New stratigraphic and palaeogeographic data on Upper Jurassic to Cretaceous deposits from the eastern periphery of the Russian Platform (Russia)

Valentina S. VISHNEVSKAYA
Institute of the Lithosphere, Russian Academy of Science, ILSAN,
22 Staromonetny, Moscow, 109180 (Russia)
valentina@ilsan.msk.ru

Patrick DE WEVER
Laboratoire de Géologie, Muséum national d'Histoire naturelle,
43 rue de Buffon, F-75231 Paris cedex 05 (France)
dewever@mnhn.fr

Evgeniy Yu. BARABOSHKIN
Moscow State University, Geological Faculty,
Vorobjovy Gory, 119899 Moscow (Russia)
barabosh@geol.msu.ru

Nikita A. BOGDANOV
Institute of the Lithosphere, Russian Academy of Science, ILSAN,
22 Staromonetny, Moscow, 109180 (Russia)
bogdanov@ilsan.msk.ru

Nikita Yu. BRAGIN
Geological Institute of Russian Academy of Science,
Pyzhevsky per., 7, Moscow, 109017 (Russia)
bragin@ginran.msk.ru

Lubov G. BRAGINA
Geological Institute of Russian Academy of Science,
Pyzhevsky per., 7, Moscow, 109017 (Russia)
bragin@ginran.msk.ru

Alesia S. KOSTYUCHENKO
Technical University,
Leningradskoe shosse 112-1-1-211, Moscow, 125445 (Russia)
valentina@ilsan.msk.ru

Emmanuelle LAMBERT
Laboratoire de Géologie, Muséum national d'Histoire naturelle,
43 rue de Buffon, 75231 Paris cedex 05 (France)
geolhote@mnhn.fr

Yuriy M. MALINOVSKY
Institute of the Lithosphere, Russian Academy of Science, ILSAN,
22 Staromonetny, Moscow, 109180 (Russia)
barejko@ilsan.msk.ru

Kulyash M. SEDAEVA
Moscow State University, Geological Faculty,
Vorobjovy Gory, Moscow, 119899 (Russia)
koozminov@mtu-net.ru

Galina A. ZUKOVA
Simbirsk Geological Survey,
3a Dovatora, Uljanovsk, 432000 (Russia)

Vishnevskaya V. S., De Wever P., Baraboshkin E. Yu. *et al.* 1999. — New stratigraphic and palaeogeographic data on Upper Jurassic to Cretaceous deposits from the eastern periphery of the Russian Platform (Russia), *in* Crasquin-Soleau S. & De Wever P. (eds), Peri-Tethys: stratigraphic correlations 3, *Geodiversitas* 21 (3) : 347-363.

ABSTRACT

The Late Jurassic and Late Cretaceous were periods when, after prolonged continental erosion, stable marine sedimentation took effect on the Russian Platform. The sediments which accumulated have diverse lithological compositions and a mixture of transient and endemic faunas. Lithological diversity and a wide variety of facies has led to problems in stratigraphical correlation of Late Mesozoic sequences and discrepancies in palaeogeographical reconstructions. Different faunal groups belonging to a wide variety of palaeozoogeographic provinces exist within these deposits. Therefore, we use all available microfossils (radiolarians, foraminiferas, nannoplankton) and macrofossil groups (ammonites, buchias, inoceramides) in order to establish the synchronicity of anoxic and other events, to propose biostratigraphic zonations and model the palaeogeography for Late Jurassic: lower Kimmeridgian and middle Volgian as well as Cretaceous time. We suggest that the Peri-Tethys of Eastern Europe is a unique area in which to solve the problem of stratigraphic correlation as it incorporates both Boreal and Transitional to Tethyan palaeoclimatic provinces.

KEY WORDS
Jurassic,
Cretaceous,
stratigraphy,
ammonites,
radiolarians,
foraminifera,
nannofossils,
palaeogeographical map.

RÉSUMÉ

Nouvelles données stratigraphiques et paléogéographiques sur les dépôts jurassiques et crétacés de l'extrémité orientale de la Plate-forme russe (Russie).

Le Jurassique supérieur et le Crétacé forment une période où, après une longue érosion continentale, une sédimentation marine stable s'installe sur la plate-forme russe. Les sédiments accumulés ont des lithologies variées et présentent un mélange de faunes endémiques ou transitionnelles. La diversité lithologique et la grande variété de faciès ont rendu complexes les corrélations stratigraphiques pour ces séries du Mésozoïque tardif et ont même créé des désaccords dans les reconstitutions paléogéographiques. Différents groupes fauniques, appartenant à une grande variété de provinces paléobiogéographiques existent dans ces dépôts. De ce fait, nous avons été conduits à utiliser tous les groupes disponibles de microfossiles (radiolaires, foraminifères, nannoplancton) et de macrofossiles (ammonites, buchias, inocéramides) afin d'établir le synchronisme des événements, anoxiques ou autres, pour proposer des zonations biostratigraphiques et des modèles paléogéographiques pour le Jurassique supérieur : Kimméridgien inférieur et Volgien moyen ainsi que pour le Crétacé. Nous pensons que la partie péri-téthysienne de l'Europe orientale est un endroit unique pour résoudre les problèmes de corrélation stratigraphique puisqu'il incorpore des éléments fauniques de provinces boréales et de la transition vers les provinces paléoclimatiques téthysiennes.

MOTS CLÉS
Jurassique, Crétacé, stratigraphie, ammonites, radiolaires, foraminifères, nannofossiles, carte paléogéographique.

INTRODUCTION

Our research team has undertaken field work in Volga River Basin (August 1995, members of field work team were as follow: E. Baraboshkin, N. Bragin, E. Lambert, V. Vishnevskaya, G. Zukova; August 1997, V. Vishnevskaya, G. Zukova) and in the Timan-Pechora Basin (September 1995, A. Kostyuchenko, G. Sedaeva, V. Vishnevskaya). All previously published and unpublished data concerning of these regions were revised and taken into account.

The aim of our field trips was to collect precise and well-located samples with fossil material in order to establish accurate biostratigraphical correlations and to propose palaeogeographic reconstructions which could provide a basis for modelling of palaeogeographic maps.

During the field work, we investigated and sampled the following areas in detail: (1) Kimmeridgian-Volgian portion of the standard Gorodische Section of Volga River Basin and Ukhta outcrop as well as 21 outcrops and 52 boreholes of the Volga-Kama and Timan-Pechora Basin (Figs 1-5); (2) middle Volgian-Hauterivian sections near Gorodische and New Berdianka villages (Figs 2, 3); (3) Aptian-Albian sections from boreholes of the Penza region (10 km of Penza town, west of Volga River); (4) Barremian-Turonian section to the north of Uljanovsk city; (5) Cenomanian-Maastrichtian sections near Shilovka settlement (50 km south of Uljanovsk city).

MAIN LITHOFACIES AND STRATIGRAPHY OF THE KIMMERIDGIAN

The lower Kimmeridgian is represented by organic shale (Fig. 5, borehole 18) with clay (Fig. 5, boreholes 15-17, 19, 20, 22, 23, 25-27), glauconitic sandstone, aleurolite (almost equivalent to silt-stone in Russian literature) and clay (Fig. 5, boreholes 24, 28), and micrite in the outcrops of the Ukhta section. Rare phosphatic pebbles and pyritic concretions were also found.

The time interval investigated corresponds to the early Kimmeridgian in terms of standard ammonite zonation for the Boreal Realm of the Russian Plate. Within the Barents-Pechora area, the *Amoeboceras ravni* zone and in the Volga-Kama-Oka Basin, the *A. kitchini* zone are present. Other characteristic ammonites are *Rasenia trimera* Oppel and *R. stephanoides* Oppel.

Kimmeridgian strata, which yielded radiolarians (Kozlova 1994; Vishnevskaya 1997), are well represented in the Timan-Pechora Basin. The Pechora-Volga sedimentary basin was probably produced by a Late Jurassic phase of rifting (Kostiuchenko 1993), and was filled with radiolarian-bearing clay and shale deposits in a subplatform environment.

