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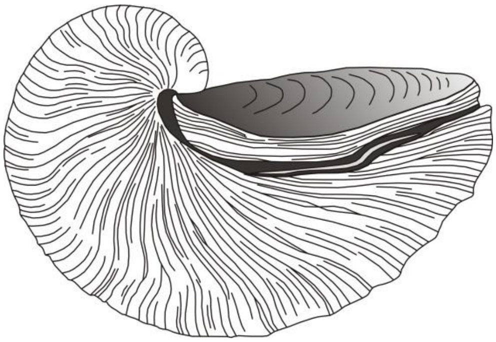

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Review of the Upper Volgian ammonite biostratigraphy of Arctic

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Although the lower boundary of the Berriasian Stage and thus the Cretaceous System still not defined by accepted GSSP, recent advances in Boreal-Tethyan correlation of the J/K boundary beds has shown that nearly all discussed GSSP levels falls within the Boreal Upper Volgian Substage (cf. Wimbledon et al., 2011; Bragin et al., 2013; Shurygin, Dzyuba, 2015). Thus improving of the both high-resolution stratigraphy and interregional correlation of the Upper Volgian has a special significance for tracing the lower boundary of the Cretaceous System in high latitudes of the Northern Hemisphere.

Upper Volgian in the type area of the Volgian Stage, the Russian Platform, is now well-subdivided by ammonites, which permits to recognize succession of 4 zones and 11 biohorizons (Rogov, 2014). However, this succession is based mainly on eudemic ammonites belonging to taxa which are rarely occurs outside this region (i.e. *Kachpurites, Garniericeras* and *Craspedites* (*Trautscholdiceras*). In spite of some minor differences between local Late Volgian ammonite faunas outside the Russian Platform the single zonal scale, which was at first created based on sections of the rivers Kheta and Boyarka (Khatanga depression), can be accepted for nearly all Arctic areas (Rogov, Zakharov, 2009).

Here generalized succession of zones, subzones and biohorizons of the Upper Volgian of Arctic is provided (fig. 1).

Craspedites okensis Zone.

Base of this zone and the Upper Volgian Substage is marked by FAD of *Craspedites (Craspedites)* belonging to the *C. (C.) okensis* group. Since the pioneering works on the Upper Volgian of Siberia this zone is subdivided on two subzones (Okensis below and Originalis above), the latter is recognized by co-occurrences of *Craspedites (C.)* ex gr. *okensis* and *C. (Taimyroceras)* spp. From the other hand, in the both Boreal and Subboreal areas the lineage *Craspedites (C.) praeokensis* Rogov, MS – *C. (C.) okensis* can be traced, but relation between these horizons and the former subzones within the Okensis Zone remains unclear. Recent field works held at the Kheta river (2015) has revealed that upper part of the Okensis Zone is dominated by eudemic species *Khetoceras margaritae* (*margaritae* horizon), which co-occurred with *C. (C.) okensis*, while in situ records of *C. (Taimyroceras)* in the Okensis Zone were not found. Rare *Praechetaites* were also reported from the Okensis Zone of the Kheta river by Shulgina (1967). In the Nordvik section as well as in Spitsbergen and Western Siberia *C.* (*Taimyroceras*) ex gr. *originalis* occurred with *C. (C.) okensis*. As follow from distribution of *Craspedites (C.) praeokensis* Rogov, MS and *C. (C.) okensis* in the Russian Platform, the Okensis zone is corresponding to the Fulgens and Catenulatum zones of the type area of the Volgian Stage.

Craspedites taimyrensis Zone.

Lower boundary of the Taimyrensis Zone is defined by disappearance of the *Craspedites (Craspedites)*, and assemblage of this zone is consists from *C. (Taimyroceras)*, which are represented by the index species and few still undescribed species. Unfortunately in the type section of this zone at the Kheta river Upper Volgian deposits are now hardly accessible because they are covered by numerous glacial boulders, and in situ ammonite occurrences here are relatively uncommon. At least two ammonite assemblages could be tentatively recognized here, the lower which consists from typical *C. (T.) taimyrensis* and *C. (T.) discoides* Rogov MS (in cannon-ball-like concretions) and upper with crushed *C. (T.)* ex gr. *taimyrensis* (in giant carbonate concretions). Assemblage with *C. (T.) discoides*

Rogov MS has also been found in Spitsbergen and the Nordvik section, while typical *C. (T.) taimyrensis* are known also from Western Siberia and Subpolar Urals. Age of the *C. (T.) canadensis* in the Ellesmere Island (Arctic Canada) is also corresponding to the Taimyrensis Zone. Variability and dimorphism of *C. (T.) canadensis* are very close to those of the *C. (T.) taimyrensis*. Stratigraphic range of the Taimyrensis Zone is nearly coincides with those of the Nodiger Zone of the Russian Platform.

