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# Correlation of the Barremian belemnite successions of northwest Europe and the Ulyanovsk – Saratov area (Russian Platform)

EVGENIJ J. BARABOSHKIN[1] & JÖRG MUTTERLOSE[2]

[1]*Geological Faculty, Moscow State University, Leninskie Gory, 119992, Moscow, Russia.*
*E-mail: Barabosh@geol.msu.ru*
[2]*Institut für Geologie, Mineralogie und Geophysik, Ruhr-Universität Bochum, Universitätsstrasse 150, D-44801 Bochum, Germany. E-mail: joerg.mutterlose@rub.de*

ABSTRACT:

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The marine sedimentary successions of Barremian age yield, both in northwest Europe and on the Russian Platform, diverse and abundant belemnite faunas. These include the genera *Praeoxyteuthis*, *Aulacoteuthis* and *Oxyteuthis* and are attributed to the boreal belemnite family Oxyteuthididae. The Oxyteuthididae are endemic to northwest Europe (northern Germany, northeast England, North Sea) and the Russian Platform, where they evolved in isolation. They possibly derived from the belemnite genus *Acroteuthis* in Late Hauterivian time. Phylogenetically they are interpreted as the latest off shoot of the Belemnitina, which became extinct in the Early Aptian. Since ammonites are extremely rare on the Russian Platform oxyteuthid belemnites have been used to establish a biozonation scheme with seven belemnite zones (from bottom to top): *Praeoxyteuthis hibolitiformis* Zone (Early Barremian), *Praeoxyteuthis jasikofiana* Zone (Early Barremian), *Praeoxyteuthis pugio* Zone (earliest Barremian), *Aulacoteuthis descendens* Zone (late Early Barremian), *Oxyteuthis brunsvicensis* Zone (early Late Barremian), *Oxyteuthis germanica* Zone (Late Barremian), and *Oxyteuthis lahuseni* Zone (latest Barremian/Aptian). Apart from the *O. lahuseni* Zone this zonation can be correlated to the well established belemnite scheme of northwest Europe, allowing a detailed correlation of the Barremian of both areas.

**Key words:** Barremian, Biostratigraphy, Northwest Europe, Russian Platform, Belemnites, *Oxyteuthis*.

## INTRODUCTION

Ammonites and belemnites are the most powerful macropalaeontological index fossils allowing a biostratigraphic zonation of the Late Hauterivian and Barremian sediments of northwest Europe (northeast England, north Germany) and the Russian Platform (Ulyanovsk – Saratov area). Ammonites, common in sediments of Barremian age in northwest Europe, are extremely rare or even absent on the Russian Platform (= RP). Belemnites of the family Oxyteuthididae are, however, present both in northwest Europe and on the RP.

Ammonites were first used to subdivide the Late Hauterivian – Barremian succession of northwest Germany by KOENEN (1902) and that of Speeton by LAMPLUGH (1889). These zonations were refined in recent years, resulting in a relatively detailed ammonite scheme (e.g. KEMPER 1976). Fundamental changes occur across the Hauterivian – Barremian boundary interval, where the late Hauterivian ammonite genus *Craspedodiscus* is replaced by the heteromorph genera *Crioceratites*, *Paracrioceras*, *Simancyloceras* and *Parancyloceras*. Though these ammonite taxa are present in the Barremian succession in particular of north-

west Germany, their occurrence is always relatively rare. Belemnites on the other hand are the most abundant macrofossils in the Barremian of northwest Europe. The belemnite succession of the Late Hauterivian – Barremian sequence has been described in quite some detail by STOLLEY (1925) and MUTTERLOSE (1983). Based on these findings a solid belemnite zonation scheme has been established. The Barremian part is being characterized by the belemnite family Oxyteuthididae including the genera *Praeoxyteuthis*, *Aulacoteuthis* and *Oxyteuthis*.

The changes in the composition of the Late Hauterivian – Barremian ammonite assemblages of the RP clearly reflect an increasing palaeobiogeographic isolation (BARABOSHKIN 2001, BARABOSHKIN & *al*. 2003). The Late Hauterivian ammonite genus *Craspedodiscus*, which is viewed by RAWSON (1971) as a subgenus of *Simbirskites*, became extinct close to the Hauterivian/Barremian boundary. Barremian heteromorph ammonites, being present in northwest Europe, are unknown from the RP. Their quotations in the literature were not confirmed so far and the only ammonite being described from the Barremian of the RP is *Aconeceras* (BARABOSHKIN & *al*. 2001). Thus there is no ammonite zonation scheme available for Barremian of the RP. Belemnites, represented by the family Oxyteuthididae, are more common in the Barremian than ammonites. The Barremian belemnite sequence has hitherto not been studied in detail, due to the lack of material collected bed-by-bed. Most of the rostra described so far were loose specimens, collected on the beach of the Volga River.

From 1995 to 2000 extensive field studies have been carried out in beds of Hauterivian and Barremian age, which are exposed along the Volga River (Russia) between the towns of Ulyanovsk in the north and Saratov in the south (Text-fig. 1). About 200 belemnites have been collected and subsequently been studied in detail, in order to resolve the stratigraphic sequence of Barremian belemnites. As the result of this study a new belemnite zonation scheme was proposed (BARABOSHKIN 2001; BARABOSHKIN & *al*. 2001, 2003) and recently modified (BARABOSHKIN 2003). It is the purpose of this paper to examine and compare the stratigraphic occurrence of oxyteuthid belemnites in northwest Europe and the RP. Further on we want to correlate the Barremian of both areas and discuss the possible evolution patterns of the Oxyteuthididae.

The figured material is deposited in the Museum of the Earth of the Moscow State University, Russia; = MSU, collections No. 97, 99, 104, and in the Department of Geology and Palaeontology of the University of Hannover, Germany; = SGPI. A list of taxa quoted in the text is given in Appendix 1.