The Kimmeridgian clay of Pechora and Ukhta regions is also rich in glauconite and montmorillonite. Glauconite (15-30%), montmorillonite (10-30%), hydromica (10-30%) and chlorite (5-10%) are the dominant components in Kimmeridgian bituminous clay whereas glauco-

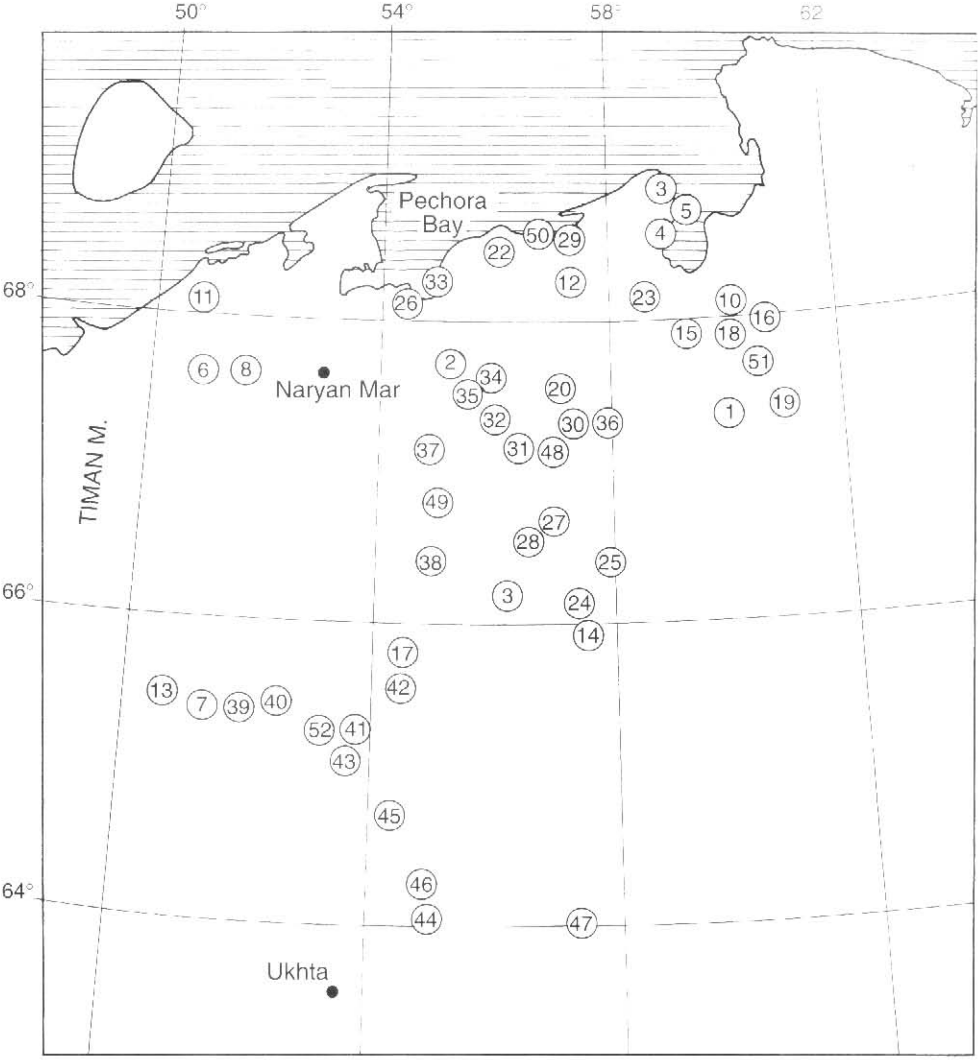

FIG. 1. — The location of investigated boreholes and outcrops of Timan-Pechora Basin (the numbers correspond to their official record).

nite (30-40%), kaolinite (25-30%), and montmorillonite (20-30%) predominate in the organic-rich Volgian shale.

The Kimmeridgian clay (5-45 m) from the Pechora and Ukhta regions has a conformable stratigraphic contact with the underlying strata (Fig. 5) and demonstrates a succession of transgressive and regressive characters up to Volgian strata.

Radiolarian taxa make up only a minor part of the total fauna. Practically all taxa present are known in the Boreal province of the Russian Platform and Circum-Pacific Rim. The lower Kimmeridgian radiolarian assemblage of the *Parvicingula vera* zone of the Barents-Pechora-Ukhta region includes: *Archaeocenosphaera inequalis* (Rust), *Praeconocaryomma* ex gr. *sphaeroconus* (Rust), *Pseudocrucella* aff. *prava* Blome, *Crucella crassa* (Kozlova), *C. squama* (Kozlova), *C.* aff. *mexicana* Yang, *Orbiculiforma* cf. *iniqua*

— The location of investigated sections of Volga Basin and stratigraphic column of the Volgian stage of the Gorodische

Blome, *O.*? *retusa* (Kozlova), *Pantanellium tierrablankaense* Pessagno & McLead, *Parvicingula inornata* Blome, *P.* cf. *blowi* Pessagno, *P. haeckeli* (Pantanelli), *P. burnensis* Pessagno & Whalen, *P. pizhmica* Kozlova, *P. pusilla* Kozlova, *P. papulata* Kozlova, *P. santabarbarensis* Pessagno, *P.*? *enormis* Yang, *P.*? *blackhornensis* Pessagno & Whalen, *Excingula*? *bifaria* Kozlova.

The lower Kimmeridgian *Parvicingula vera* zone of the Barents-Timan-Pechora Basin (Vishnevskaya & De Wever 1996) is probably equivalent to the lower Kimmeridgian *Crucella crassa* assemblage of Kozlova (1994) and correlates with the *Buchia concentrica* zone, *A. ravni* ammonite zone and *Epistomina unzhensis* foraminiferal zone as well. This interval probably corresponds to the Kimmeridge Clay Hydrocarbon Formation of the North Sea which contains abundant *P. jonesi* (Dyer & Copestake 1989).

A study of *Parvicingula* distribution shows a predominance of this genus in the Kimmeridgian of the Timan-Pechora and Barents regions. Species of this genus are represented by a wide range of morphotypes. The co-occurrence of Arcto-Boreal foraminiferal assemblages together with Jurassic radiolarians and *Buchias* confirms the possibility of using *Parvicingula* as palaeoclimatic indicator (Vishnevskaya 1996). For example, the main Kimmeridgian representatives of the Moscow region are *Parvicingula vera* Pessagno & Whalen, *P. inornata* Blome, *P. elegans* Pessagno & Whalen. Parvicingulides prevail, comprising 50% of this assemblage and in the middle Volgian of the Moscow Basin, are represented by *P. haeckeli* (Pantanelli), *P. hexagonata* (Heitzer) (Bragin 1997).

In the Gorodische Section (Volga Basin) *Parvicingula jonesi* (Pessagno) is the dominant species in the Kimmeridgian and the percentage of parvicingulides in the total radiolarian fauna reaches 50-60%.

