Plankton evolution and biostratigraphy during Late Jurassic and Early Cretaceous

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Abstract: Characteristic morphology, quick turnovers in evolution and assemblages composition of ancient planktonic organisms like phototrophic algae producing cysts or calcite plates, radiolarians, planktonic crinoids, as well as associations of loricated protozoans made them a favourable tools for interregional correlation. Thus nannofossils, calcareous dinoflagellates, radiolarians, sacoccomids, and calpionellids are playing a key role in the biostratigraphy of Upper Jurassic/Lower Cretaceous sequences. In the combination with macrofossils like were ammonites or belemnites, also magnetic, chemical, cyclicity and eustatic records are suitable for their high resolution stratigraphy and interpretations of their life conditions. This paper summarize up to date results concerning the evolution of Late Jurassic and Early Cretaceous calcareous dinoflagellates and calpionellids and their interrelationship with another stratigraphicaly important planktonic groups.

Introduction

The arrangement of Late Jurassic and Early Cretaceous facies was controlled by interrelated factors, such as by the gradual break-up of Pangea that created individual often interconnected basins and that controlled their subsidence, subsequent thermal subsidence which together with eustasy and climate variation affected the chemistry and the trophic state of ocean water (Baumgartner 2013). At that time rich planktonic assemblages developed in these basins, slopes, intrashelf elevations and partialy also in the distal parts of carbonate ramps being characterized by a permanent current regime positively influencing the nutrient input.

Calpionellids and dinoflagellates were sensitive to environmental perturbations such a change of the water temperature, chemistry and the nutrient supply. It is worth to mention, that the abundance and size of calpionellid loricas were influenced by water temperature and fluctuation of the sea-level. These parameters decreased also towards the open sea — they were less frequent in deep basins in which radiolarians prevailed, being very rare or seldom in reefal and lagoonal settings or in proximal settings with permanent river-influenced elevated nutrient level and with changes in surface water chemistry (Reháková 2000a; Kowal-Kasprzyk & Reháková 2019). On the other hand, calcareous dinoflagellates prefering rather more nutritional environments are generaly rare elements of assemblages. However, few blooming events probably influenced by such ecological factors as sea-level fluctuations, sea-water temperature changes were distinguished (Reháková 2000b; Jach & Reháková 2019). Several stages could be selected in the evolution of these two microplanktonic groups.

Oxfordian stage

The Lower Oxfordian basal ribbon radiolarites with occasional thin shale interbeds were replaced by limy radiolarites and radiolarian limestones (Baumgartner 2013, Jach et al. 2014). The zonation of the silica rich sediments is based on the radiolarian Unitary Association Zones (UAZs) proposed by Baumgartner et al. (1995). UAZs 5-9 were defined for this stage. The concentration of radiolarians in chert beds is regarded as the effect of productivity cycles in response to the Milankovitch climatic oscillations (Baumgartner 2013; De Wewer et al. 2014). The carbonatic basinal deposits contain dinoflagellate cyst associations of the Parvula and Fibrata acme zones (Reháková 2000b). A rich cyst association of the same age was documented also in shalower coastal parts (Keupp & Ilg 1989). Also fragments of *Bositra* shells formed a persistend part of dysaerobic microfacies. At the end of the Oxfordian *Bositra* filaments slowly decreased in abundance being substituted by planktonic crinoids of *Saccocoma* sp., and protoglobuligerinid rock-forming foraminifera (Mutterlose & Böckel 1998) the appearance of which may have been related to the sea-level rise and opening of new niches (Reháková 2000a).

Kimmeridgian stage

The variegated red nodular limestones representing the Ammonitico Rosso type of facies were deposided in the basins and their elevated zones. At the beginning of this stage planktonic foraminifera were still abundant but soon they were replaced by rapid increase of saccocomids and shortly after the blooms of green algae which produced spores of *Globochaete alpina* Lombard. Environmental conditions were favourable for their development up to the Early Berriasian. On the base of morphology of skeletal saccocomid elements and their succession against the ammonite zones seven saccocomid biozones were distinguished by Benzaggagh et al. (2015). Biozones Sc1 and Sc2 were defined for the Late Oxfordian and Kimmeridgian. Abundant calcareous dinoflagellates of the Parvula acme Zone followed by less frequent cysts of Moluccana and Borzai zones were observed in nodular limestones (Reháková 2000b; Jach et al. 2014; Michalík et al. 2016; Grabowski et al. 2019). Nannofossils of this stage were included into the NJT 14 Zone (Casellato 2010). The majority of radiolarians were calcified. Radiolarian UAZ 10 was determined in Kimmeridgian deposits (Baumgartner et al. 1995; Jach et al. 2014).