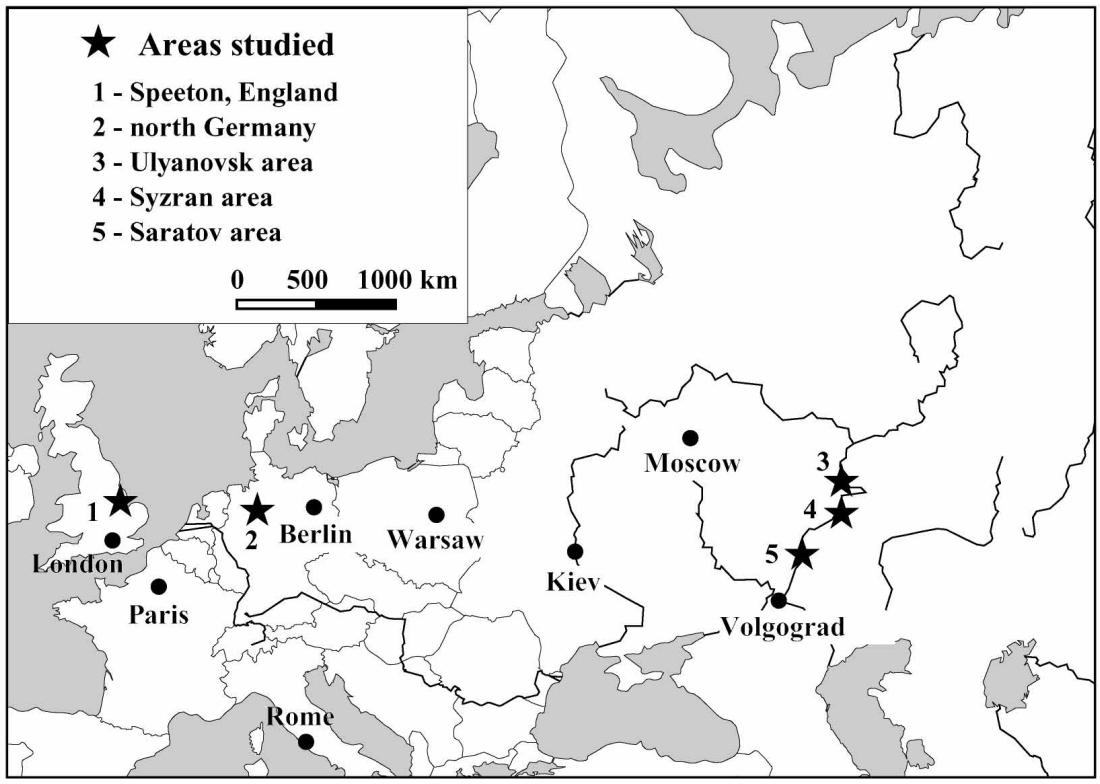



Fig. 1. Areas studied for Barremian belemnites

## THE BELEMNITE SUCCESSION OF NORTHWEST EUROPE

### Previous studies

The first quotation of an oxyteuthid belemnite, goes back to STROMBECK (1861), who described *Belemnites brunsvicensis* (= *Oxyteuthis brunsvicensis*) as the most common belemnite from the early Cretaceous of northwest Germany. A consistant biozonation scheme of the Barremian of northwest Germany based on belemnites was proposed by STOLLEY (1911). The belemnite family Oxyteuthididae was interpreted by STOLLEY (1925) as a phylogenetic lineage with the earliest species (*Praeoxyteuthis hibolitiformis*) originating in the Late Hauterivian *Simbirskites discofalcatus* ammonite Zone. The Late Hauterivian – Early Barremian belemnite succession is replaced in late Early Barremian time by the ventrally grooved genus *Aulacoteuthis*, which grades into the Late Barremian belemnite genus *Oxyteuthis*. Based on material from Speeton (northeast England) these observations were questioned by SWINNERTON (1955), who misinterpreted the Late Hauterivian grooved genus *Acroteuthis* as an oxyteuthid *Aulacoteuthis*. Subsequently MUTTERLOSE (1980, 1983) performed a detailed study of Barremian belemnites both from northwest Germany and Speeton. This study resulted in a solid taxonomic and stratigraphic analyses of the northwest European Oxyteuthididae, allowing the recognition of five belemnite zones (MUTTERLOSE 1983, 1990). These findings are also applicable for the Speeton section (RAWSON & MUTTERLOSE 1983).

### Material and lithology (Text-fig. 1)

The subsequent zonation scheme is based on bed-by-bed collections of belemnites performed in claystone sequences in northern Germany and Speeton (northeast England; Text-fig. 1). The Barremian of both areas is characterised by medium to dark grey claystones with low calcium carbonate percentages. Sideritic concretions, glauconitic layers and finely laminated horizons, the Blätterton, are intercalated. The Blätterton horizons reflect periods of impoverished oxygenation of the northwest European Basin.

A total of 2000 belemnites has been collected bed-by-bed from 14 sections in northwest Germany, 2000 belemnites were collected from Speeton, resulting in 4000 specimens which were evaluated statistically. An additional 1000 guards from museum collections were considered. A detailed account and description of the background data, as well as an analyses of the data is given by MUTTERLOSE (1983).

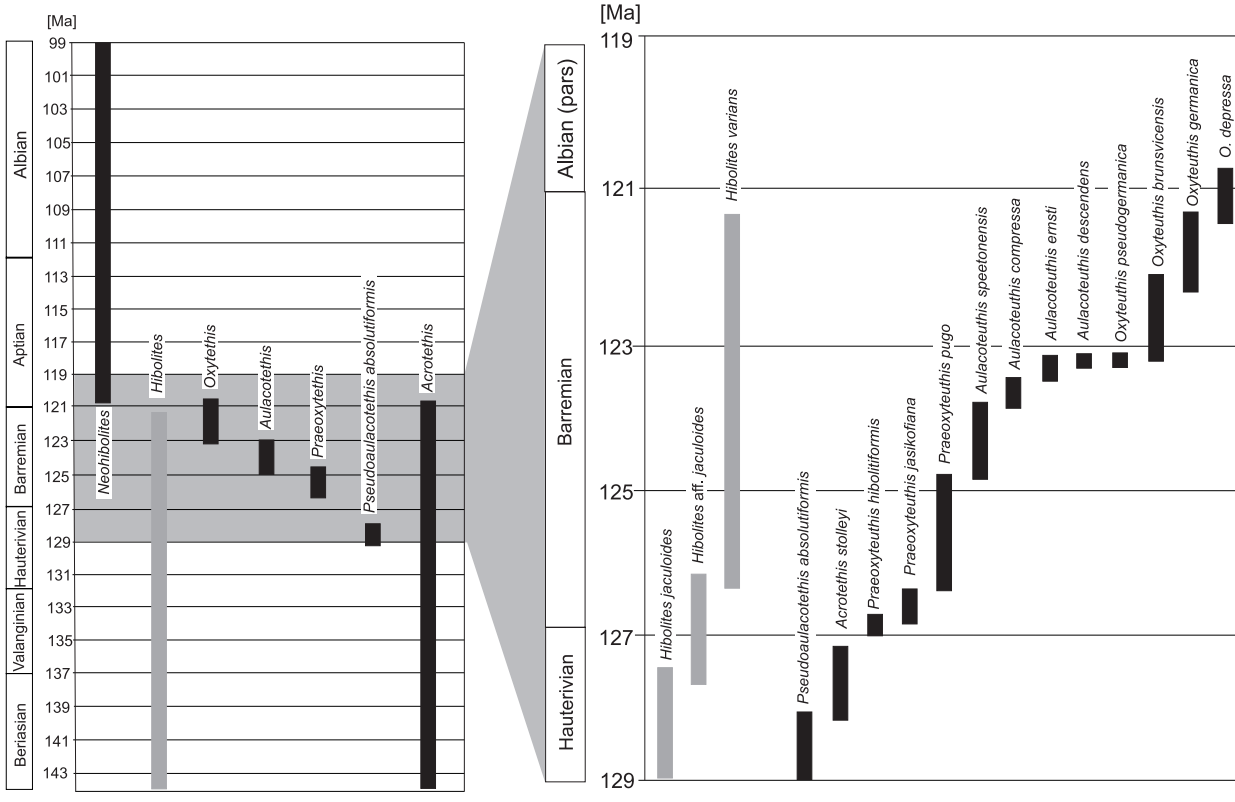



Fig. 2. Belemnite succession of the northwest European (Germany, England) Barremian. Black: boreal taxa; dark grey: cosmopolitan taxa; pale grey: tethyan taxa