Radiolarian-bearing organic black shale and bituminous clay which were deposited in anoxic environments are assigned to the lower Kimmeridgian (*Cymodoce* zone). This interval exhibits black shale layers with a high TOC (more 10%) content and good petroleum potential (Baudin *et al.* 1996). Ammonite horizons containing *P. densicostata* and *P. baylei* can be recognised in the lowermost part of Kimmeridgian of the Gorodische Standard Section (*Baylei* zone of the Standard Scale

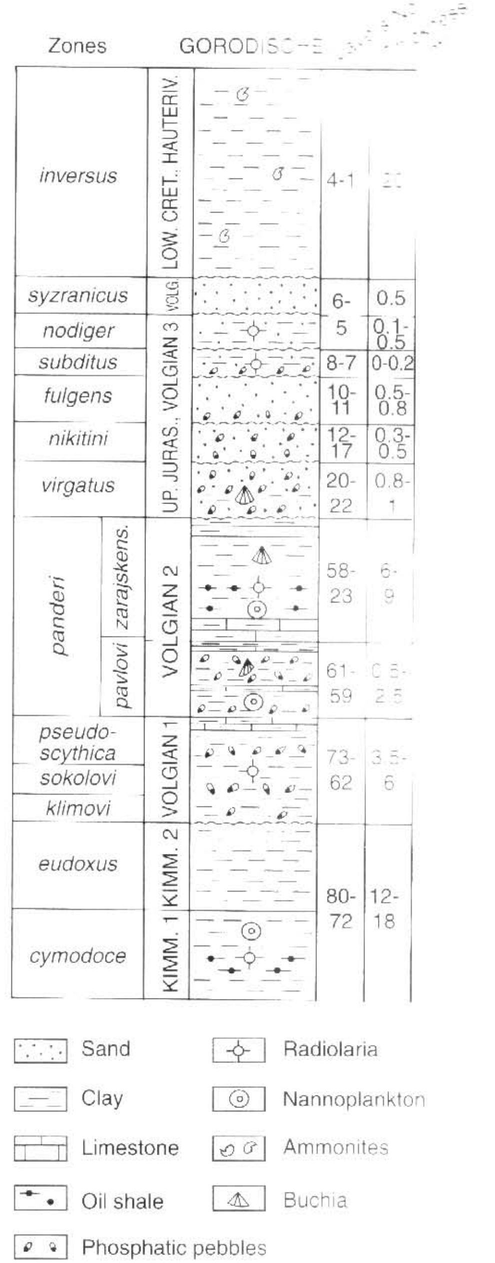

FIG. 3. — Composite column of the Kimmeridgian-Hauterivian stages of the Gorodische Section

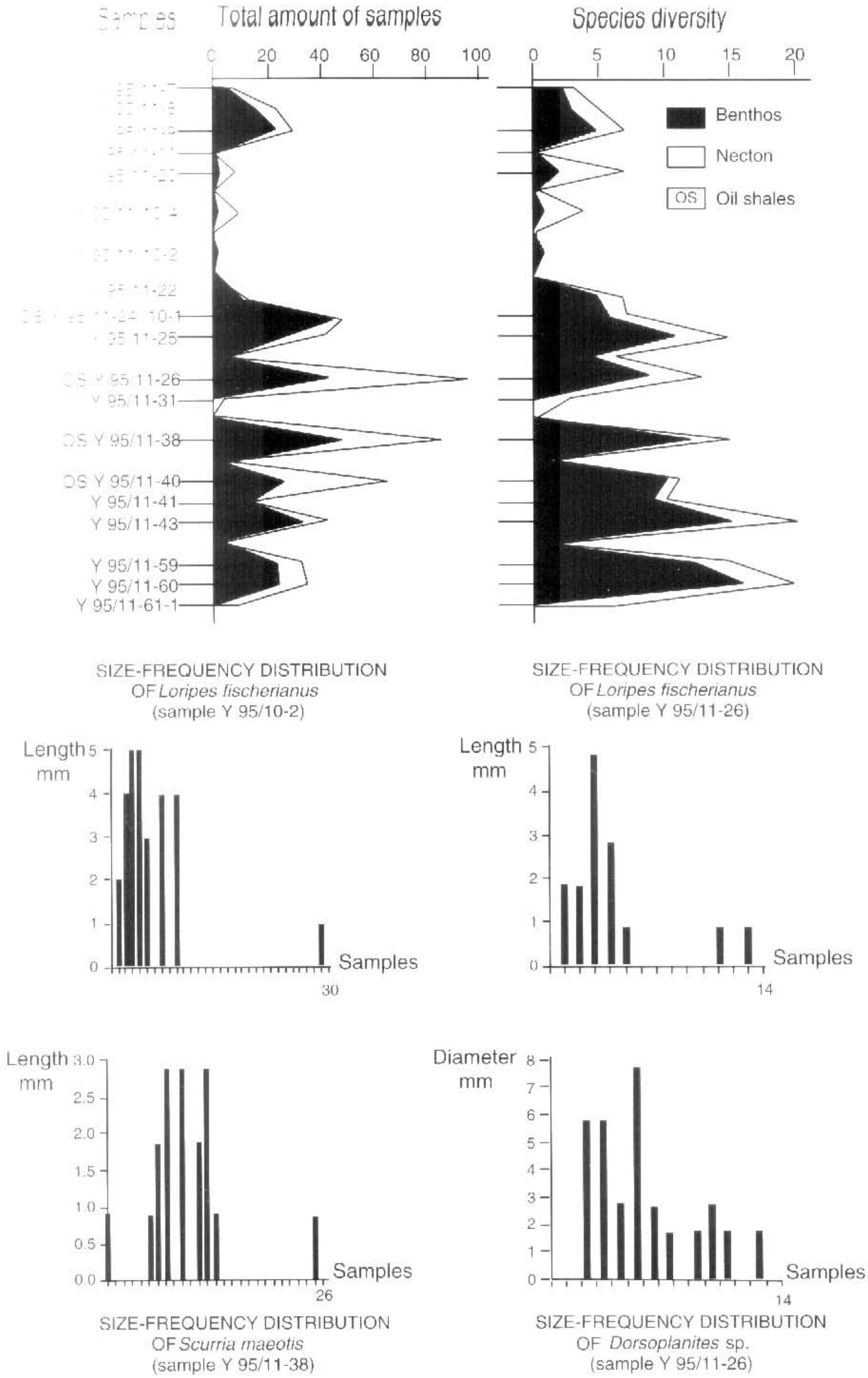

FIG. 4. — The distribution of sampling and percentages of macrofauna in the Gorodische Section.

The upper Kimmeridgian (*Eudoxus-Autissiodorensis* ammonite zones) sequences of the Gorodische Section are represented by clay marl with abundant nannofossils. *Tergestiella margereli*, *Watznaueria communis* and *W. britannica* are the dominant species. The characteristic species are *Stephanolithion bigoti*, *Discorhabdus tubus*, *Podorhabdus cylindratus*, *P. decussatus*, *P. cuvillieri*, as well as the smallest individuals of *Nannoconus steinmanni* (= *N. colomi*). This nannoplankton assemblage is similar to the NW European *Vekshinella stradneri* assemblage of Bernard & Hay (1974). A more precise Kimmeridgian radiolarian zonation may be developed in the near future.

The North Caucasus Kimmeridgian-Tithonian assemblages include only rare *P. dhimenaensis* (Baumgartner) and Berriassian assemblages include *P. boesii* (Parona) (Vishnevskaya *et al.* 1990). The content of parvicingulides is less than 5% of the total assemblage in the Tethyan Realm.

VOLGIAN BIOSTRATIGRAPHY OF THE PECHORA BASIN AND GORODISCHE STANDARD SECTION

Volgian strata have a transgressive character in the Pechora region (Fig. 5). Among radiolarians which occur within the middle Volgian *Dorsoplanites panderi* ammonite zone, *Parvicingula papulata* Kozlova, *P. conica* (Khabakov), *P. cristata* Kozlova, *P. rugosa* Kozlova, *P. simplicim* Kozlova are the dominant species. Parvicingulides again comprise up to 90% of faunas in the Barents-Pechora region. Ammonites, buchias and foraminifera are also abundant in these strata.

The Gorodische Standard Section is the section which has been most completely processed for macro- and microfauna (Figs 2-4).

Studies of the macrofaunal assemblage from the Gorodische Section show (cf. Mitta 1993), that strata in the section can be confidently assigned to two ammonite subzones of the (middle Volgian) *Dorsoplanites panderi* zone: The *Pavlovia pavlovi* bottom subzone and *Zaraiskites zarajskensis* top subzone, which were established by Gerasimov & Michailov (1966).

