Microbiostratigraphy of the Volgian Stage (Upper Jurassic), Volga River, USSR

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With 12 figures in the text and 3 appendices

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Abstract: Well-preserved calcareous and organic-walled microfossils are recorded from the proposed Volgian Stage lectostratotype at Gorodishche, near Ul'yanovsk, and from the Middle Volgian of a section at Kashpir, near Syzran, USSR. The biostratigraphical and regional significance of the microfauna and flora is discussed in relation to the classic Upper Jurassic sequence of southern England.

Zusammenfassung: Aus der vorgeschlagenen Lokalität des Lectostratotypus der Volgium-Stufe von Gorodishche bei Ul'yanovsk sowie aus dem Mittel-Volgium von Kashpir bei Syzran, UdSSR, werden gut erhaltene Mikrofossilien mit kalkiger und auch solche mit organischer Wand aufgeführt. Es wird die biostratigraphische und regionale Bedeutung jener Mikrofauna und -flora im Zusammenhang mit der klassischen Folge des südenglischen Ober-Jura diskutiert.

Introduction (ARL, PFR)

During an excursion to the Volga Basin of the USSR in 1977, one of us (PFR) collected a series of samples from the proposed lectostratotype of the Upper Jurassic Volgian Stage at Gorodishche and from a second site at Kashpir. The samples were small but very fossiliferous and the material well-preserved, the structural stability of the Russian Platform having helped to minimise diagenetic effects (ARKELL 1956: 491-2). We have investigated calcareous nannofosils, ostracods, foraminifera and palynomorphs, especially dinocysts, from the samples for purposes of comparison with assemblages from Upper Jurassic sites in Europe, particularly from the classic area of southern England.

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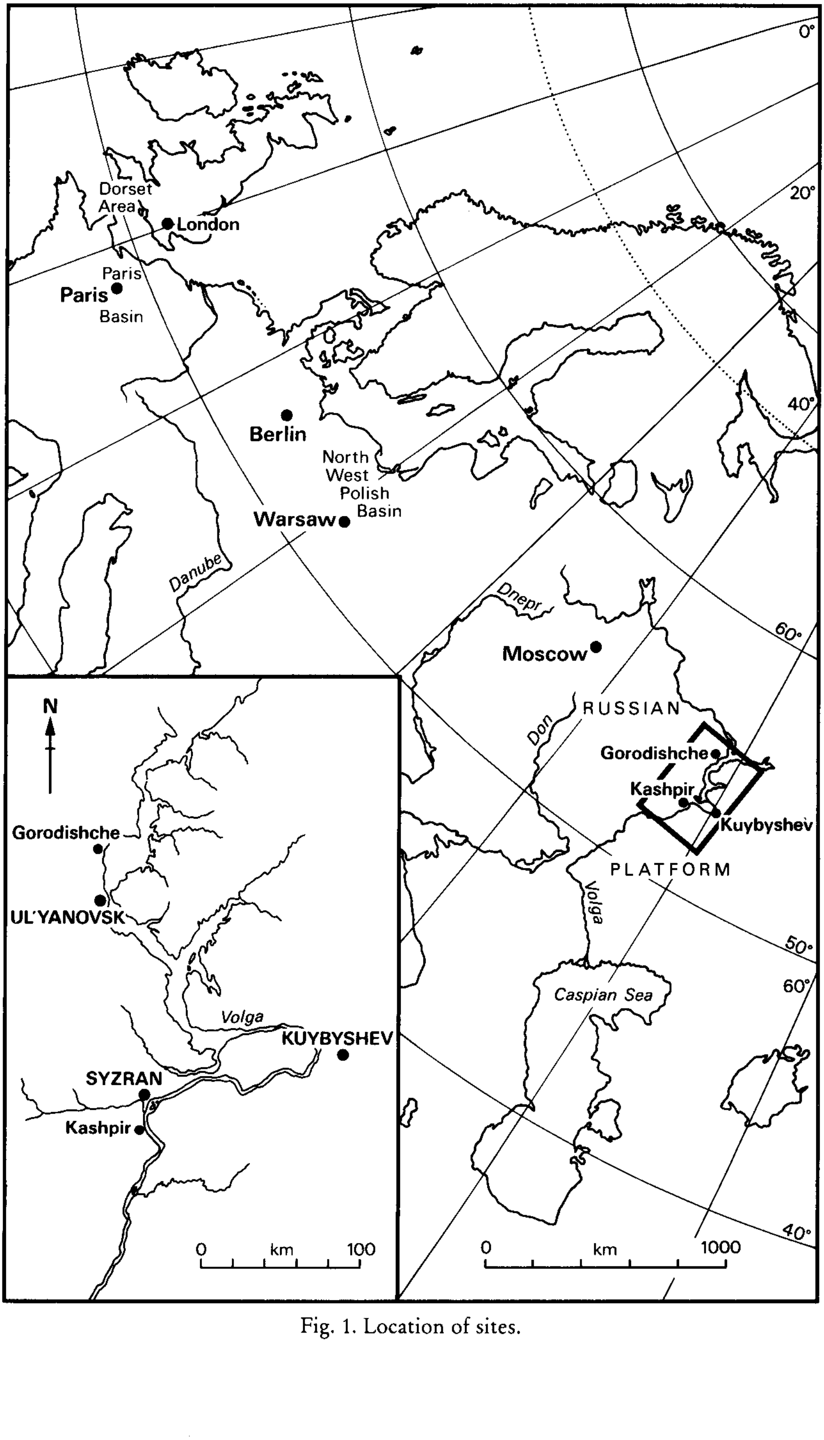

