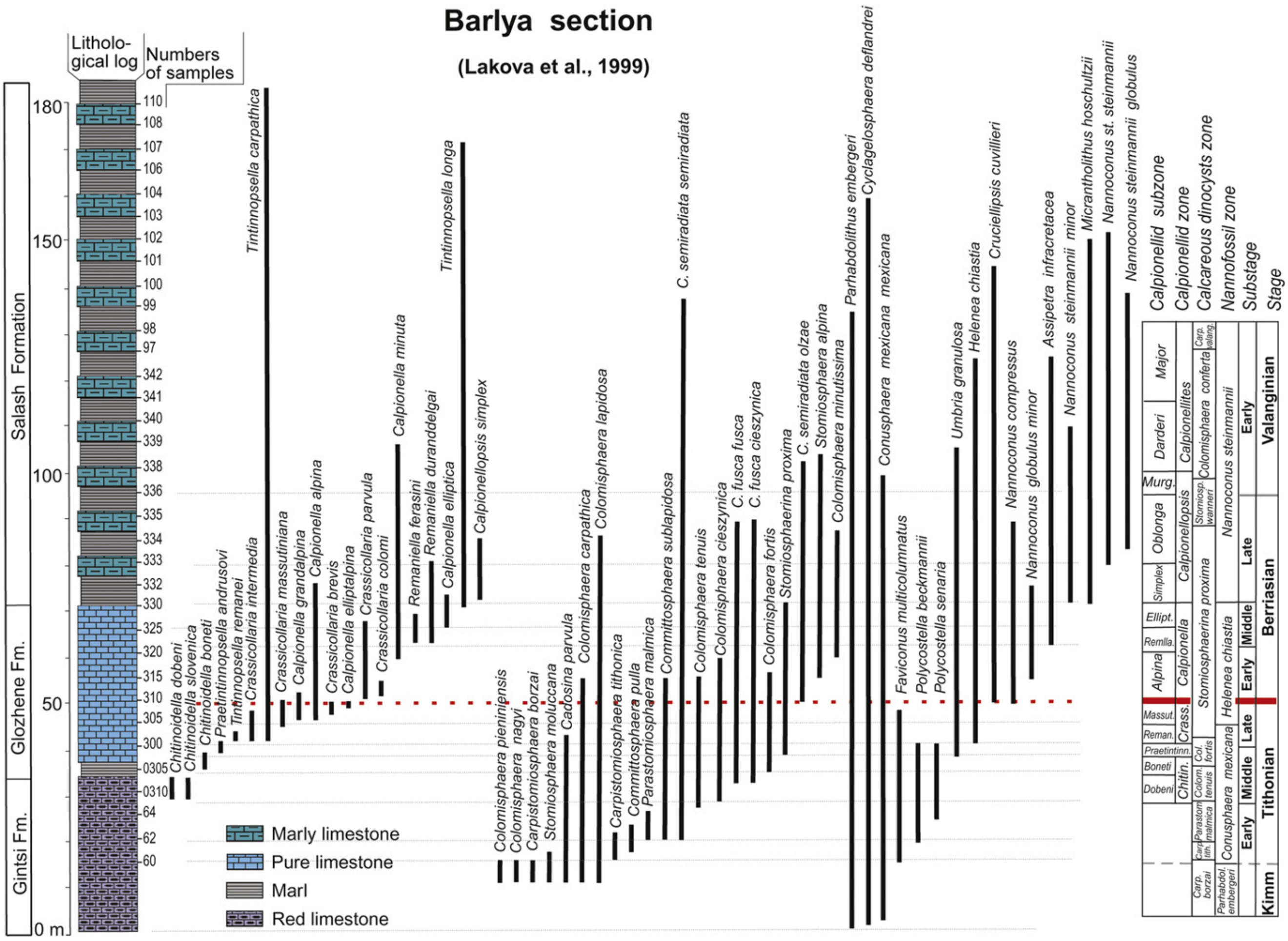

**Figure 10** Barlya section from Western Balcanides: calpionellid, nannofossil and calcareous dinoflagellate microbiostratigraphy (after Lakova, 1994; Lakova et al., 1999).

radiolarians enabling correlation of different biostratigraphical zonations. UA11 radiolarian association accompanied by nannoconids of the CC1 zone appears below boundary between the Crassicollaria- and Calpionella zones (regarded as the J/K boundary). This situation resembles the Bosso River section in Italy (Baumgartner, 1984).

Biofacies and magnetostratigraphy of Jurassic–Cretaceous sequence in the Lókút section (the Transdanubian Range in Northern Hungary) were studied in detail for their calcareous micro- and nannoplankton content, and for their magnetic parameters (Grabowski et al., 2009). Magnetozones from M21r to M18r were identified.