The *pavlovi* subzone (layers 61-59) is characterised by clayey-carbonate succession [illegible] phosphorite and marcasite horizons (Fig. 3). Several erosional surfaces are recognised in the subzone. Other ammonites include *Zaraiskites* sp., *Z.* cf. *tschernyschovi*, *Z.* cf. *michalskii*, *Dorsoplanites* aff. *panderi*, *D.* sp., *Pavlovia* sp., numerous rostrums of *Lagonibelus* (*L.*) *parvula* together with a benthic faunal assemblage of the bivalves *Loripes fischerianus*, *Buchia russiensis*, *Oxytoma* sp., *Protocardia concinna*, *Gresslya alduini*, gastropods *Eucyclus* sp., *Apporhais* sp., brachiopods *Lingula* sp., *Rusiella* sp., *Rhynchonella loxie*; scaphopods *Laevidentalium*, as well as serpulids. These assemblages permit us to characterise sedimentary conditions as weakly anoxic shallow water.

A somewhat richer fossil complex is present in the *zarajskensis* subzone (layers 58-23). The rocks of this subzone have rhythmical structure. Rhythms usually begin with horizons of reworked and dissolved fauna. They are overlain by carbonate clays topped with oil shale. The quantity of organic matter increases from 1-1.5% up to almost 22% at the background of decrease of carbonate matter (Fig. 3). Rhythmic changes in the benthic assemblage occur from a prevalence of benthos to an upsection increase of nekton (Fig. 4). In the oil shales young populations of lost *Loripes fischerianus* and *Scurria maeotis* usually prevail, together with nepionic ammonites. This demonstrates a strong anoxic impulse during the oil shale formation. The following faunal assemblage was determined from that interval: ammonites *Zaraiskites* cf. *scythicus*, *Z. pilicensis*, *Z. quenstedtii*, *Z. stchukinensis*, *Dorsoplanites panderi*; belemnites *Lagonibelus* (*L.*) *magnifica*, *L.* (*Holcobeloides*) *volgensis*, *L.* (*L.*) cf. *rosanovi*; bivalves *Astarte* sp., *Gresslya alduini*, *Buchia mosquensis*, *B. russiensis*, *Oxytoma* sp., *Loripes fischerianus*, *Nucula* sp., *Panopea* sp., *Limatula consobrina*, *Liostrea plastica*; gastropods *Scurria maeotis*, *Eucyclus* sp.; scaphopods *Laevidentalium* sp.; brachiopods *Lingula* sp., *Rhynchonella rouillieri* and other fauna.

The radiolarians *Orbiculiforma* ex gr. *mclaughlini* Pessagno, *Stichocapsa*? *devorata* (Rust), *Phormocampe favosa* Khudyaev, *Parvicingula hexagonata* (Heitzer), *P. cristata* Kozlova, *P. conica* (Khabakov), *P.* aff. *alata* Kozlova, *P. multipora*

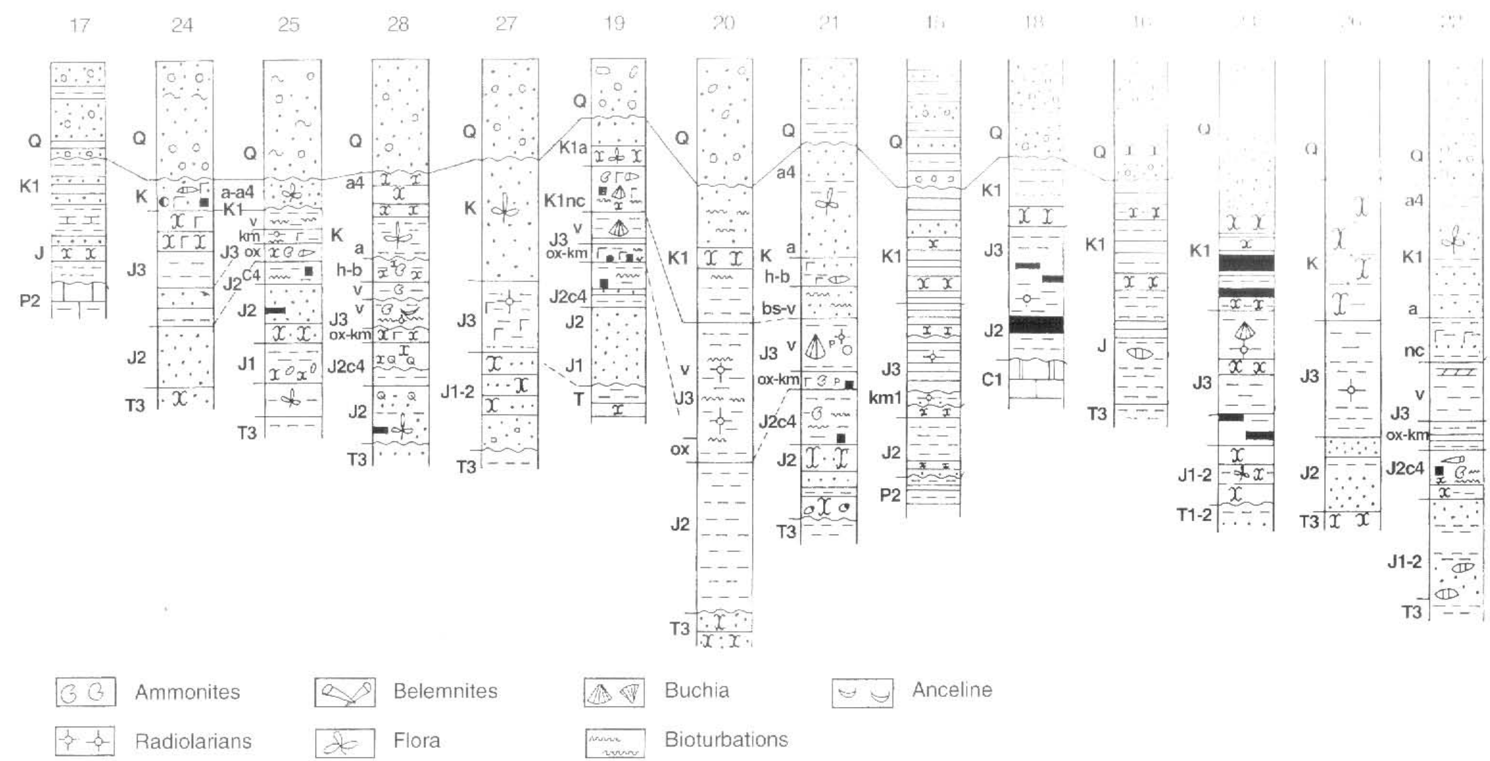

FIG. 5. — The distribution of Jurassic facies within the sections of the north-eastern part of the Russian Platform. For the location of boreholes see in Fig. 1. For legend of columns 1-14 see Vishnevskaya (1998), 29-52 see Vishnevskaya & Sedaeva (1999). **P**, Permian; **T**, Triassic; **J**, Jurassic; **K**, Cretaceous; **Q**, Tertiary; **a**, Aptian; **al**, Albian; **h-b**, Hauterivian-Barremian; **bs-v**, Berriassian-Valanginian; **nc**, Neocomian; **v**, Volgian; **ox-km**, Oxfordian-Kimmeridgian; **cl**, Callovian.

(Khudyaev), *P.* aff. *haeckeli* (Pantanelli), *P.* aff. *spinosa* (Grill & Kozur), *Plathycryphalus? pumilus* Rust, *Lithocampe* cf. *terniseriata* Rust were recovered from within the *Dorsoplanites panderi* ammonite zone in the *Z. zarajskensis* subzone – the uppermost part of nannofossil *Watznaueria communis* zone of the Gorodische Section, where dominant species of coccoliths are *W. martelae*, *W. strigosa*, *W. tubulata*, *W. ovata*.

Higher in the section (layers 22-20) thin members of quartz-glauconitic sands and sandstones build up the succession. They contain horizons with reworked phosphorites. Faunas are located predominantly in rewashed pebbles. In layer 20, remains of strongly reworked zonal index *Virgatites gerassimovi* were found together with *Loripes* sp. and dissolved rostrums of *Lagonibelus* (*H.*) *volgensis*. There are many radiolarians reworked from the *Z. zarajskensis* subzone within the phosphorite pebbles.