Tithonian stage

Thin rhythmic alternation of marls, shales and limestones and their lateral equivalent — variegated pseudonodular limestones passing to the Biancone type of facies dominated in basinal and distal part of carbonate ramps of this stage. Saccocomids and globochaetes dominated in Early Tithonian microfacies in which Saccocoma biozones Sc 3, Sc 4 and Sc 5 were established (Benzaggagh et al. 2015). In microfacies radiolarians are scattered in matrix. Majority of them are calcified, but those replaced by chalcedony or microcrystalline silica allowed to distinguished UAZ 11 in the Lower Tithonian deposits (Baumgartner et al. 1995; Jach et al. 2014). Early Tithonian calcareous dinoflagellate associations are abundant and diversified and offered to events for the establishment of followed cysts zones: Pulla acme, Tithonica, Malmica, Semiradiata, Tenuis, Fortis and Proxima (Lakova et al. 2009; Reháková 2000b). According to Jach & Reháková (2019) the blooms of cysts in some of above mentioned cyst zones could indicate warmer surface seawater corresponding with the arid phase of the “Hudlestoni event” (Hesselbo et al. 2009). In the uppermost part of Early Tithonian the first calpionellids (chitinoidellids of the Dobeni Subzone, Chitinoidella Zone) appeared being followed by their Late Tithonian more advanced descendants of the Boneti Subzone which were the ancestors of the evolutionary lineagues of transitional and hyaline calpionellids of the Praetintinnopsella and Crassicollaria zones (Reháková & Michalík 1997). During the first Remanei Subzone of the Crassicollaria Zone saccocomids were still abundant (Sc 6 and Sc 7 biozones of Benzaggagh et al. 2015); during the second, more diversified Intermedia Subzone they declined in abundance and prior to J/K boundary in the third Colomi Subzone they were very seldom among the planktonic assemblages which were dominated by small calpionellid forms of Crassicollaria and Calpionella and by globochaetes. At the end of Late Tithonian dinoflagellate cysts were rapidly reduced; few long living forms persisted up to Late Berriasian. Sacoccomids disapeared, those which sporadicaly were found in Berriasian deposits may be regarded as redeposited fragments due they are often accompanied by reworked Tithonian calpionellids and dinoflagellate cysts (Michalík et al. 2016; Svobodová et al. 2019; Grabowski et al. 2019). Early Tithonian nannofossils of the upper part of NJT14, then NJT 15 zones were rather poor preserved, they increased in abundance and diversity along the Late Tithonian Crassicollaria Zone and provided the marker of the NJT 16 and NJT 17 zones (Casellato 2010). Well-preserved radiolarians allowed to establish the Late Tithonian UAZs 12, 13 /or Loopus primitivus and Pseododictyomitra carpatica zones (Baumgartner et al. 1995; Matsuoka 1995).

Berriasian stage

The Biancone type limestones with cherts and locally with rhythmic stratiformed chert layers together with deeper marly limestones intercalated by marls are typical slope, basinal and most distal part of carbonate ramps of this stage. Nannofossils, calpionellids and globochaetes dominated in plankton assemblages. The succession of calpionellids allowed to distinguished Early Berriasian Calpionella Zone with the Alpina, Ferasini and Elliptica subzones and the Late Berriasian Calpionellopsis Zone with the Simplex, Oblonga and Murgeanui Subzones (Remane et al. 1986; Pop 1994; Reháková & Michalík 1997 and further calpionellid zonations summarized in Lakova & Petrova 2013). The Proxima cyst Zone represent the interval of very rare, long living cysts. Shortly before the onset of Late Berriasian Calpionellopsis Zone the widespread cysts event called as the Fusca Acme appeared which may be also interpreted as the result of the increased temperature in surface seawater layers comparable with those mentioned in Tithonian Semiradiata Zone (Jach & Reháková 2019). Small stomiosphaerid cysts followed by bigger colomisphaerids have been included to the latest Berriasian Wanneri and Conferta cysts zone (Reháková 2000b; Lakova et al. 1999). Nannofossils associations were divided into NKT and NK-1, NK-2a zones (Bralower et al. 1989; Casellato 2010). Radiolarians were splitted into UAZs 13, 14, 15 /or Pseododictyomitra carpatica Zone (Baumgartner et al. 1995; Matsuoka 1995).

Valanginian stage

Compared to Berriasian stage, the lithological character of Valanginian deep water deposits did not changed. From the top of the Berriasian the marly limestones and marly intercalations are more frequent and thicker. Locally the cherts and stratiform chert layers are common in Biancone limestones of this stage. Previously highly diversified calpionellid associations rapidly decreased in diversity and abundance. Calpionellites Zone with the Darderi and Major subzones and the Tintinnopsella Zone were distinguished (Reháková & Michalík 1997). The last calpionellid species are supposed from the Late Valanginian, when they extinct. These which were described from Hauterivian or younger deposits are rather reworked. Short flourishment of small cadosinid cysts was described as Acme Minuta Zone. It was followed by the further Vogleri and Valanginiana cyst Zone (Reháková 2000a). Nannofossils associations of this stage were divided into NK-2b and NK–3 zones (Bralower et al. 1989). Planktonic favusellid foraminifera appeared in assemblages once again after a longer break lasting from the Early Kimmeridgian (Reháková 2000a). In sediments of this stage rich in radiolarians the UAZs 16, 17, 18 were distinguished (Baumgartner et al.1995). In some cases, the laminae rich in radiolaria and sponge spicules could have been linked with the periodically active countour currents which locally persisted until the Hauterivian.

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