Bucur (1992) summarized existing data on the Upper Jurassic–Lower Cretaceous biostratigraphy in the Moldova Noua zone of the Southern Carpathians (Romania) including the calpionellid and nannofossils distribution previously recorded by Pop (1989) and Melinte (1991), respectively. Crivina (Reşiţa Basin) and N. Sviniţa (Sirinia Basin; Fig. 9) sections were documented in detail by Pop (1989). The J/K boundary was situated within the Tithonian–Middle Berriasian sequence of the Marila Limestone Formation and the boundary itself was characterized by the "explosion" of small-to medium sized *C. alpina* loricas.

A joint study of calpionellids, nannofossils and calcareous dinoflagellates in Barlya (Fig. 10) and Belotintsi section from the Western Balcanides was published by Lakova et al. (1999). The Tithonian/Berriasian boundary was traced at the base of Calpionella zone by the explosion of *C. alpina* and the LO of *Calpionella elliptalpina*, both events occurring together with the FO of *C. cuvillieri* and *Nannoconus compressus*.

Skourtsis-Coroneou and Solakius (1999) examined Jurassic/Cretaceous boundary in the Paramythia section (Ionian zone, Western Greece; Fig. 11). They localized it within the Vigla Limestone Formation, where the predominance of *C. alpina* followed by rare *C. parvula* and sporadic *Tintinnopsella carpathica* was recorded. Stable isotopes ($\delta^{18}O$, $\delta^{13}C$) curves were also used in palaeoenvironmental interpretation.

## 3. Discussion and conclusions

Up to present, remarkable advances in calpionellid and nannoplankton biostratigraphy across J/K interval have been published. The phyletic evolution of these small planktonic protozoans and autotrophic algae respectively includes a number of events useful for global correlation of pelagic carbonate sequences. Despite of certain global similarity, details of these events were different due to changes of determining paleoenvironment. The boundary level should be situated within a bundle of events allowing good correlations in the case of absence of the primary ammonite marker.