Fig. 1. Location of sites.

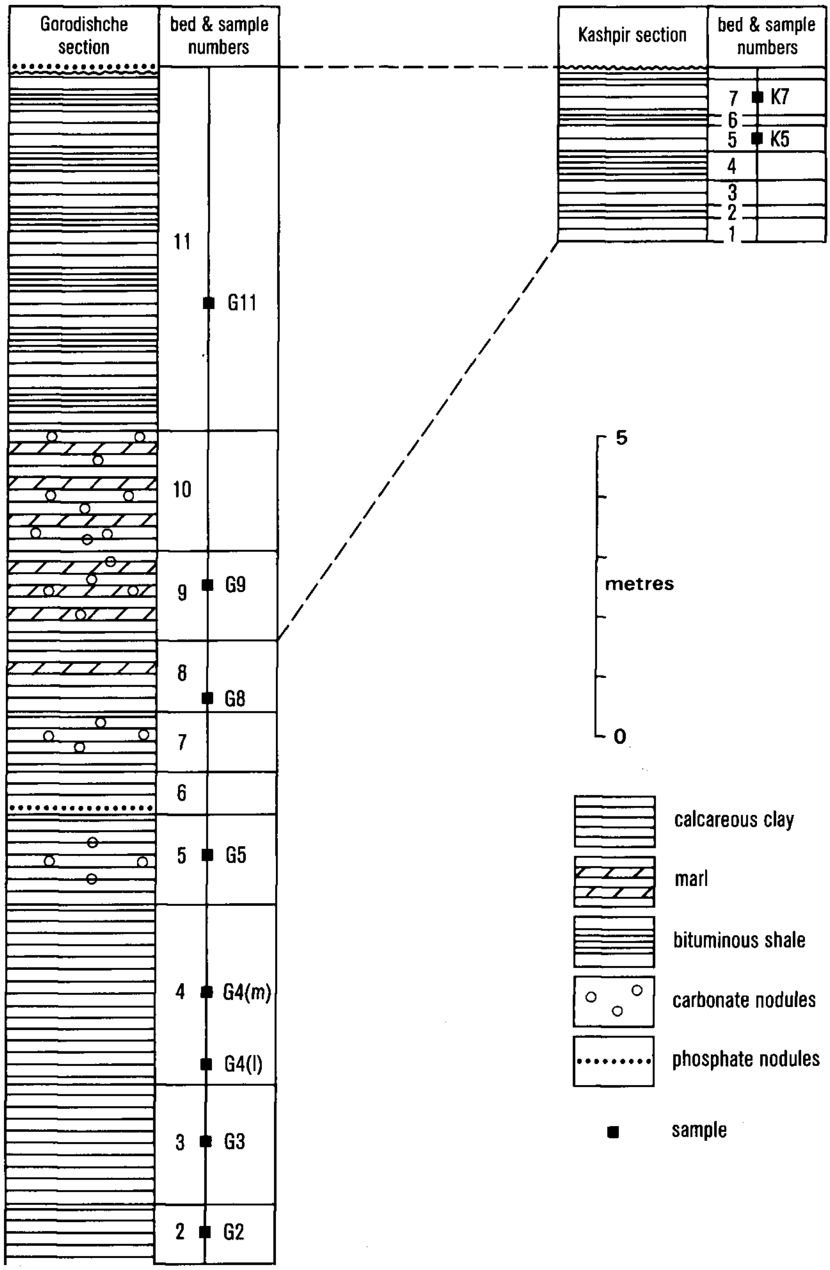

Fig. 2. The Gorodishche and Kashpir sequences (from MESEZHNIKOV [Ed.] 1977).

The Gorodishche section lies on the right bank of the Volga River, 25 km north of Ul'yanovsk (formerly Simbirsk) and 1 km south of Gorodishçhe village (Fig. 1). First described by MURCHISON (1845), it has been redescribed several times, most recently by MESEZHNIKOV (Ed.) (1977). The bed numbers and ammonite zones used here follow MESEZHNIKOV's guide, English language copies of which have been deposited in the libraries of the British Geological Survey and Geological Society of London. The sequence is summarised in Fig. 2 and correlation of the Volga zones