**Belemnite zonation (Text-fig. 2)**

The belemnite family Oxyteuthididae, which is common in sediments of Barremian age in the Boreal Realm, is the last off shoot of the suborder Belemnitina. The Belemnitina are characterised by a lack of alveolar grooves. The Oxyteuthididae, which include the genera *Praeoxyteuthis*, *Aulacoteuthis* and *Oxyteuthis*, are extremely common and the most useful index fossils in the Barremian of northwest Europe (MUTTERLOSE 1983, 1990). They underwent an endemic evolution in the North Sea area. The species succession of the Oxyteuthididae both in northwest Germany and at Speeton (northeast England) clearly shows an evolutionary lineage: *Praeoxyteuthis jasikofiana* (Hauterivian – Barremian boundary interval) – *Praeoxyteuthis pugio* (earliest Barremian) – *Aulacoteuthis* spp. (late Early Barremian) – *Oxyteuthis brunsvicensis* (early Late Barremian) – *Oxyteuthis germanica* (mid Late Barremian) – *Oxyteuthis depressa* (latest Barremian). Various species of the *Aulacoteuthis* plexus form an evolutionary lineage, which characterises a distinctive level in the upper Lower Barremian without any other belemnites. Consequently STOLLEY (1925) and subsequent workers (e.g. MUTTERLOSE 1983) used *Aulacoteuthis* as an index for the late early Barremian *Aulacoteuthis* beds. In addition, *Aulacoteuthis* was used as the marker for the Lower/Upper Barremian boundary in northwest Europe (e.g. MUTTERLOSE 1983, 1992, 1998), with the first occurrence of its successor *Oxyteuthis* at the base of the Upper Barremian. Based on these observations the northwest European succession has been subdivided into five belemnite zones (*Praeoxyteuthis pugio*, *Aulacoteuthis*, *Oxyteuthis brunsvicensis, Oxyteuthis germanica*, and *Oxyteuthis depressa* zone; Text-fig. 2), the late Early Barremian can be further subdivided into four subzones (*Aulacoteuthis speetonensis*, *Aulacoteuthis compressa*, *Aulacoteuthis ernsti*, *Aulacoteuthis descendens* subzones; Text-fig. 2).

## THE BELEMNITE SUCCESSION OF THE RUSSIAN PLATFORM

**Previous studies**

The Barremian stratigraphy of the RP (Ulyanovsk – Saratov area) has been the subject of controversial discussions for more than 150 years for three reasons. Ammonites are essentially absent, *in situ* findings of belemnites have been extremely rare and extended landslides along the Volga River make it difficult to study the Barremian succession bed-by-bed. YUAZYKOV (1832) was the first, who named the Hauterivian – Barremian succession in the vicinity of Simbirsk as "Bessonovo Clay" and dated it as Jurassic. Subsequently PAVLOW (1887, 1892) divided the Hauterivian – Barremian succession into the lower "*Simbirskites* Beds" and the upper "Belemnite Beds". The *Simbirskites* Beds were assigned a middle – late Neocomian age (= Hauterivian; PAVLOW 1892). Most of the Belemnite Beds were considered to be of late Neocomian age, the uppermost part was placed in the Aptian (PAVLOW 1901). MILANOVSKY (1940) compared the distribution of the ammonites with those described by KOENEN (1902) and STOLLEY (1925) from Germany and by SPATH (1924) from Speeton. According to these observations the *Simbirskites* Beds of the Ulyanovsk – Saratov area should be assigned a Late Hauterivian age, the Belemnite Beds a Barremian age. CHERNOVA (1951) made a detailed study of the *Simbirskites* Beds. Based on the composition of faunas in Crimea, the Northern Caucasus and western Europe, the Hauterivian / Barremian boundary was defined above the *Simbirkites versicolor* ammonite Zone and below the *Simbirskites discofalcatus* / *S. decheni* ammonite Zone. The Belemnite Beds were considered to be of Late Barremian age and subdivided into a lower *Oxyteuthis jasykowi* horizon, a middle *Oxyteuthis brunsvicensis* horizon and an upper horizon without belemnites. This view was shared by many subsequent workers of the RP (e.g. SAZONOVA 1958, GERASIMOV & *al*. 1962, IVANOVA 1959, RESHENIYA 1962). GLASUNOVA (1959, 1969) also accepted the view of MILANOVSKY (1940) and named additional reasons for placing the Hauterivian/Barremian boundary above the *Craspedodiscus discofalcatus* Zone: (1) changes of the mineralogical composition of the deposits; (2) changes of the bivalve and foraminifera assemblages; (3) ammonites are completely replaced by belemnites. All these changes were caused by general shifts in the palaeoceanography of the RP Basin, possibly reflecting a reduction of salinity in the basin. The Belemnite Beds were considered to equate the Barremian *Oxyteuthis jasykowi* belemnite Zone.

After the acceptance of the Hauterivian/Barremian boundary at the top of *Pseudothurmannia angulicostata* ammonite Zone at the Lyon Colloque (1963), the Barremian of the RP was defined to comprise the *Oxyteuthis jasykowi* belemnite Zone only (ALEKSEEV & *al*. 1993, SHULGINA 1996). Based on new integrated stratigraphic data and belemnites collected bed-by-bed (BARABOSHKIN 2001, 2002; BARABOSHKIN & *al*. 1999, 2001, 2003) the boundaries of the Barremian were defined in the Ulyanovsk – Saratov area and a new belemnite zonation was proposed (BARABOSHKIN 2003).

**Material and lithology (Text-figs 1, 3)**

The Lower Cretaceous succession of the Ulyanovsk – Saratov area is represented by an alternation of claystones and sandstones, which crop out over a distance of 400 km from Ulyanovsk in the north to Volsk in the south along the Volga River. Thirteen sections, which expose Late Hauterivian – Barremian beds have been logged and sampled for belemnites (Text-figs 1, 3). These include the following localities: 1. Polivna section, 10 km north of Ulyanovsk (N 54°23,372'; E 48°23,013'): 11 belemnites from the Barremian. 2. Kremenki Village sections, 15 km south of Ulyanovsk (N 54º8,892'; E 48°24,317'): 50 belemnites from the Barremian. 3. Sengiley Town section (N 53°58,886'; E 48°47,203'): 15 belemnites from the Barremian. 4. Novokashpirsky Town sections, 5 km south from Syzran City (N 53°02,429'; E 48°26,867'): 16 belemnites from the Barremian. 5. Forfos Mountain sections, 30 km south from Syzran City (N 52°58,416'; E 48°29,618'): 53 belemnites from the Barremian. 6. Tcherny Zaton section, 35 km north from Khvalynsk Town: 12 belemnites from the Barremian. 7. Fedorovsky Stvor section, 15 km north from Khvalynsk Town: 10 belemnites from the Barremian. In addition six sections, partly yielding belemnites parly barren, have been investigated. Since these are of minor importance they are not shown on Text-fig. 3.

Belemnites are overall quite rare in the studied sections. Usually rostra found *in situ* are replaced by gypsum. Nevertheless their preservation is sufficient for