<table>
<tr><th>NW Europe</th><th>E. Greenland, Norwegian Sea shelf</th><th colspan="2">Spitsbergen</th><th>Franz-Josef Land</th><th colspan="3">Russian Platform</th><th>Western Siberia</th><th colspan="3">Northern Siberia</th><th>NE Russia</th><th>Arctic Canada</th></tr>
<tr><th>Zone</th><th>Zone</th><th>Zone/Subz.</th><th>Biohor.</th><th>Zone</th><th>Zone</th><th>Subzone</th><th>Biohorizon</th><th></th><th>Zone</th><th>Subzone</th><th>Biohor.</th><th></th><th>Zone</th></tr>
<tr><td>Volgidiscus lamplughi</td><td>Chetaites chetae</td><td>?</td><td></td><td>Chetaites chetae</td><td colspan="2">Volgidiscus singularis</td><td>Volgidiscus singularis</td><td>Chetaites chetae</td><td colspan="2">Chetaites chetae</td><td rowspan="2"></td><td>Chetaites chetae</td><td>?</td></tr>
<tr><td rowspan="4">Subcraspedites preplicomphalus (pars)</td><td rowspan="4">?
Beds with Subcraspedites sowerbyi</td><td>Craspedites (Taimyroceras) taimyrensis</td><td></td><td rowspan="4">?</td><td colspan="2">Craspedites (Trautscholdiceras) nodiger</td><td>C. (T.) milkovensis
C. (T.) nodiger
C. (T.) transitionis</td><td>Craspedites (Taimyroceras) taimyrensis</td><td colspan="2">Craspedites (Taimyroceras) taimyrensis</td><td rowspan="4">?</td><td>Craspedites (Taimyroceras) taimyrensis</td></tr>
<tr><td rowspan="2">Craspedites okensis: Originalis</td><td rowspan="2">Craspedites okensis</td><td colspan="2">Garniericeras catenulatum</td><td>Garn. catenulatum
Garn. internicarinatum</td><td>Garniericeras catenulatum</td><td rowspan="3">OKENSIS</td><td>Craspedites (Taimyroceras) originalis</td><td>Khet. marg.</td><td rowspan="3">Beds with Subcraspedites spp.</td></tr>
<tr><td rowspan="2">FULGENS</td><td>Kachpurites subfulgens</td><td>Kachpurites involutus
Kachpurites subfulgens
K.cheremkh.</td><td rowspan="2">Kachpurites fulgens</td><td rowspan="2">Craspedites (Craspedites) okensis</td><td></td></tr>
<tr><td>Okensis</td><td>Craspedites praeokensis</td><td>Kachpurites fulgens</td><td>K.tenuicost.
K.evolutus
Crasp. praeok.</td><td>Crasp. praeok.</td></tr>
</table>

Fig. 1. Panboreal correlation of the Upper Volgian Substage by ammonites.

Chetaites chetae Zone.

Lower boundary of this zone should be defined by FAD of the ammonites genus *Chetaites*, while *C. (T.)* ex gr. *taimyrensis* occurred in the Taimyrensis, Chetae and Sibiricus zones, while their rare occurrences are known also from the Kochi zone. Uncommon *Praechetaites* were also found loose from this zone. Very important is record of *Volgidiscus* in the type section of the Chetae Zone (Kheta river). This section is hardly accessible now, while its description (cf. Golbert et al., 1981) providing more or less enough information about ammonites and other important fossils occurred here. This zone could be easily traced in other Boreal regions by occurrence of the index-species, which is easily distinguished from other coeval ammonites. *Chetaites chetae* / cf. *chetae* occurred in the topmost part of the Volgian Stage in Nordvik, recently they were discovered in the Franz-Josef land. In the Western Siberia *Chetaites* occurred together with *Craspedites (Taimyroceras)* and first *Shulginites*, while in the shallow-water deposits of Subpolar Urals topmost Volgian is characterized by *Shulginites* and *Subcraspedites* (Maurynia) or by *Chetaites chetae* and *Praechetaites* (Yanu-Mania). Differences between ammonite assemblages from the uppermost Volgian of the different sections of Subpolar Urals could be caused by their possible different age (in terms of ammonites biohorizons) rather than by facial differences, because similar assemblages were reported also from deep-water black shales of the central part of the Western Siberia. *Chetaites chetae* are also known from East Greenland, where they occurred at the topmost part of the Volgian (Surlyk et al., 1973). *Chetaites* ex gr. *chetae* is also occurred in uppermost Volgian of NE Russia. Presence of *Volgidiscus* and early *Shulginites* in the Chetae Zone provides its correlation with Singularis Zone of the Russian Platform and Lamplughi Zone of NW Europe.

It should be noted that all zonal boundaries of the Arctic Upper Volgian ammonite zones has significant correlational potential across the Panboreal Superrealm, although their possible infrazonal subdivision still remains tentative.

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Resolving the positioning of the Tithonian/Berriasian stage boundary and the base of the Cretaceous System.

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Since the setting up of a new ICS Berriasian Working Group in July 2007, there has been a new phase of activity on refining Tithonian and Berriasian correlations, directed towards addressing the outstanding issue of the choice of a Jurassic/Cretaceous boundary (Wimbledon et al 2011). The definition of a putative J/K boundary level in Tethys is less of a problem nowadays, but long-range correlation to other areas is difficult. Both austral and boreal regions were isolated and far from Tethys, and had, in diversity terms, more impoverished biotas; also, extensive areas of the world were then land, with non-marine sedimentation and biotas. Therefore, there has always been much effort by many colleagues put into trying to improve correlation between marine to non-marine areas and from the core area of oceanic Tethys to isolated seas, seaways and landlocked basins towards the two poles.

A decision was made early by the new Berriasian WG to dispense with previous diversions and pre-occupations, and to direct all energies towards factual matters that would promote a decision on selecting a primary marker for the base of the Berriasian. Therefore, the WG has concentrated on the detailed documentation of known key sections and seeking out new useful localities, giving special attention to integrating data from as many fossil groups as possible, preferably calibrated with magnetostratigraphy (Grabowski 2011). Numerous sites, from California and Mexico to Tibet and the Russian Far East, have been studied and assessed. Our first decision as a