with their English equivalents shown in Fig. 3. Samples were also collected from the Middle Volgian of Kashpir, near Syzran, about 165 km south of Gorodishche, which is the second most important site of the Volga region.

Stage terminology

In this paper the stage name Kimmeridgian is used in the English sense, as defined on the Dorset coast in southern England (see COPE et al. 1980: 76-80), and Russian usage of the name is, for reasons of clarity, given in inverted commas i.e. "Kimmeridgian". Similary, the term Volgian is used in a Russian sense, although the two stages overlap in time.

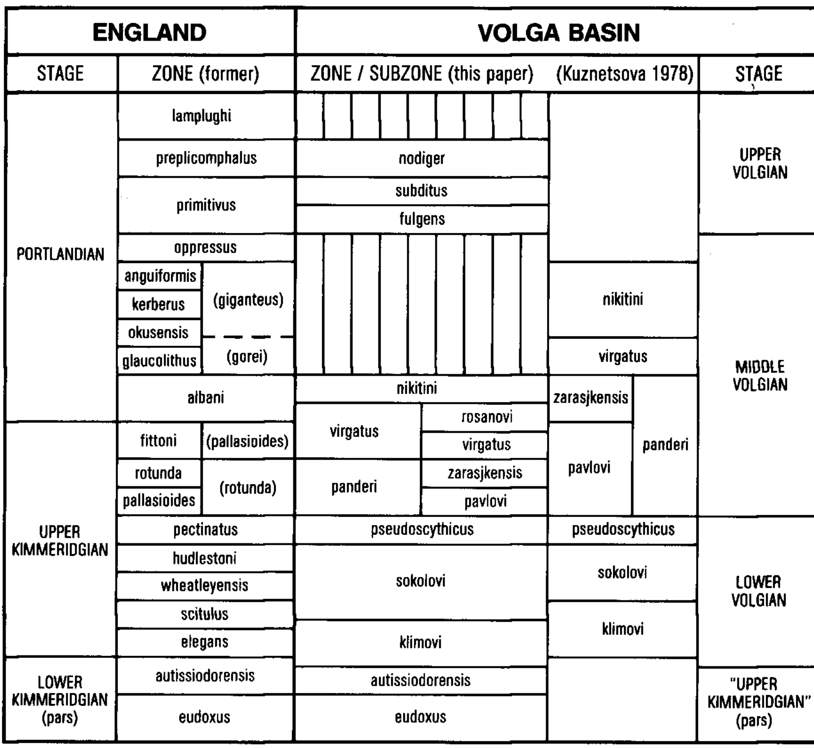

Fig. 3. Ammonite correlation between the Volga Basin and England.