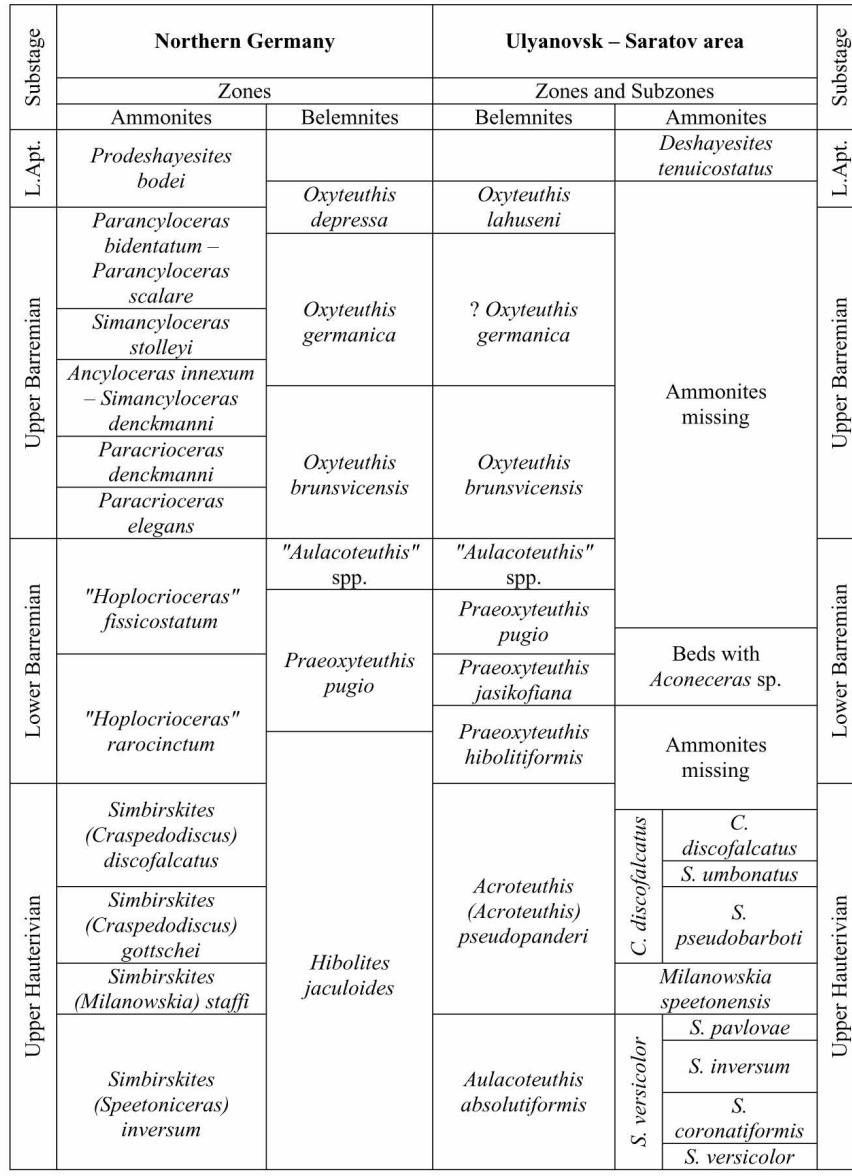



Fig. 4. Biostratigraphic zonation and correlation of the Barremian of northern Germany and the Ulyanovsk – Saratov area (Russian Platform)

determination. Rostra, which were washed out from outcrops and found on the beach, are much better preserved. Both types of rostra were collected and the original position (possible zonal intervals) of the removed belemnites was defined in accordance with the distribution of belemnites *in situ*. Poorly preserved rostra were not deposited in the museum and the numbers of belemnites in the description of the composite section reflect only a part of the material available.

A composite section including the Upper Hauterivian – Barremian sediments of the Volga River sections has been compiled. From bottom to top ten lithological units (IV – XIII) were differentiated in the course of our field work. The Barremian / Aptian boundary was defined at the base of unit XIII due to the recognition of the M0 magnetic anomaly. This is supported by dinocyst data (BARABOSHKIN & *al*. 1999). The total thickness of the Barremian in the Ulyanovsk region is about 70-75 m, in the Syzran – Khvalynsk region about 125 m. A more detailed account of the lithological units IV – XIII is given in Appendix 2.

**Belemnite zonation (Text-fig. 4, Plate 1)**

According to the belemnite finds in the Ulyanovsk – Saratov area it is possible to recognise seven belemnite biozones for the Barremian interval. The following zones can be differentiated from bottom to top (Text-fig. 4):

***Praeoxyteuthis hibolitiformis* Biozone:** The belemnite assemblage consists of *Praeoxyteuthis hibolitiformis, Praeoxyteuthis* ex gr. *jasicofiana*, *Praeoxyteuthis* sp. (Plate 1). The base is defined by the first occurrence (=FO) of *P. hibolitiformis*. The zone is of earliest Barremian age and can be further defined by the last occurrence (=LO) of simbirskitid ammonites and the FO of belemnites (*Praeoxyteuthis*). This zone correlates to lithostratigraphic Units V, VI and the basal part of Unit VII.

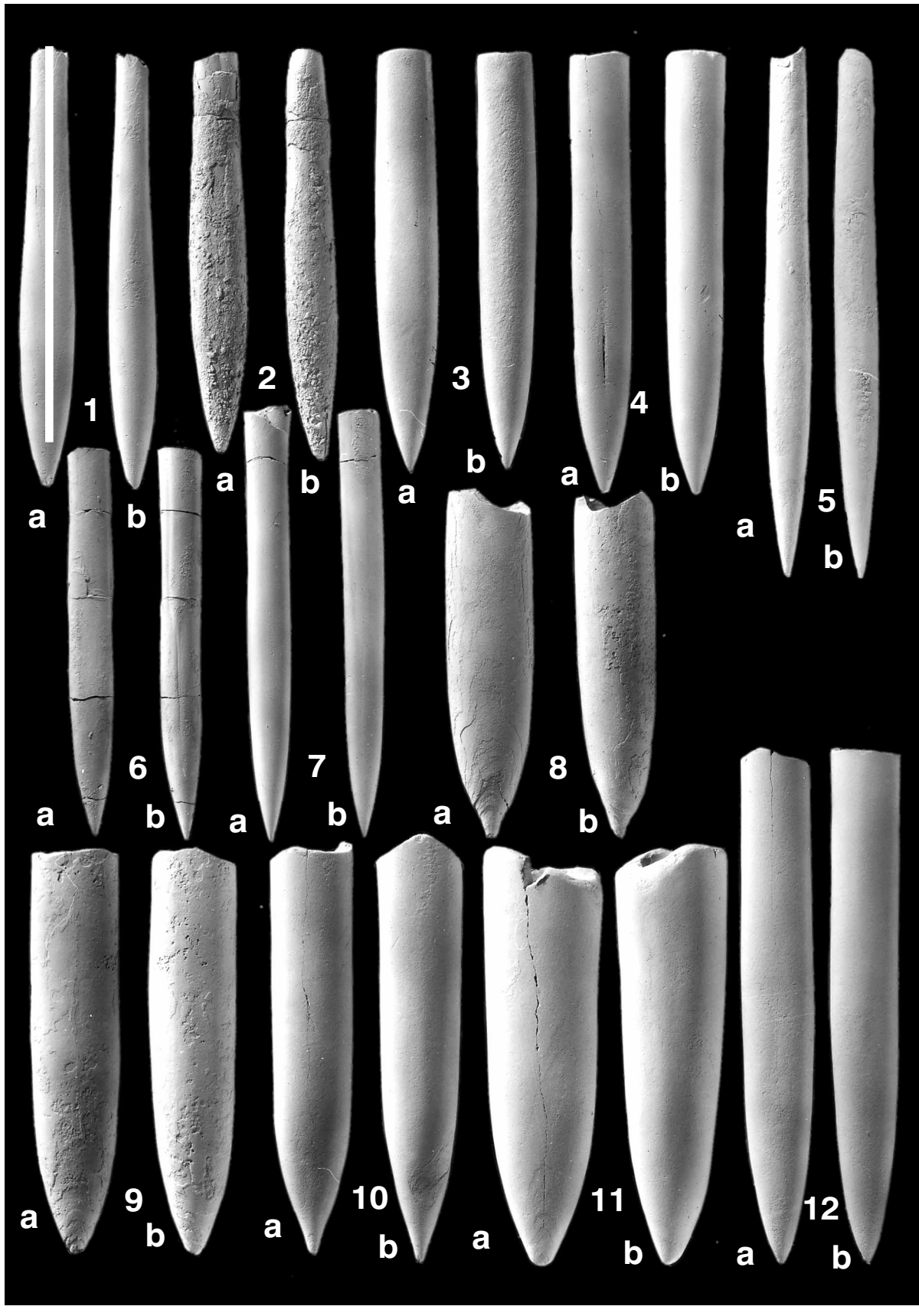
***Praeoxyteuthis jasikofiana* Biozone:** The belemnite assemblage is made up by *Praeoxyteuthis jasikofiana*, *P.* cf. *jasikofiana*, *P.* aff. *jasikofiana*, and *Praeoxyteuthis* sp. (Plate 1). The base is defined by FO of true *Praeoxyteuthis jasikofiana* and the LO of *P. hibolitiformis.* The zone is of earliest Barremian age and corresponds to the upper part of lithostratigraphic Unit VII.