Ammonites from the succeeding *Virgatites virgatus* next zone were not discovered. However, on the basis of stratigraphic position in a detailed section, this zone most likely occurs between layers 18 and 20.

The uppermost part of section is comprises dense thin members of carbonate sandstones with huge ammonites *Epivirgatites bipliciformis* and *E. nikitini* (layers 17-12) from the middle Volgian *E. nikitini* zone.

Sandstones of the upper Volgian *Kachpurites fulgens* zone lie above an erosional surface. They contain *Craspedites nekrassovi*, *C.* sp. and *Kachpurites fulgens* associated with *Buchia piochii*, *B.* sp., belemnites *Acroteuthis* (*A.*) *russiensis* and *A.* (*A.*) *mosquensis*, which were found in layers 11 and 10.

Overlapping layers 7, 8 also lie above erosional surfaces erosion and are characterised by reworked *Craspedites* cf. *okensis*, which is the diagnostic form of the upper Volgian *Craspedites subditus* zone. The belemnites *Acroteuthis* (*A.*) *mosquensis* and bivalve *Buchia piochii* and *B. tenuicollis* occur together with these ammonites. Radiolarian species *P. cristata* Kozlova, *P. alata* Kozlova, *P. blowi* (Pessagno) and *Stichocapsa devorata* (Rust) are common within these strata in which the parvicingulid content is 50-60%.

No ammonite fauna was found in layers 6-5, but based on existing literature. Meanwhile, these strata can be correlated with the upper Volgian *Craspedites nodiger* zone and lower Valanginian *Temnoptychites syzranicus* zone. The uppermost part of Volgian stage is characterised by appearance, within the radiolarian microfauna, of the Mediterranean species *P. boesii* (Parona).

The appearance of this Mediterranean species taxon notwithstanding, radiolarian assemblages are dominantly Boreal in character and the types of radiolarian assemblages present have not been described previously. The proposed middle Volgian *Parvicingula haeckeli* zone is closely correlated to the *Parvicingula papulata* zone of the Pechora Region (Kozlova 1994). It correlates with the ammonite *Dorsoplanites panderi* zone which can, in turn, be correlated with the *Evolutinella emeljanzevi-Trachammina septentrionalis* or *Saracenaria pravoslavlevi* foraminiferal zone (Kozlova 1994) in the Pechora Basin, *Lenticulina biexcavata* zone (Ljurov 1995) in the Sysola hydrocarbon Basin, and *Parhabdolithus embergeri* nannoplankton zone in Middle Volga hydrocarbon Basin. We can trace last zone through both Southern England and North France (Vishnevskaya & De Wever 1996). Due to the presence of index species, it is possible to correlate this interval with buchias *Buchia mosquensis-B. russiensis* zone of the Russian Platform (Sey & Kalacheva 1993).

The proposed upper Volgian *Parvicingula blowi* zone probably corresponds to the *Pseudocrolanium planocephala* assemblage of the Pechora and North Siberia regions which was established by Kozlova (1994) and can be correlated with *Buchia piochii-B. terebratuloides* zone of the Russian Platform (Sey & Kalacheva 1993).

JURASSIC PALAEOGEOGRAPHY

The Jurassic stratigraphic sequences in the Timan-Pechora Basin (Fig. 5) clearly show a transgressive depositional system starting with Early-Middle Jurassic sands and deepening upward to the accumulation of the higher grade source rocks in the Volgian time. The mass extinction, observed here and especially in the Gorodische Section of the Volga-Urals Basin

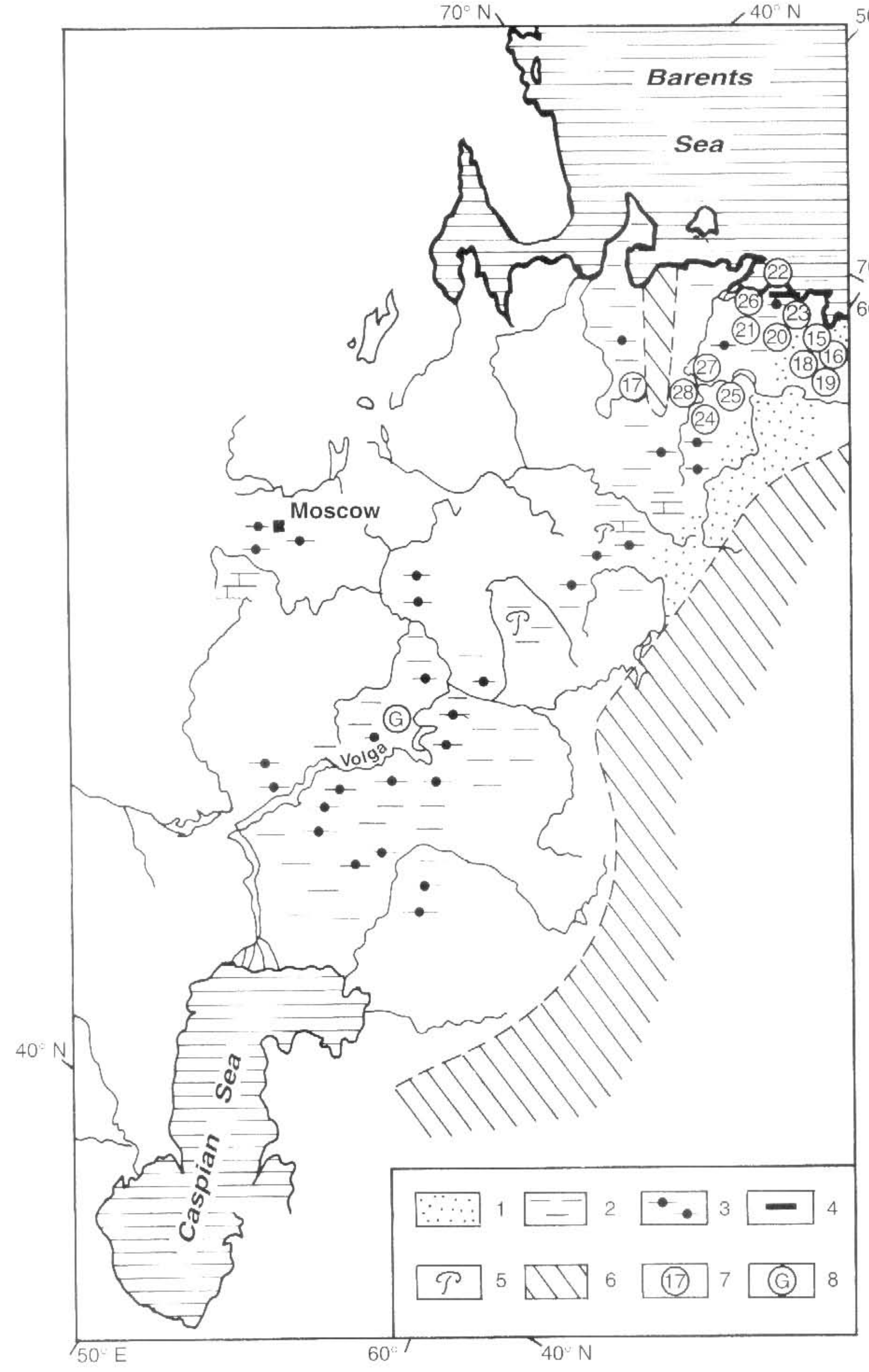

FIG. 6. — Schematic palaeofacies location map of the Kimmeridgian time (adopted after Sedaeva & Vishnevskaya 1995). **1**, coastal marine sandstone and siltstone; **2**, marine clay; **3**, anoxic organic shale; **4**, lignite coal and organic detritus; **5**, phosphate; **6**, supposed land; **7**, location of sections from Fig. 5 (number in circle); **8**, location of the Gorodische outcrops (letter in circle).

(only about 40 species of ammonites, 20 species of aucellids, 22 species of benthic foraminiferas and 20 species of planktonic foraminiferas, 10 species of belemnites, 5-40 calcareous nannofossil taxa, 20 species of radiolarians and several species of algae were recognised within *Dorsoplanites panderi* zone), probably resulted from the cumulative effects of a constant alternation of transgressive and regressive episodes. This type of sedimentation and palaeoenvironments survived into late Volgian time, but a change of conditions had already appeared by the end of Volgian time.