The Volga Basin ammonite zones and their correlation with England (PFR)

The ammonite zones of the Volga region used in this paper follow MESEZHNIKOV (Ed.) (1977). The zones of the Volgian Stage are based on detailed monographic studies of the Dorsoplanitinae by MIKHAILOV (1966) and the Craspeditidae by GERASIMOV (1969). The ammonite sequence in the corresponding beds in England was imperfectly documented at that time but has since become better known. Hence views on correlation between the two areas differ considerably (Fig. 3); Soviet workers (e.g. KUZNETSOVA 1978) followed essentially the correlations of GERASIMOV et al. (1975, but written much earlier), while English workers were able to take advantage of new discoveries in eastern and southern England (CASEY 1967, 1973; COPE 1967, 1978; WIMBLEDON & COPE 1978; COX & GALLOIS 1981).

The Kimmeridgian zones of Aulacostephanus eudoxus and A. autissiodorensis are common to both areas, although the upper boundary of the latter zone appears to be drawn higher in England than in the Volga region. This is indicatd by COX & GALLOIS's (1981) evidence that in southern England *Gravesia* first appears in the upper half of the autissiodorensis Zone and extends to the base of the Pectinatites scitulus Zone. The genus is limited to the Subplanites klimovi Zone in the Volga region. The upper boundary of the klimovi Zone probably correlates with a level low in the scitulus Zone.

There is general agreement for equating the Volga Subplanites pseudoscythicus Zone with the English Pectinatites pectinatus Zone, although CALLOMON & BIRKELUND (1982) suggest that the pseudoscythicus faunas are reminiscent of the wheatleyensis Zone. Above this level correlations diverge rapidly (Fig. 3). The Volgian Palovia pavlovi Subzone is equated by Soviet workers with the whole of the English Pavlovia beds, while COPE (1978: 531) correlates it with the (revised) P. pallasioides Zone alone. The overlying Volgian subzone of Zaraskaites zarasjkensis was compared with the basal Portlandian Progalbanites albani Zone; the latter correlation follows ARKELL's (1956) view that *Zaraskaites* and *Progalbanites* are synonymous. CASEY (1967) disputed this and recorded from the albani Subzone the younger Volgian genus *Epivirgatites*; two Dorset specimens of *E. nikitini* have since been figured by COPE (1978: pl. 55, figs. 3, 31). Hence the nikitini Zone is at least the partial equivalent of the albani Zone. There is no firm evidence for the exact correlation of the intervening zarasjkensis Subzone and the Virgatites virgatus Zone with their English equivalents: the tentative correlation in Figure 3 follows COPE (1978: fig. 13).

Correlation of higher Volgian levels is beyond the scope of this paper as the youngest clay sample collected came from the zarasjkensis Subzone. However, the younger zones are shown on Figure 3 to indicate the considerable hiati that CASEY (1967, 1973) has recognised in the Volga Basin.

Calcareous nannofossils (MKEC)

Awareness of the potential of calcareous nannofossils for biostratigraphical and correlatory purposes has increased in recent years as a result of data from burgeoning industrial application. The greatest wealth of information relates to the Upper Cretaceous and Tertiary but knowledge of the middle part of the Mesozoic is now growing rapidly.

Diverse assemblages containing 41 species were recorded (see Fig. 4 and Appendix 1), in 8 samples from Gorodishche and 2 from Kashpir; a further sample from the Hauterivian of Gorodishche was barren. New taxa found in this work are described in COOPER (1987).

Gorodishche, Bed 2 [eudoxus Zone]. Nannoflora very similar to those from the eudoxus zone of Cambridgeshire (COOPER, in prep.) and of boreholes elsewhere in England (GALLOIS & MEDD 1979), with 22 out of 26 species common to both regions. Correlation between the eudoxus Zone (Lower Kimmeridgian) of England and the eudoxus Zone ("Upper Kimmeridgian") of Volga Basin is very good.

Gorodishche, Beds 3 and 4 (lower) [autissiodorensis Zone]. Nannoflora similar to that of Bed 2 (eudoxus Zone), however, this differs markedly from the autissiodorensis Zone assemblages of England where a marked reduction in number of species occurs (COOPER, in prep.). At Kimmeridge Bay, Dorset this phenomenon may be a preservational feature as most types of microfossils are rare between the autissiodorensis and hudlestoni Zones (KILENYI 1969, LLOYD 1959, SARJEANT 1962). 10 species only occur in both regions.