***Praeoxyteuthis pugio* Biozone:** Typical belemnites of this zone are *Praeoxyteuthis pugio*, *P.* cf. *pugio*, *P.* aff. *pugio*, *P. jasikofiana* (only at the base), and *Praeoxyteuthis* sp. (Plate 1). The base is defined by the FO of *P. pugio.* The zone is of Early Barremian age and coincides with lithostratigraphic Units VIII and IX.

***Aulacoteuthis descendens* Biozone:** Belemnites of this assemblage are *Aulacoteuthis* cf. *descendens*, *Aulacoteuthis speetonensis*, and *Aulacoteuthis* sp. (Plate 1). The base is defined by the FO of the belemnite genus *Aulacoteuthis.* The zone is of late Early Barremian age and corresponds to lithostratigraphic Unit X and Subunit XI a.

***Oxyteuthis brunsvicensis* Biozone:** The belemnite fauna includes *Oxyteuthis brunsvicensis*, and *Oxyteuthis* sp. (Plate 1). The base is defined by the FO of the belemnite genus *Oxyteuthis* with *O. brunsvicensis* being the first species. The

Plate 1. Belemnites from the Ulyanovsk –Saratov area (Russian Platform). All specimens have been coated with $NH_4Cl$ and are figured in natural size. 1 – *Praeoxyteuthis hibolitiformis* (STOLLEY, 1811), MSU 104/1 [Cp00-8/1]; a – ventral view, b – lateral view, venter to the left. Right bank of Volga River, Forfos Mt. (Syzran region), on a beach; Lower Barremian, *Praeoxyteuthis hibolitiformis* Zone. **2** – *Praeoxyteuthis jasicofiana* (LAHUSEN, 1874); MSU 97/2 [Cp98-5/5]; a – ventral view, b – lateral view, venter to the left. Right bank of Volga River, Forfos Mt. (Syzran region), bed 5; Lower Barremian, *Praeoxyteuthis jasicofiana* Zone. **3** – *Praeoxyteuthis pugio* (STOLLEY, 1925); MSU 104/2 Cp00-24-25/1A; a – ventral view, b – lateral view, venter to the right. Right bank of Volga River, Forfos Mt. (Syzran region), on a beach; Lower Barremian, *Praeoxyteuthis pugio* Zone. **4** – *Aulacoteuthis speetonensis* (PAVLOW, 1892); MSU 104/2 [Y97-27/3]; a – ventral view, b – lateral view, venter to the left. Right bank of Volga River, near Bueraki Village (Ulyanovsk region), on a beach; Lower Barremian, *Aulacoteuthis* Zone. **5** – *Praeoxyteuthis pugio* (STOLLEY, 1925); MSU 97/10 [Cp98-5c]; a – ventral view, b – lateral view, venter to the left. Right bank of Volga River, Forfos Mt. (Syzran region), on a beach; Lower Barremian, *Praeoxyteuthis pugio* Zone. **6** – *Praeoxyteuthis pugio* (STOLLEY, 1925); MSU 104/4 [Cp98-6/4-1]; a – ventral view, b – lateral view, venter to the left. Tcherny Zaton section near Tcherny Zaton Village, bed 4, Lower Barremian, *Praeoxyteuthis pugio* Zone. **7** – *Praeoxyteuthis pugio* (STOLLEY, 1925); MSU 97/3 [Cp98-5/19-1]; a – ventral view, b – lateral view, venter to the right. Right bank of Volga River, Forfos Mt. (Syzran region), bed 19, Lower Barremian, *Praeoxyteuthis pugio* Zone. **8** – *Oxyteuthis barremicus* GLASUNOVA, 1969; MSU 104/5 [Cp00-10-11/1]; a – ventral view, b – lateral view, venter to the left. Right bank of Volga River near Kremenki Village (Ulyanovsk region), on a beach; Upper Barremian, *Oxyteuthis lahuseni* Zone. **9** – *Oxyteuthis lahuseni* (PAVLOW, 1901); MSU 104/6 [Cp00-10-11/4]; a – ventral view, b – lateral view, venter to the left. Right bank of Volga River near Kremenki Village (Ulyanovsk region), on a beach; Upper Barremian, *Oxyteuthis lahuseni* Zone. **10** – *Oxyteuthis lahuseni* (PAVLOW, 1901). No. MSU 104/7 [Y97-27/4]. a – ventral view, b – lateral view, venter to the left. Right bank of Volga River, near Bueraki Village (Ulyanovsk region), on a beach; Upper Barremian, *Oxyteuthis lahuseni* Zone. **11** – *Oxyteuthis barremicus* GLASUNOVA, 1969; MSU 104/8 [Cp00-5-6/1A]; a – ventral view, b – lateral view, venter to the left. Right bank of Volga River near Zakharievsky RudnikVillage (Ulyanovsk region), on a beach; Upper Barremian, *Oxyteuthis lahuseni* Zone. **12** – *Oxyteuthis brunsvicensis* (STROMBECK, 1861); MSU 104/9 [Y97-27/6]; a – ventral view, b – lateral view, venter to the right. Right bank of Volga River, near Bueraki Village (Ulyanovsk region), on a beach; Upper Barremian, *Oxyteuthis brunsvicensis* Zone.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zone is of early Late Barremian age and equates lithostratigraphic Subunit XI b.

***Oxyteuthis germanica* Biozone:** *Oxyteuthis* cf. *germanica*, and *Oxyteuthis* sp. are typical belemnites of this zone. The base is defined by the FO of *O. germanica*. The zone is of Late Barremian age, its base corresponds to the base of lithostratigraphic Unit XII.

***Oxyteuthis lahuseni* Biozone:** The assemblage of this zone contains *Oxyteuthis lahuseni*, *O. barremicus* and *Oxyteuthis* sp. (Plate 1). The base is defined by the FO of *O. lahuseni*. The zone is of latest Barremian age and extends into lower part of the Aptian succession.

## CORRELATION OF THE BELEMNITE ZONATION SCHEMES (Text-fig. 4)

The observed sequences of belemnites in northwest Europe and on the RP correlate in general very well (Text-fig. 4). Both areas are characterised by an evolutionary lineage leading from ungrooved *Praeoxyteuthis* over grooved *Aulacoteuthis* to ungrooved *Oxyteuthis*. This allows for a correlation of the Late Hauterivian – early Barremian *Praeoxyteuthis* Beds, the late Early Barremian *Aulacoteuthis* Beds, and the Late Baremian *Oxyteuthis* Beds. Apart from the Late Hauterivian *P. hibolitiformis* and the latest Barremian / Early Aptian *O. lahuseni* belemnite Zone, all zones observed on the RP correspond to belemnite zones in northwest Europe. Thus most of the Barremian sequence of both areas can be correlated on a zonal scale, resulting in a standard belemnite zonation for the Barremian of the Boreal Realm. Differences in both scales include the Late Hauterivian and the Late Barremian. The absence of the RP taxa *P. hibolitiformis* and *O. lahuseni* from northwest Europe ask for explanations.