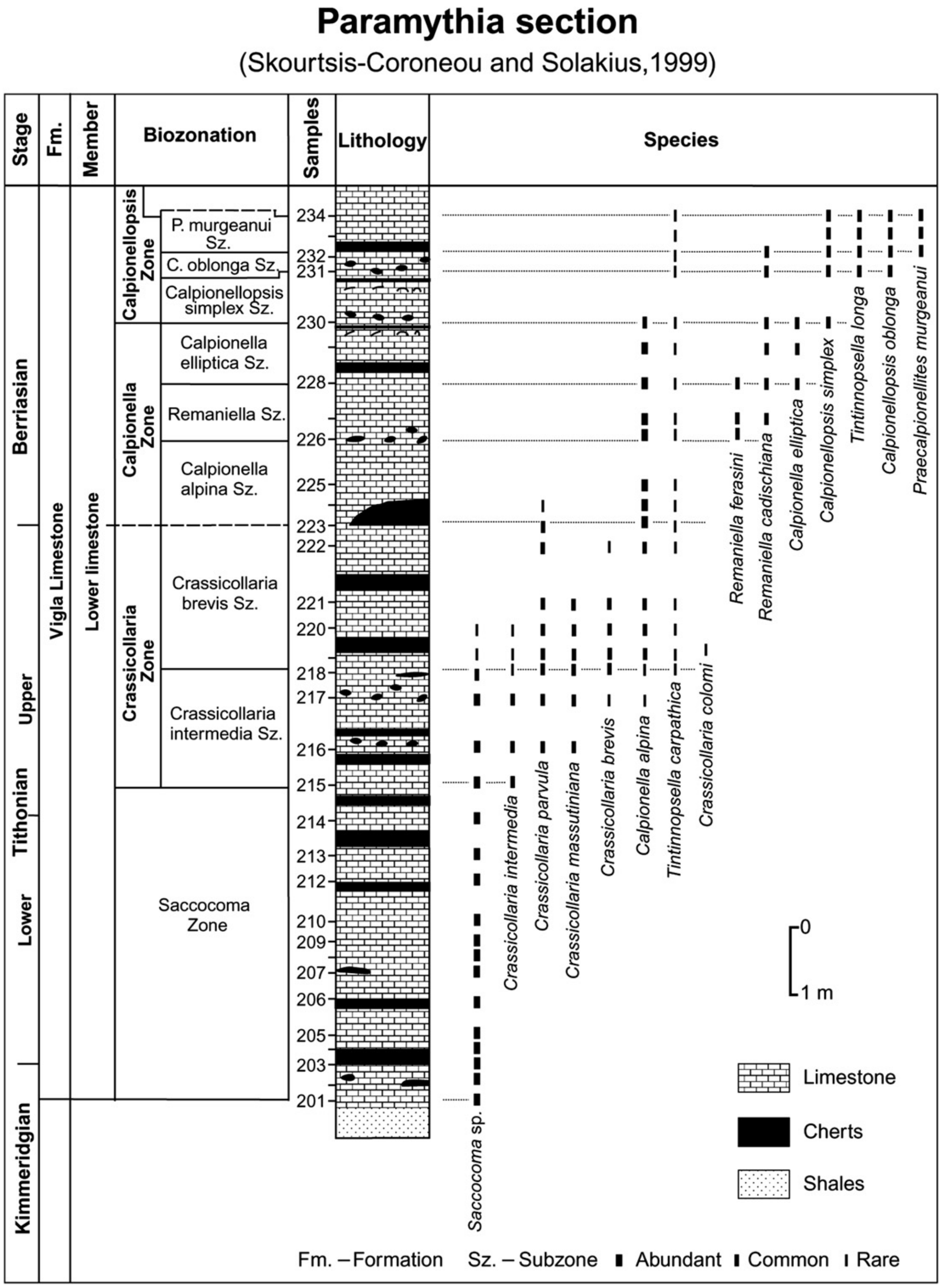

**Figure 11** Jurassic/Cretaceous boundary in the Paramythia section (Ionian zone, Western Greece): calpionellid distribution and micro-biostratigraphy of the Vigla Limestone Formation (after Skourtsis-Coroneou and Solakius, 1999).

Tithonian Mediterranean index fossils absent from Mexican sections, Alpina Subzone being poorly evidenced. Trans-Atlantic correlation is possible using Late Berriasian biomarkers only. On the other hand, in Cuba, the Intermedia/Alpina boundary was well detected by calpionellids.

The J/K boundary defined by foraminifers and ostracods in offshore boreholes in NW Atlantic (Nova Scotia) was placed below the standard Crassicollaria/Calpionella boundary. However, the number of samples was insufficient to reach a statistical value.

Rio Argos section was well documented by ammonites and calpionellids (with the exception of the Upper Tithonian part, which is poorly exposed), however, the rocks in all the sequence were remagnetized. Location of the J/K boundary estimated would be desirable to revised with the attempt to determine the position of calpionellid and nannofossil events and their correlation with sequence stratigraphic pattern of this section.

In a contrary, an integrated ammonite-, calpionellid-, and magneto- stratigraphy have been used in the Puerto Escaño section. Notably, the contact of the Crassicollaria- and the Calpionella calpionellid zones does not coincide with the transition of the Grandis- and the Jacobi ammonite zones, as the base of the Alpina Subzone (coinciding with possible J/K boundary) was placed into microbreccia layer. An "epibole" of the *C. parvula* was documented approximately 40 cm above.

The Bosso Valley- and the Brodno sections were documented by both calpionellids and magnetic properties. The start of morphological change of *C. alpina* defined as possible J/K boundary is not expressive, being suppressed by redeposition phenomena in a dynamic environment. The "epibole" of *C. parvula*, recorded in both section can also be associated with redeposition. Synsedimentary erosion at that time was a current phenomenon, recorded also in other section elsewhere (e.g., Hlboča, Strážovce sections in Western Carpathians).

Calpionellid frequencies in the Nutzhof section, representing deeper basinal setting are rather low. The microfossils are dominated by nannoplankton. Although the interval of *C. alpina* morphological change is easily recognizable, any definition of "bloom" of this species in these conditions is hardly defensible. The condition in the Torre de Busi section is rather similar.

The J/K boundary in pelagic sections of Southern Carpathians was characterized on ammonite- and calcareous microplankton distribution. The "explosion" of small-to medium sized loricas of *C. alpina* was adopted as the J/K boundary index. However, nannofossils events taken for the boundary estimation do not answer modern views.

In last years, ad hoc teams belonging to the Berriasian Working Group made progresses (Wimbledon, 2009; Wimbledon et al., 2011) providing complex integrated study of the J/K boundary interval. The bioevent represented by the *C. alpina* morphological change seems an easy recognizable phenomenon. As well as the recognition of nannofossil events, like the FOs of *N. wintereri*, *C. cuvillieri*, *N. kamptneri minor*, and *N. steinmanni minor.*

This review reveals that selected sections should be re-evaluated as far as bio-, calpionellid and calcareous nannofossil-, magneto- and isotope stratigraphies are concerned. The gaps in different complexity of data in documentation of the key sections net must be removed to enable worldwide (both lateral and time) correlation of individual (bio-, chemo- and magneto-) events at the J/K boundary in detail. The ambition of the Berriasian Working Group is to contribute to the definition of the last Phanerozoic System Boundary (J/K) not yet fixed, and to the choice of its GSSP.

## Acknowledgments

This is a contribution to the APVV-0280-07, APVV-0248-07, APVV-0465-06, APVT 51-011305, and VEGA 0196 and 0065 Grant Projects. The authors are indebted to three anonymous reviewers, who contributed decisively to the quality of this contribution.

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