Gorodishche, Bed 4 (middle) [autissiodorensis Zone]. Assemblage differs from that of the lower part of Bed 4 in both diversity and abundance. *Ellipsagelosphaera* species are most abundant whereas others decrease eg. *Axopodorhabdus cylindratus, Biscutum ellipticum, Vekshinella dibrachiata* and *Retecapsa schizobrachiata* have local extinction points here.

Gorodishche, Bed 5 [klimovi Zone]. Nannofloral assemblage further reduced in diversity and abundance; last occurrence of *Podorhabdus grassei.*

Gorodishche, Bed 8 [pseudoscythicus Zone]. Closely comparable with assemblage of Bed 5, but commonly species are reduced in abundance. LAD of *Axopodorhabdus cylindratus.*

Gorodishche, Bed 9 [panderi Zone, pavlovi Subzone]. LAD of *Actinozygus fragilis.* Good correlation with pallasioides Zone of England, especially via FAD of *Stephanolithion atmetros.*

Gorodishche, Bed 11 [panderi Zone, zarasjkensis Subzone]. Nannoflora more abundant than in Bed 9. LAD of *Stephanolithion bigoti, S. helotatus, Stradnerlithus senarius, Str. tortuosus,* and *Ellipsagelosphaera reinhardti;* local disappearance of *Cyclagelosphaera margereli.*

Kashpir, Beds 5 and 7 [panderi Zone]. Minor differences between the assemblages of each bed and of Gorodishche Beds 9 and 11. The differences between the nannofossil assemblages of the Middle Volgian of Gorodishche and Kashpir suggest that the Kashpir samples are slightly younger, viz. LAD of *Diadorhombus horrelli* and *Stradnerlithus delftensis* at Kashpir, and occurrence of *A. fragilis, C. margereli, Str. senarius and Str. tortuosus* at Gorodishche only.

The "Upper Kimmeridgian" nannoflora of the Volga River sections is diverse and in the eudoxus Zone provides a good correlation with the eudoxus Zone of southern England. The boundary between the "Upper Kimmeridgian" and

SAMPLE	GORODISHCHE									KASHPIR	
	G2	G3	G4(l)	G4(m)	G5	G8	G9	G11		K5	K7
1 Ellipsagelosphaera keftalrempti gp.	◐	◐	◐	◐	◐	●	◐	◐		◐	◐
2 Ellipsagelosphaera britannica gp.	◐	◐	●	●	◐	◐	◐	◐		◐	○
Cyclagelosphaera margereli	◐	◐	◐	○	◐	◐	◐	•			
Zygodiscus erectus	○	○	○	•	•	•	○	○		○	○
Watznauria barnesae	○	○	○	○	○	○	○	○		○	○
Cyclagelosphaera tubulatum	○	○	○	•	○	•	○	○		○	•
Stephanolithion bigoti	○	○	○	•	o	•	•	o			
Parhabdolithus embergeri	○	○	◐	○	○	○	○	◐		○	○
Axopodorhabdus cylindratus	•	○	○	o	o	o					
Vekshinella dibrachiata	•	•	○	•							
Staurorhabdus quadriarcullus	•	•	○	•	•	o	o	○		○	○
Polypodorhabdus escaigi	•	•	•	•	•	o	o	•		•	•
Paractinozygus gorodishchensis	•	•	•	•	•	o	o	○		•	o
3 Ethmorhabdus gallicus gp.	•	•	•	•	•	o	•	•		•	o
Zygodiscus noelae	•	•	o	•	•	•	•	○		○	•
Hexapodrhabdus cuvillieri	•	•	o								
Podorhabdus grassei	•	•	•	···	o						
Biscutum dubia	•	•	○	•	•	•	•	○		◐	•
Stradnerlithus delftensis	•	o	o	···	···	···	o	•		•	
Chiastozygus leptostauros	o	o	•	···	···	···	···	•		···	•
Stradnerlithus comptus	o	o	•	···	···	o	···	○		•	o
Actinozygus fragilis	o	•	○	o	o	•	•				
Actinozygus geometricus	o	o	•	···	o	•	•	o		···	•
Retacapsa schizobrachiata	o	o	···	o							
Biscutum ellipticum	o	•	○	•	···	···	○	•		○	•
Tubirhabdus patulus	o										
Cretarhabdus conicus		•	•	•	•	•	o	○		•	•
Diadorhombus horrelli		o	···	···	···	···	···	···		o	
Stradnerlithus bifurcatus		o									
Stradnerlithus senarius		o	o	o	···	···	o	•			
Stephanolithion helotatus			•	•	•	•	o	•		o	
Stradnerlithus tortuosus			o	o	···	···	o	o			
Anfractus harrisonii			o								
Rotelapillus radians			o	···	···	···	···	o			
Stradnerlithus rombicus			o								
Stephanolithion atmetros							o	•		•	•