*P. hibolitiformis* has been described by STOLLEY (1925) from the Late Hauterivian of northwest Germany, but MUTTERLOSE (1983) included this species in *P. jasikofiana*. This interpretation of *P. jasikofiana* includes rather spindle shaped belemnites (MUTTERLOSE 1983, plate 1, figs 6, 8, 10), formerly included in *P. hibolitiformis*. Due to the scarcety of *P. hibolitiformis* like specimens in the northwest European sections, so far only three or four specimens were observed, there was not enough material available to separate this species clearly from *P. jasikofiana*. If this view is correct *P. hibolitiformis* is a younger synonym of *P. jasikofiana*. Alternatively the Oxyteuthididae may have originated on the RP with *P. hibolitiformis* being the forerunner of *P. jaskofiana*. While *P. hibolitiformis* was restricted to the RP, *P. jasikofiana* was able to migrate to northwest Europe.

*O. lahuseni* is present in latest Barremian sediments of the RP only, while *O. depressa* marks the latest Barremian of northwest Europe. This difference may simply reflect an increasing degree of isolation of both basins and a trend to endemic evolution in both areas. This idea is supported by the expansion of continental conditions in the Arctic basin (BARABOSHKIN 2001, BARABOSHKIN & *al*. 2003) and an increase of fresh water influence in the northern part of the RP (VASILENKO 2001, BASOV & VASILENKO 1999).

## EVOLUTION AND MIGRATION PATTERNS OF THE OXYTEUTHIDIDAE

The suborder Belemnitina, which made its first occurrence in the earliest Jurassic and became extinct in the Aptian, is interpreted here as a group of belemnites characterised by the absence of alveolar grooves. Representatives of two taxa, the Cylindroteuthididae and the Oxyteuthididae, are common in Late Hauterivian and Barremian sediments of the Boreal Realm. Cylindroteuthididae and Oxyteuthididae differ by the courses of their internal axial lines (MUTTERLOSE & BARABOSHKIN 2003) and their external lateral lines (=Seitendoppellinien) (GUSTOMESOV 1963). While the Cylindroteuthididae became extinct in the Barremian, the Oxyteuthididae are the last representatives of the suborder Belemnitina. Oxyteuthididae are known from northwest Europe, the RP, and probably from Eastern Greenland (FREBOLD 1935). The informations on their presence in other areas of central Europe (BLASZKEWICZ & *al*. 1989) and the Tethys (STOYANOVA-VERGILOVA 1965, TOPCHISHVILI & *al*. 2002) seem to be either wrong or at least highly doubtful. There are currently two main problems with the Oxyteuthididae. These are the origination of the group and the convergent evolution of ventral grooves.

The origin of the Oxyteuthididae in the Late Hauterivian has been a matter of discussion for quite some time. Since this group is limited to northwest Europe and the RP there are only two possible ancestors. (1). The Tethyan derived belemnopseid *Hibolites*, which invaded northwest Europe in the Hauterivian. Indeed resemble the early spindle shaped forms of *Praeoxyteuthis* (either *P. hibolitiformis* or *P. jasikofiana*) *Hibolites* morphologically quite closely. *Hibolites* is, however, characterised by a ventral alveolar groove, which is missing in early *Praeoxyteuthis* and all later oxyteuthid taxa. (2). Some slender cylindroteuthid species of the genus *Acroteuthis* may have given way to the first Oxyteuthididae. This is supported by the generally flattened venter in both Cylindroteuthididae and Oxyteuthididae and the trend to develop ventrally api-

cal grooves. The only problem for this reasoning is the spindle shaped morphology of the early *Praeoxyteuthis* (either *P. hibolitiformis* or *P. jasikofiana*), which is uncommon for both Cylindroteuthididae and Oxyteuthididae. The external lateral lines are another feature important for reconstructing possible evolutionary lineages. The external lateral lines are double in *Hibolites* and diverge in the alveolar region, while *Praeoxyteuthis* has double lines only in the apical part of the rostrum. We prefer an origination from *Acroteuthis,* because both, Cylindroteuthididae and Oxyteuthididae, were purely Boreal groups, not observed in the Tethys

Both Cylindroteuthididae and Oxyteuthididae show convergent evolution with relatively slender ventrally grooved genera evolving in the early Late Hauterivian ("*Pseudoaulacoteuthis absolutiformis*") and in the early Late Barremian (*Aulacoteuthis* spp.). "*P. absolutiformis*" is currently an invalid taxon, which supposedly will replace the valid species *Aulacoteuthis absolutiformis* by an application to the commission on zoological nomenclature (for further discussion of these taxonomic problems see MUTTERLOSE & BARABOSHKIN 2003). The Cylindroteuthididae are characterised by ventrally displaced curved axial lines, while the Oxyteuthididae have a central to slightly ventrally displaced straight axial line. The ventrally extremely displaced apical line of "*Pseudoaulacoteuthis absolutiformis*" from the Hauterivian of the Russian Platform suggests that this species should be included in the Cylindroteuthididae (for further discussion see MUTTERLOSE & BARABOSHKIN 2003). The Hauterivian "*Pseudoaulacoteuthis absolutiformis*", which is here thought to be part of the Cylindroteuthididae, developed from *Acroteuthis*. "*Pseudoaulacoteuthis absolutiformis*" is restricted to the Russian Platform and has not been recorded from northwest Europe. There is no direct evidence of the origin of "*Pseudoaulacoteuthis absolutiformis*". All Neocomian sections of the Ulyanovsk – Saratov area are characterised by a stratigraphic gap at the base of the Upper Hauterivian. The first appearance of "*Pseudoaulacoteuthis absolutiformis*" was recognised 8.5 m above the base of the Upper Hauterivian *Speetoniceras versicolor* ammonite Zone, no belemnites were recorded below this level.

The late Early Barremian *Aulacoteuthis ernsti* and other taxa of the genus *Aulacoteuthis* (*A. speetonensis*, *A. compressa*, *A. descendens*), showing a distinctive ventral groove, are included in the Oxyteuthididae. These taxa are restricted to a relatively short interval of the late Early Barremian and have been observed both in northwest Europe and on the Russian Platform. Grooved Barremian *Aulacoteuthis* developed from ungrooved *Praeoxyteuthis*, and the genera form a phylogenetic lineage linked by intermittent forms. The Barremian *Aulacoteuthis* showed rapid speciation, and during a period of several 100.000 years four species evolved successively (MUTTERLOSE 1998): *A. speetonensis – A. compressa – A. ernsti – A. descendens*. The most obvious feature is the evolution of a ventral groove, culminating in *A. ernsti*. Subsequently the ventral groove became shallow (*A. descendens*) and disappeared finally. The newly evolving ungrooved taxa are assigned to the genus *Oxyteuthis*.

Both the Hauterivian "*Pseudoaulacoteuthis absolutiformis*" *sensu* SINZOW and the late Early Barremian *Aulacoteuthis* spp. are clearly endemic lineages limited to the palaeogeographically restricted seas of Russia and northwest Europe. The evolution of a ventral groove is thus viewed as a convergent feature repeating itself at least twice during the evolution of the suborder Belemnitina. Similar ventral grooves characterize the boreal belemnite taxa *Holcobelus* and *Holcobeloides*, both of which are not related to either of the *Aulacoteuthis* discussed here.