The proposed schematic palaeogeographic maps of the Kimmeridgian and Volgian time (Figs 7, 8) indicate the location of the eastern rim of shallow sea with excellent environments for oil and fuel-rich organic source rocks (Figs 5, 6). Similar to Recent seas and to an ancient sea, for example, the Devonian Sea (Vishnevskaya 1993), the maximum concentrations of phytoplankton, siliceous plankton and benthos, carbonaceous plankton, nekton and benthos were found in the water immediately bordering the continent. This type of relative increase in the proportion of lipid rich organic matter in the bottom sediments and its good preservation probably took place in response to the preservative character of phosphorus, the content of which is very high in these strata (Baudin *et al.* 1996).

It is well-known that in the Tethyan Realm the genus *Parvicingula* is rare whereas the content of this genus in the Boreal (Khydjaev 1931; Sedaeva & Vishnevskaya 1995) and Australian provinces (Baumgartner 1993) is much greater. From these data, we can assume that cold water environments dominated the north-eastern Russian Platform Jurassic oil-shale-bearing basin. The preponderance of parvicingulides possibly indicates upwelling conditions which have could existed offshore (Figs 6-8). The abundant remains of sponge spicules, which settled along the shelf edge confirm this conclusion.

JURASSIC BIOSTRATIGRAPHY AND PALAEOGEOGRAPHY

Detailed analysis of taxonomic variety of faunal assemblages and some morphological peculiarities of shells allow us to establish biostratigraphic correlations and to reconstruct the possible bathymetric and topographic features of sedimentary basins. One would notice that Jurassic radiolarian fauna was firstly found from the Gorodische Standard Section of the Volga Basin. It represents new data on the palaeontological characteristics of the Upper Jurassic Russian Regional Volgian Stage. The lower Kimmeridgian ammonite *Amoeboceras kitchini* (Salfeld) is typical of the Arctic (Northern Siberia, Subpolar Urals) and Boreal-Atlantic Provinces (European Russia). *Buchia* is a characteristic element of Arctic and Boreal realms. Foraminiferas are also typical of the Boreal-Atlantic Province. A typical feature of radiolarian assemblages (abundance and high taxonomic diversity of the genus *Parvicingula*) indicates Boreal affinity. The presence of the genus *Aspidoceras* in the Volga-Oka Basin, well-known in the Western Europe and Mediterranean Region, is the only indicator of possible Tethyan influence.

Some peculiarities were common for sediments of the Pechora and Volga basins:

1. Sedimentary lithologies and their thicknesses indicate uneven subsidence on the periphery of Russian Platform.

2. Alternation of deep-water and shallow-water sediments and numerous gaps indicate eustatic variations.

3. Geochemical data exhibit enrichment in organic matter.

New siliceous microfossil radiolarian assemblages have been obtained from the Volgian as dated by ammonites and calcareous nannofossils.

The co-occurrence of radiolarians with calcareous nannofossils represents the first well-dated radiolarian assemblage of this age at such a high latitude on the Russian Platform.

As might be expected many new radiolarian species of the Boreal Province are encountered.

LOWER CRETACEOUS STRATIGRAPHY OF ULJANOVSK-PENZA REGION

Berriasian strata are probably reworked in the Gorodische Section, although they were marked

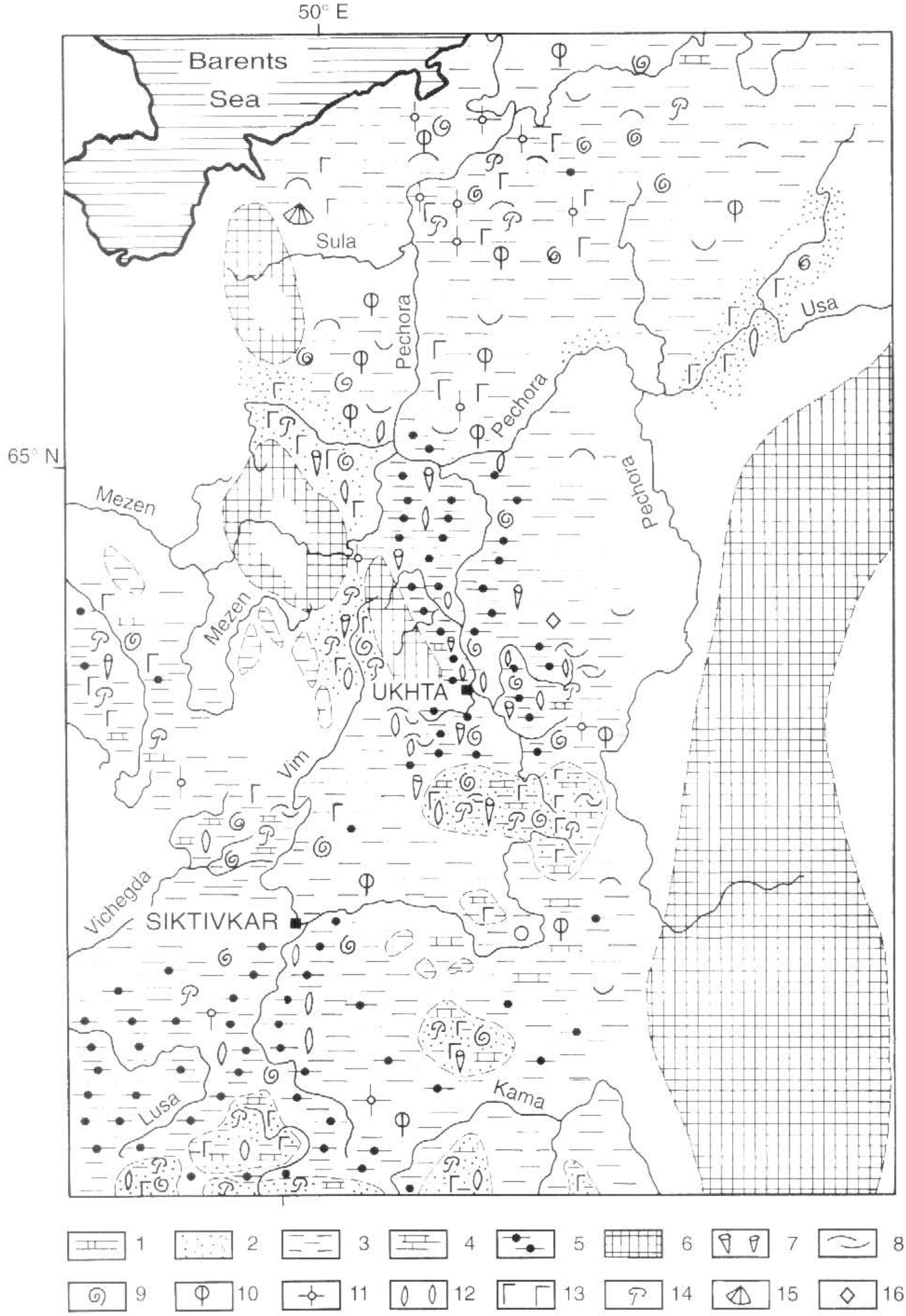

FIG. 7. — A detail palaeogeographic map of the Volgian time. **1**, marl; **2**, sand; **3**, clay; **4**, limestone; **5**, oil shale; **6**, land; **7**, sponge; **8**, aucelline; **9**, ammonite; **10**, foraminifera; **11**, radiolaria; **12**, bivalve; **13**, glauconite; **14**, phosphate; **15**, buchia; **16**, gypsum.

(?mapped) according to Mesezhnikov (1984). From our point of view, the presence of Berriasian deposits here is improbable because the section is strongly condensed. Most probably, Berriasian ammonites which are present in these strata were reworked into the base of Valanginian.