● very abundant – 10 in every field view ○ common – 1 in 10 field views o present – 1 in 1000 field views

◐ *abundant – 1 in every field view* • *rare – 1 in 100 field views* ··· *inferred*

Fig. 4. Stratigraphic distribution of calcareous nannofossils at Gorodishche and Kashpir.

Lower Volgian is marked by reduction in diversity and abundance, and the regional LAD of *Vekshinella dibrachiata* and *Retecapsa schizobrachiata.* The Lower Volgian contains essentially a transitional nannoflora from that of the "Upper Kimmeridgian" to that of the Middle Volgian. The boundary between the Lower and Middle Volgian is marked by the last occurrence of *Axopodorhabdus cylindratus.* A good correlation can be made between the base of the Middle Volgian (= base panderi Zone) and the base of the pallasioides Zone of England by the FAD of *S. atmetros.* Diversity in Lower and Middle Volgian material is lower than in "Upper Kimmeridgian" assemblages.

Of the 20 species present in the youngest sample from Kashpir 16 are also known in the Lower Cretaceous. The forms that disappear are *Ethmorhabdus gallicus, Paractinozygus gorodishchensis, Stephanolithion atmetros* and *Chiastozygus leptostauros*, however, the record is not fully known and *E. gallicus* has been reported from the Hauterivian of the NW African margin by WIND & ČEPEK (1979).

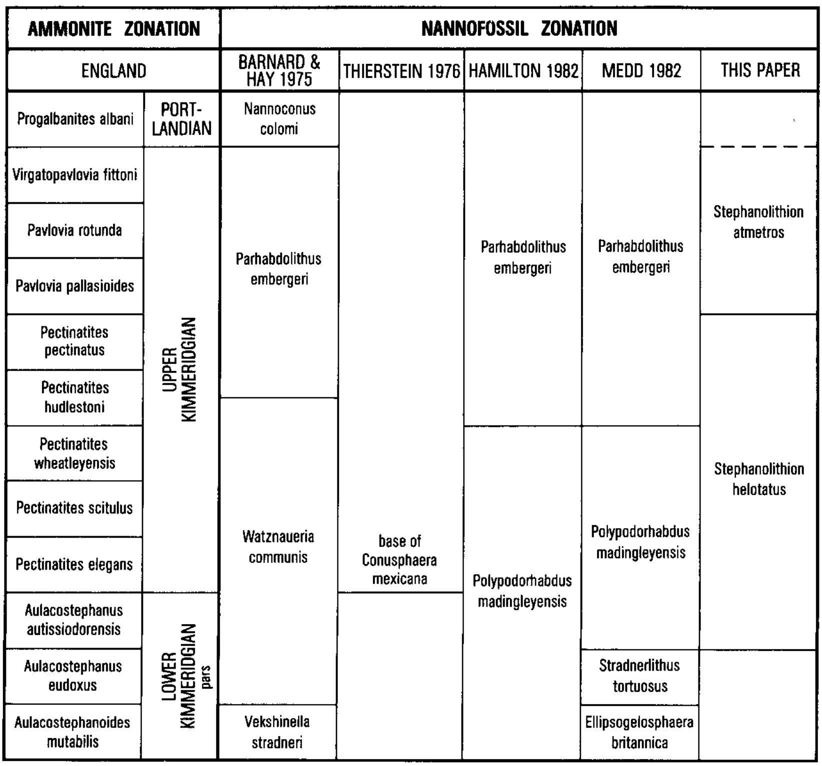

Fig. 5. Late Jurassic calcareous nannofossil zonation schemes.