## CONCLUSIONS

The Barremian succession of northwest Europe and the Russian Platform can be dated stratigraphically and correlated by using belemnites. An evolutionary lineage of oxyteuthid belemnites allows the recognition of five belemnite zones for northwest Europe and of seven belemnite zones for the RP. These two zonation schemes allow a detailed correlation of both areas, having the same taxa in common for the Late Hauterivian – Late Barremian interval. This reflects a constant exchange of faunas throughout most of the Barremian. Differences on the species level become obvious for the latest Barremian / earliest Aptian, when endemic evolution occurred in both areas due to an increasing isolation. Oxyteuthid belemnites, common only in northwest Europe and on the RP, supposedly originated from *Acroteuthis* in the late Hauterivian. The development of a ventral apical groove is thought to be a convergent feature.

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## Appendix 1

List of taxa recognized, with author attributions, dates and notes

**Ammonites (in alphabetical order):**
*Aconeceras* HYATT, 1903
*Crioceratites* LEVEILLE, 1837
*Craspedodiscus* SPATH, 1924
*Craspedodiscus barboti* (LAHUSEN, 1874)
*Craspedodiscus borealis* GLASUNOVA, 1967
*Craspedodiscus discofalcatus* (LAHUSEN, 1874)
*Paracrioceras* SPATH, 1924
*Parancyloceras* Spath, 1924
*Pseudothurmannia angulicostata* (D'ORBIGNY, 1840)
*Simancyloceras* KEMPER, 1973
*Simbirskites decheni* (ROEMER, 1841)
*Speetonicetas versicolor* (TRAUTSCHOLD, 1865)

**Belemnites (in alphabetical order):**
*Acroteuthis* STOLLEY, 1911
*Acroteuthis pseudopanderi* (SINZOW, 1877)
*Aulacoteuthis* STOLLEY, 1925
*Aulacoteuthis ascendens* STOLLEY, 1925
*Aulacoteuthis brevisulcatus* STOLLEY, 1925
*Aulacoteuthis compressa* MUTTERLOSE, 1983
*Aulacoteuthis descendens* STOLLEY, 1925
*Aulacoteuthis ernsti* MUTTERLOSE & BARABOSHKIN, 2003
*Aulacoteuthis speetonensis* (PAVLOW, 1892)
*Acroteuthis stolleyi* PINCKNEY, 1987
*Hibolites* MONTFORT, 1808
*Holcobelus* STOLLEY, 1927
*Holcobeloides* GUSTOMESOV, 1956
*Oxyteuthis* STOLLEY, 1911
*Oxyteuthis barremicus* GLASUNOVA, 1969
*Oxyteuthis brunsvicensiformis* STOLLEY, 1925
*Oxyteuthis brunsvicensis* (STROMBECK, 1861)
*Oxyteuthis depressa* STOLLEY, 1925
*Oxyteuthis germanica* STOLLEY, 1925
*Oxyteuthis lahuseni* (PAVLOW, 1901)
*Oxyteuthis pseudogermanica* MUTTERLOSE, 1983
*Oxyteuthis pugio* (STOLLEY, 1925)
*Praeoxyteuthis* MUTTERLOSE, 1980
*Praeoxyteuthis hibolitiformis* (STOLLEY, 1925)
*Praeoxyteuthis jasikofiana* (LAHUSEN, 1874)
*Praeoxyteuthis pugio* (STOLLEY, 1925)
*Pseudoaulacoteuthis* MUTTERLOSE & BARABOSHKIN, 2003
*Pseudoaulacoteuthis absolutiformis* (SINZOW, 1877)

**Bivalves (in alphabetical order):**
*Arctica* SCHUMACHER, 1817
*Astarte* SOWERBY, 1818
*Cucullaea golowkinskii* (SINZOW, 1872)
*Cymbula* SAVELIEV, 1969
*Cyprina* LAMARCK, 1812
*Eucyclus* DESLONGCHAMPS, 1860
*Heteropteria* cf. *aucella* (TRAUTSCHOLD, 1865)
*Inoceramus* (*Neocomiceramus*) POKHIALAINEN, 1972
*Leda nuda* (KEYSERLING, 1846)
*Mclearnia imperialis* (KEYSERLING, 1846)
*Nucula* LAMARCK, 1799
*Oxytoma* MEEK, 1864

**Ichnofossils (in alphabetical order):**
*Ophiomorpha* LUNDGREN, 1891
*Scolithos* HALDEMANN, 1840

## Appendix 2

A composite section of the upper Hauterivian – Barremian sediments of the Volga River area. From bottom to top ten lithological units (IV – XIII) were differentiated

**Unit IV (6 m).** Black silty claystones with fine shell detrite and rare horizons of carbonate concretions. This unit occupies the topmost part of the Upper Hauterivian succession, which is represented by silt/clay alternation, also containing numerous carbonate concretions. The fauna includes ammonites (*Craspedodiscus barboti*, *Craspedodiscus discofalcatus*, *Craspedodiscus borealis* and other taxa from the *C. discofalcatus* ammonite Zone) and belemnites (*Acroteuthis pseudopanderi*). Two specimens of the latter were collected bed-by-bed in this unit.

**Unit V (10 m).** Clayey siltstones (2,5 m), which change into black clays with rare layers of dark grey silts up-section. The siltstones contain vertical tubes of *Scolithos* at the base, which mark a soft ground level (SG). There are rare horizons of large (up to 2 m) carbonate concretions. The top of the unit is weakly eroded. At the base of the succession of the Ulyanovsk sections rare bivalves (*Heteropteria* cf. *aucella, Cymbula*? sp.) were found. In the Novokashpirsky Town sections Units V and VI are difficult to separate. In the lower part of the exposed succession, which we temporarily referred to Unit V, belemnites were found (*Praeoxyteuthis* sp. indet., P. ex gr. *hibolitiformis*, *P.* sp. (ex. gr. *jasicofiana*?) ) .

**Unit VI (22 - 24 m).** Rhythmic alternation of black silty claystones (0,5-3 m) and light grey and greenish siltstones or fine sandstones (0,1-0,75 m). The claystones contain weathered pyrite and rare horizons of ellipsoidal and spherical carbonate concretions (up to 1 m in the Ulyanovsk section). The beds are intensively bioturbated and occasionally contain thin layers of sandy tempestites. The top of the unit is well defined in all sections and represented by a SG. The SG is a distinctive half-meter glauconite layer, which was earlier considered to represent the Hauterivian/Barremian boundary (BARABOSHKIN & al. 2001). In the top rare bivalves (*Mclearnia imperialis*, *Cymbula*? sp. indet.) were observed. Belemnites (*Praeoxyteuthis* cf. *hibolitiformis, P.* ex. gr. *jasicofiana*, *P.* sp.) were found only in the Novokashpirsky Town sections.

**Unit VII (5 - 12 m).** Rhythmic alternation of bioturbated greenish fine glauconite - quartz sand stones (0,15-0,9 m) with SG surfaces at the base and black silty claystones (0,65-4 m). The SG have a thickness of 30-40 cm and contain *Scolithos*. There is 0,4-0,5 m layer of quartz - glauconite sand at the base of unit, where belemnites (*Praeoxyteuthis hibolitiformis*, *P.* cf. *jasikofiana*. *P.* sp.) were found. The belemnit assemblage near the top of Unit VII is different. It contains dissolved belemnites (*Praeoxyteuthis jasikofiana, P.* cf. *jasikofiana*, P. aff. *jasikofiana* and *P.* sp.), and rare bivalves (*Mclearnia imperialis*).