The section is terminated by black clays (layers 4-1) with siderite and limonite concretions, containing large weathered ammonites *Speetoniceras* (*S.*) *versicolor* and *S.* (*S.*) *subinversum*, which are ascribed to the *Speetoniceras inversum* zone of the top Hauterivian.

An anoxic event occurred within the lower Aptian *Deshayesites deshayesi* zone. The remainder of the lower and middle Aptian is characterised by anaerobic conditions. A late Albian radiolarian assemblage was found amongst the Albian black clay of Uljanovsk Section. It is represented by *Orbiculiforma multangula* Pessagno, *Theocampe cylindrica* Smirnova & Aliev, *Obeliscoites turris* (Squinabol).

The Barremian-Albian intervals were also investigated in two (7, 10) boreholes in the Penza area. At a depth of 89 m in borehole 10, the radiolarians *Orbiculiforma maxima* Pessagno, *Distylocapsa micropora* (Squinabol), similar to late Albian Tethyan forms (O' Dogherty 1995); *Dictyomitra communis* (Squinabol) and *Obesacapsula* sp. cf. *O. zamoraensis* Pessagno were recovered. At a depth of 105.5 m in the same borehole, typical late Albian radiolarian species *Porodiscus kavilkinensis* Aliev, *Archaeodictyomitra simplex* Pessagno, *Dictyomitra gracilis* (Squinabol), *Dictyomitra ferosia angusta* Smirnova, *Theocampe cylindrica* Smirnova & Aliev were recognised. At a depth of 106.8 m within borehole 10, the radiolarian fauna is characterised by Spumellaria only.

Within borehole 7, at a depth of 113.3 m, radiolarians *Orbiculiforma nevadaensis* Pessagno, *Obeliscoites perspicuus* Squinabol, *O.* cf. *vinassai* (Squinabol), *Xitus antelopensis* Pessagno, *X.*? *asymbatos* Foreman, which are characteristic species of the Albian to early Cenomanian, were found. At a depth of 120 m (borehole 7) radiolarians are represented by the species *Orbiculiforma nevadaensis* Pessagno and typical late Albian *Theocampe cylindrica* Smirnova & Aliev, *T. simplex* Smirnova & Aliev.

Between 123.45 and 123.50 m, the radiolarians *Porodiscus inflatus* Smirnova & Aliev, *Obeliscoites turris* (Squinabol) are present.

At a depth of 133.15 to 133.25 m the radiolarians *Dictyomitra ferosia angusta* Smirnova and *Stichomitra communis* Squinabol were recovered.

Within the interval 129.75 to 129.90 m, Albian species *Crolanium cuneatum* (Smirnova & Aliev), *C. triquetrum* Pessagno, *Porodiscus inflatus* Smirnova & Aliev were met.

At a depth of 136 m, the only species recovered was *Orbiculiforma multangula* Pessagno occurred.

From the above data we consider that the Aptian-Albian *Crolanium cuneatum* zone can be recognised in the Uljanovsk-Penza Region.

UPPER CRETACEOUS BIOSTRATIGRAPHY OF VOLGA BASIN

Upper Cretaceous radiolarians were studied from the Shilovka Section in the Uljanovsk Region and from core sections of boreholes (28, 502) from the Volgograd Region. Three radiolarian assemblages were determined: *Archaeospongoprunum bipartitum-Alievium superbum* (Turonian-Coniacian), *Pseudoaulophacus floresensis-Euchitonia santonica* (late Coniacian-Santonian or Santonian) and *Amphipyndax tylotus-Patellula planoconvexa* (late Campanian). Age data were supported by foraminiferal and nannoplankton assemblages, which have affinity with European ones. These assemblages are similar to Western Siberian Boreal associations, but include some Tethyan taxa.

The early Santonian *Euchitonia santonica-Alievium praegallowayi* zone was established by Vishnevskaya (1997). It is a characteristic Boreal zone and is widespread both in Siberian, Russian platforms and in the Pre-Caucasus. Within the Shilovka Section, it corresponds to the foraminiferal *Gavelinella infrasantonica* zone or nannoplankton *Marthasterites furcatus* zone. The late Santonian-early Campanian foraminiferal *Gavelinella stelligera* zone can be correlated with the *Orbiculiforma quadrata-Lithostrobus rostovzevi* zone. The upper part of this zone may be calibrated with the nannoplankton *Arkhangelskiella specillata* zone in the Shilovka and Tushna sec-

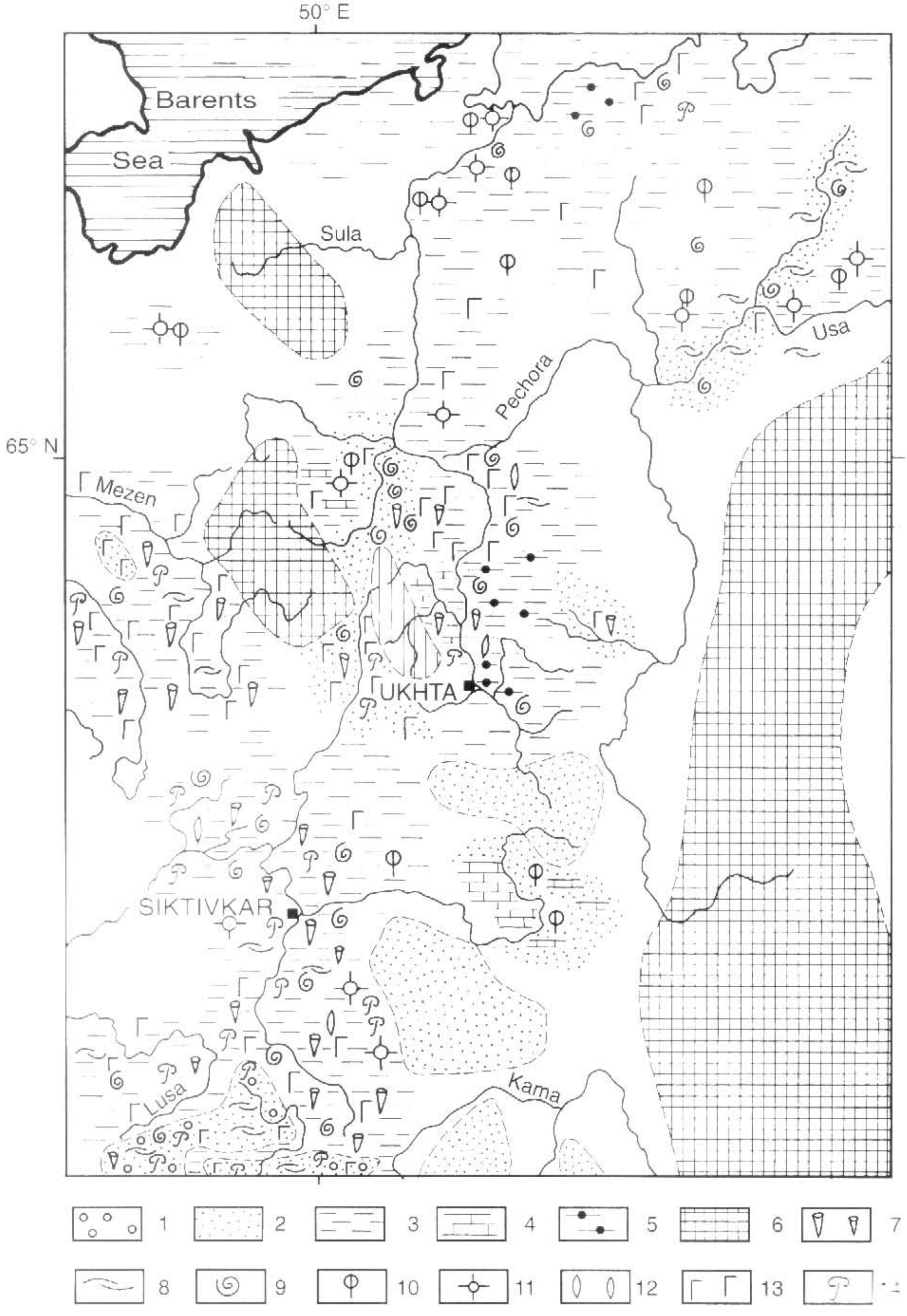

FIG. 8. — A detail palaeogeographical map of Kimmeridgian time. Legend: see on [illegible]

tions. Campanian *Prunobrachium articulatum* zone (Lipman 1952) or *Amphibrachium sibericum* zone and *Spongoprunum angustum* zones (Amon & De Wever 1994) have no analogues in the Tethyan Region. Nevertheless, the Tethyan species *Afens liriodes* Riedel & Sanfilippo was found in the interval of this zone within the Shilovka Section.