The nannofossils of the Kimmeridge area and elsewhere in southern England have recently been studied in detail (COOPER, in prep.). Assemblages from the eudoxus Zone correlate well with those recorded here from the eudoxus Zone at Gorodishche, but from the autissiodorensis to hudlestoni Zones (upper Lower Kimmeridgian to mid Upper Kimmeridgian) poor nannofloras occur at Kimmeridge, probably as a result of dissolution during deposition and/or diagenesis. A good assemblage occurs again at the base of the hudlestoni Zone, containing 16 species also found at Gorodishche. There thus appears to be a reasonable correlation between the Lower Volgian and the lower part of the Upper Kimmeridgian of England. The nannoflora is sparse from the hudlestoni Zone to the base of the pallasioides Zone where a good nannoflora, including the FAD of *Stephanolithion atmetros*, allows an accurate correlation with the pavlovi Subzone, panderi Zone (= base Middle Volgian). In this interval the two areas have 10 species in common and both show the disappearance of *Cyclagelosphaera margereli* and extinction of *Ellipsagelosphaera reinhardti.* Assemblages from the fittoni Zone in Dorset differ from the Middle Volgian material in that *Ellipsagelosphaera* is rare or absent and *Staurorhabdus quadriarcullus* is the dominant form.

Relatively little work has been done on the nannofossils of the Upper Jurassic and their biostratigraphy. Several zonations have been proposed (BARNARD & HAY 1974, THIERSTEIN 1976, HAMILTON 1982, MEDD 1982 and ROTH, MEDD & WATKINS 1983) but there are limitations to each of these schemes (Fig. 5). Provincialism among nannofossils during the late Jurassic and early Cretaceous makes a single zonation difficult to apply. COOPER (1985) has, however, been able to characterise the Jurassic/Cretaceous boundary in Tethyan sequences and this level may be correlatable into the Boreal region. Difficulties remain to be resolved even within the Boreal area, for example, *A. geometricus, V. dibrachiata* and *Z. erectus* occur in the Volgian and continue into the Cretaceous but do not seem to appear in Britain (TAYLOR 1978) or France (THIERSTEIN 1973) until the Valanginian or Hauterivian. The latter 2 species are known to occur through the Tithonian and Berriasian at DSDP Site 534A off Florida (COOPER, in prep.).

Ostracoda (NGF)

The ostracod assemblages from the Volgian sections at Gorodishche and Kashpir reflect marine, open shelf conditions of moderate water depth and are dominated by species of *Galliaecytheridea;* other numerically abundant species include *Oligocythereis kostytschevkaensis, Cytherella fullonica, Cytherelloidea* aff. *C. tenuis* and *Mandelstamia ventrocornuta.*

The entire fauna, totalling 30 species of 16 genera, is broadly characteristic of other Upper Jurassic faunas of North-western Europe, and contains such typical genera as *Schuleridea, Macrodentina (Macrodentina), Procytheropteron, Eucytherura (Vesticytherura), Protocythere, Paranotacythere (Unicosta)* and rare specimens of *Bythoceratina (Praebythoceratina), Exopthalmocythere, Bythocythere* and *Paracypris*. The *Oligocythereis* species appears to be the latest recorded occurrence of this essentially Middle Jurassic genus, while the two species of *Protocythere* are early representatives of a genus that is more commonly recognised in Lower Cretaceous faunas.

As Fig. 8 illustrates, the preservation of the material is extremely good, valves are frequently unbroken and the clay lithology permits very clean preparations which allow such features as muscle scars and internal margins to be studied with greater confidence than is usual in material of this age.

The oldest assemblage studied, from Bed G2 of Gorodishche (Fig. 7) is dominated by *Galliaecytheridea monstrata*, a species not seen in subsequent, younger samples. Species diversity than steadily increases through the "Kimmeridgian" with a rapidly increasing number of *Galliaecytheridea* species and a steady presence of *Oligocythereis kostytschevkaensis, Mandelstamia ventrocornuta, Eucytherura (Vesticytherura) costaeirregularis* and *Procytheropteron prolongatum*.