**Unit VIII (8 – 15 m).** Black and brown homogeneous bioturbated claystones with rare siderite concretions and remains of ammonites (*Aconeceras* sp.). The claystones becomes more sandy toward the top and up to 1.5 m bioturbated (*Scolithos*, *Ophiomorpha*). Above the base with its SG surface belemnites (*Praeoxyteuthis jasikofiana*, *P.* aff. *Pugio*, *P.* sp.) were found. The claystones contain belemnites (*Praeoxyteuthis pugio*, *P.* cf. *pugio)* and bivalves (*Leda* cf. *nuda*).

**Unit IX (20 - 25 m).** Brown - grey fine laminated silty claystones with cross-bedded sand (0,1-0,2 m) at the base. Rare belemnites (*Praeoxyteuthis pugio*) and sporadic bivalves (*Inoceramus* (*Neocomiceramus*) sp., *Cyprina*? sp. indet. *Oxytoma* sp., *Nucula* sp.) have been observed.

**Unit X (6.8 m).** Alternation of cross-bedded siltstones (0,2-0,3 m) and black claystones (0,03-0,05 m) with numerous diagenetic carbonate concretions. The claystones contain belemnites (*Aulacoteuthis* sp. juv.).

**Unit XI (10 m).** Claystone unit. In the Novoulyanovsk region (Kremenki Village) this unit contains large (up to 5-6 m) carbonate concretions.

**Subunit XI a (2.6 m).** Silty claystones at the base with fine siderite and pyrite concretions. The top is cemented by siderite and eroded. There are two-valved bivalves (*Astarte* sp.) preserved in alive position. Rare belemnites (*Aulacoteuthis* cf. *descendens*, *Aulacoteuthis* sp.) were collected in the upper part of this member.

**Subunit XI b (7.4 m).** Dark claystone with a bed (0,2 m) of bright - green quartz - glauconite sand. At the base rare reworked belemnites (*Aulacoteuthis* cf. *descendens, Aulacoteuthis* sp. and non-reworked *Oxyteuthis* cf. *brunsvicensis*, *Oxyteuthis* sp.) have been observed.

**Unit XII (6 – 3.5 m).** Greenish-grey cross- to parallel laminated siltstones or fine sands (up to 0,3 m) and dark grey bioturbated claystones. The unit contains lenses of cross-bedded sands and siderite layer (0,1 m) at the top. Belemnites (*Oxyteuthis* cf. *germanica*, *Oxyteuthis* sp.) are rare, while bivalves (*Cucullaea golowkinskii*, *Nucula* sp.) and gastropods (*Eucyclus* sp.) are common.

**Unit XIII (20 – 25 m).** Grey clays in the basal part (1,5 m) are replaced by silty clays higher in the sequence, where yellow - grey cross-laminated siltstones (0,05-0,1 m) alternate with dark grey clays (0,01-0,02 m). Rare horizons of siderite concretions occur. Belemnites (*Oxyteuthis lahuseni, O. barremicus*, *O.* cf. *germanica*, reworked at the base) and bivalves (*Arctica*? sp., *Cymbula*? sp., *C. nuda*) were observed.

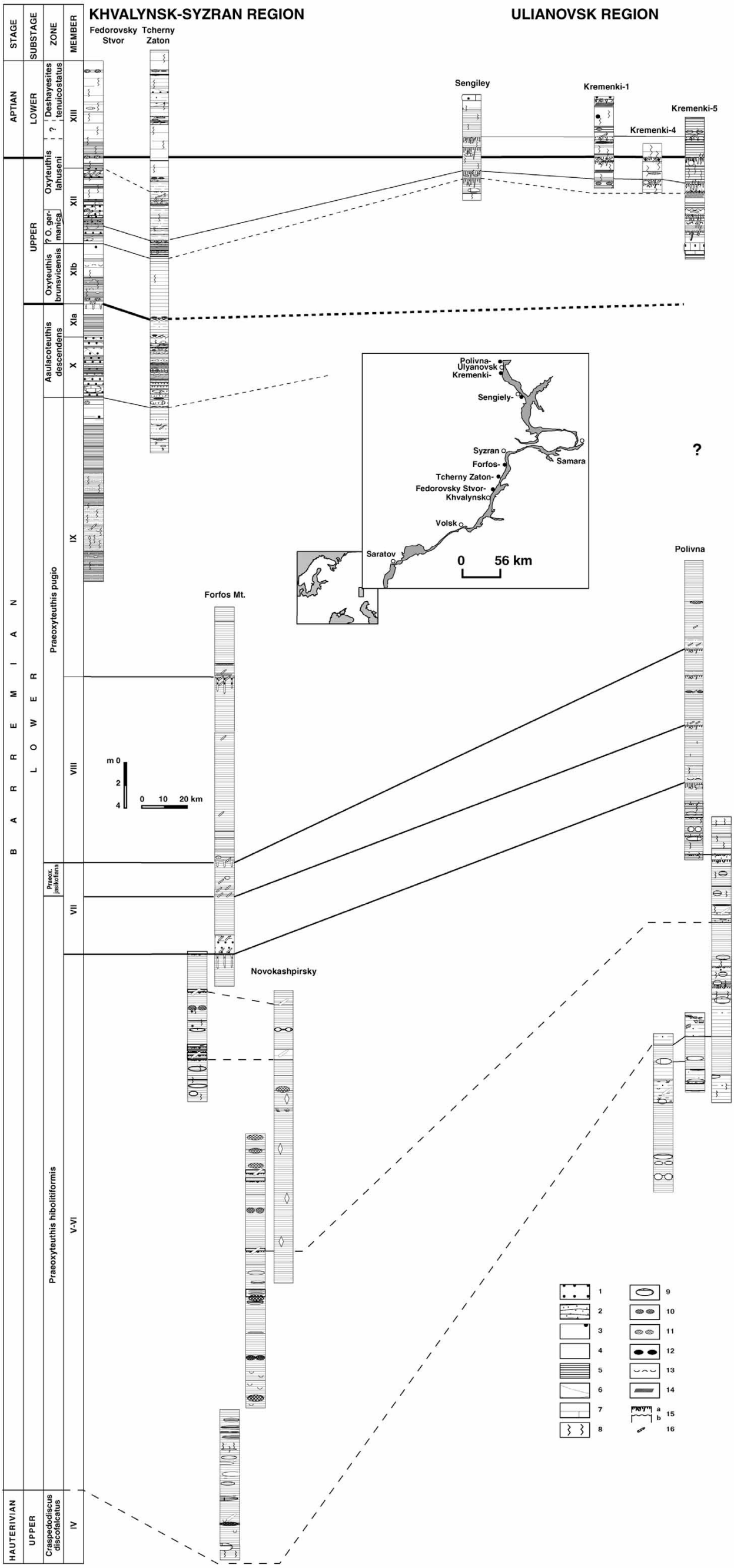


Fig. 3. Correlation of the Barremian sections of the Ulyanovsk – Saratov area (Russian Platform). Black dots indicate sections discussed here, white spots major cities for orientation. Legend: 1 – sand; 2 – clayey sand; 3 – silt; 4 – silty clay; 5 – clay; 6 – cross-bedding; 7 - clayey limestone; 8 – bioturbations; 9 – carbonate concretions; 10 – siderite concretions; 11 – sulphide concretions; 12 – phosphorites; 13 – shell detrite; 14 – limonitisation; 15 – softgrounds (a) and erosional surfaces (b); 16 – belemnites