CONCLUSION

The proposed biostratigraphic subdivisions based on new palaeontological data are clearly definable. They have a proven wide geographic distribution and can be useful for correlation of sedimentary sequences as well as biotic and abiotic events.

The direct correlation of Peri-Tethyan radiolarian zonations with oceanic ones and those of the Tethyan region is very difficult owing to provinciality of species. Only one Jurassic zone, the upper Volgian-lower Berriasian *Parvicingula blowi* zone, can probably be compared with zonations of Baumgartner (1993) for the Argo Basin. The upper Berriasian-lower Valanginian *Parvicingula khabakovi-Williriedellum salumicum* zone (Vishnevskaya 1996), which is widespread in the Russian and Siberian platforms within the ammonite *Bojarkia mesezhnikovi* zone, can be compare with some Tethyan ones owing to the presence of numerous *Parvicingula boesii*.

Biostratigraphic correlations of microfossils (radiolarians, foraminiferas and nannoplankton) and macrofossils (ammonites, buchias) is proposed in order to establish the synchronicity of events and consequently of more general geological processes.

Acknowledgements

We express our gratitude to Professor A. Nikishin and anonymous reviewers for their stimulating comments and criticism on the paper. We are grateful to J. Aitchison who helped us to improve the English. Special thanks are due to Peri-Tethys Programme (grants 9518 and 95-96/18) and Russian Foundation for Basic Research for financial support (Grant RFFI 97-05-65566) and to CNRS-ESA 7073.

REFERENCES

Amon E. & De Wever P. 1994. — Upper Cretaceous biostratigraphy of the borders of the Ural belts: Western Siberian and Eastern Volga-Ural Basins: 229-262, *in* Roure F. (ed.), *Peri-Tethyan Platforms*. Technip ed., Paris.

Baudin F., Hantzpergue P., Mitta V., Olferiev A. & Zakharov V. 1996. — Biostratigraphic correlations and black shale deposits of the Upper Jurassic from the Russian Platform. *Abstracts of Peri-Tethys Conference*, Amsterdam: 7, 8.

Baumgartner P. O. 1993. — Lower Cretaceous radiolarian biostratigraphy and biogeography of northwestern Australian (ODP sites 765 and 766 and DSDP site 261), Argo Abyssal Plain and lower Exmouth Plateau. *Proceedings of the ODP, Scientific Results*, Washington 123: 299-342.

Bernard T. & Hay W. 1974. — On Jurassic coccoliths; tentative zonation of the Jurassic of Southern England and North France. *Eclogae geologicea helveticae*, Basel 67 (3): 563-585.

Bragin N. Y. 1997. — Radiolaria from the phosphorites basal horizons of the Volgian Stage in the Moscow region. *Revue de Micropaléontologie*, Paris 40 (4) : 285-296.

Dyer R. & Copestake P. 1989. — A review of latest Jurassic to earliest Cretaceous Radiolaria and their biostratigraphic potential to petroleum exploration in the North Sea. *Northwest European Micropaleontology and Palynology*, London: 214-235.

Gerasimov P. A. & Mikhailov N. P. 1966. — Volgian Stage and the geostratigraphical scale for the Upper Series of the Jurassic System. *Proceeding of Academy of Sciences USSR*, ser. geol., Moscow, No. 2: 118-138 [in Russian].

Khudyaev J. 1931. — On the Radiolaria in phosphates in the region of the Syssola River. *Transactions of the Geological and Prospecting Service of U.S.S.R.*, Moscow, Fascicle 46: 1-48.

Kostiuchenko S. L. 1993. — The continental plate tectonic model of the Timan-Pechora province based on integrated deep geophysical study. *Zonenshain memorial Conference on Plate Tectonics*, GEOMAR, Kiel: 85, 86.

Kozlova G. E. 1994. — Mesozoic radiolarian assemblage of the Timan-Pechora oil field. *Proceeding of Sankt-Petersburg International Conference*, St-Petersburg: 60-75.

Lipman R. X. 1952. — Materials on monographic study of Upper Cretaceous radiolarians from Russian platform. *Paleontology and Stratigraphy*, Gosgeolisdat, Moscow: 24-51 [in Russian].

Ljurov S. B. 1994. — Division of Jurassic sequences of the Middle Vichegda. *Abstracts of International Symposium "Biostratigraphy of oil fields"*, December 1994, St-Petersburg: 59, 60.

Meseznikov M. S. 1984. — Excursion 060. Boundary beds of Jurassic and Cretaceous in the [illegible] and Riazanian region: 38-49, *in* [illegible] regions of European part of the [illegible] *summary guidebook of excursions 059,* [illegible] *XXVII International Geological Congress.* Nauka, Moscow.

Mitta V. V. 1993. — *Ammonites and zonal stratigraphy of the Middle Volgian of Central Russia.* Naukova Dumka, Kiev, 132 p. [in Russian].

O'Dogherty L. 1995. — Biochronology and paleontology of Mid-Cretaceous radiolarians from Northern Apennines (Italy) and Betic Cordillera (Spain). *Mémoires de Geologie*, Lausanne, n° 21, 415 p.

Sedaeva G. M. & Vishnevskaya V. S. 1995. — Jurassic paleoenvironments of the North-Eastern European platform. *Zonenshain Conference on Plate Tectonics*, GEOMAR, Kiel: 205.

Sey I. I. & Kalacheva E. D. 1993. — Buchiids and zonal stratigraphy of the Upper Jurassic deposits of the northern Far East of Russia. *Geologia and Geofizica*, Novosibirsk, 34 (8), 12 p. [in Russian].

Vishnevskaya V. S. 1993. — Model of sedimentary basin for the Domanik-type deposits: new version. *Zonenshain memorial Conference on Plate Tectonics*, GEOMAR, Kiel: 151-152.

— 1996. — Parvicingula as indicator of Jurassic to Early Cretaceous paleogeographical and sedimentological paleoenvironments within North Peri-Tethys. *Abstracts of Moscow Peri-Tethys Workshop*, Moscow: 30, 31.

— 1998. — The domanikoid facies of the Russian platform and basin paleogeography, *in* Crasquin-Soleau S. & Barrier E. (eds), Peri-Tethys memoir 3: Stratigraphy and evolution of Peri-Tethyan Platforms, *Mémoires du Muséum national d'Histoire naturelle*, Paris, 177 : 45-69.

Vishnevskaya V. S., Agarkov Yu. V., Zakariadze G. S. & Sedaeva K. M. 1990. — Late Jurassic-Cretaceous radiolarians of the Great Caucasus as key to determine age and paleoenvironment of the Lesser Caucasus ophiolites. *Reports of Russian Academy of Science*, Moscow 310 (6): 1417-1421.

Vishnevskaya V. S. & De Wever P. 1996. — About possibility to correlate North Peri-Tethyan radiolarian events with others zonations. *Abstracts of Moscow Peri-Tethys Workshop*, Moscow: 31, 32.

Vishnevskaya V. S. & Sedaeva K. M. 1999. — Reconstructions of sedimentary paleoenvironments of the north-eastern European platform and adjoining areas for some intervals of Jurassic: 94-98, *in Geology and mineral resources of European North-Eastern Russia: New results and new perspectives, Proceeding of XIII Geological Congress of Komi Respublica*. Volume 2. Geological Institute of Uralian Branch of Russian Academy of Sciences, Siktivkar.

Submitted for publication on 22 April 1997;
accepted on 30 June 1998.