Within the Lower and Middle Volgian beds the fauna undergoes a continued increase in diversity, and while *Galliaecytheridea* species remain numerically dominant *Cytherella fullonica* becomes established as a steady element in the assemblages. Other new species which make their first appearance within the Volgian do not show the same continuity and no species other than those already mentioned occurs in more than a single sample. In the Kashpir section, the more diverse Middle Volgian fauna can also be recognised with a significant number of specimens of *Cytherelloidea* aff. *C. tenuis*. Their presence, alongside *Cytherella fullonica*, seems to indicate the onset of slightly warmer conditions during the early Volgian, which may generally reflect inreasingly favourable conditions

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Fig. 6. Calcareous nannofossils. Scanning electron micrographs of Gorodishche material.

1: *Anfractus harrisonii* MEDD 1979. Distal view, × 10,600; UCL-1506-20. Sample G4(1), "Kimmeridgian".

2: *Cretarhabdus conicus* BRAMLETTE & MARTINI 1964. Distal view, × 7,275; UCL-1513-16. Sample G5, Lower Volgian.

3: *Actinozygus fragilis* ROOD & BARNARD 1972. Distal view, × 10,900; UCL-1499-4. Sample G4(1), "Kimmeridgian".

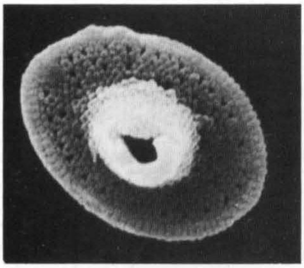
4: *Actinozygus geometricus* (GÓRKA 1957) ROOD, HAY & BARNARD 1971. Proximal view, × 11,250; UCL-1504-4. Sample G9, Middle Volgian.

5: *Stradnerlithus comptus* BLACK 1971. Distal view, × 11,550; UCL-1504-9. Sample G11, Middle Volgian.

6: *Stradnerlithus delftensis* (STRADNER & ADAMIKER 1966) BLACK 1971. Proximal view, × 14,250; UCL-1504-22. Sample G2, "Kimmeridgian".

7: *Stradnerlithus tortuosus* NOËL 1973. Proximal view, × 9,700; UCL-1506-16. Sample G4(1), "Kimmeridgian".

8: *Stradnerlithus senarius* (WISE & WIND 1977) GALLOIS & MEDD 1979. Distal view, × 11,250; UCL-1513-3. Sample G11, Middle Volgian.



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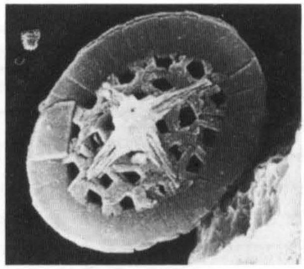

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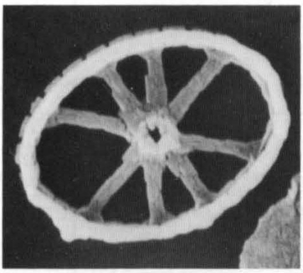

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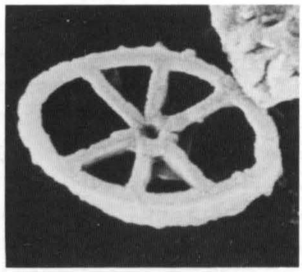

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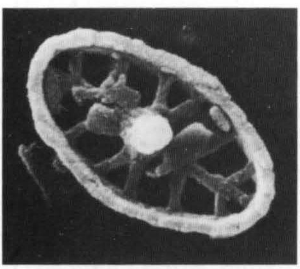

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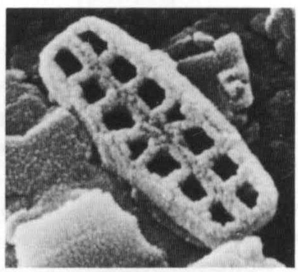

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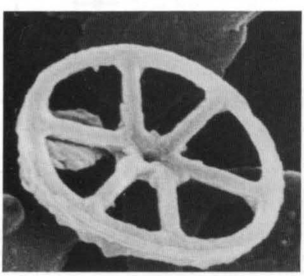

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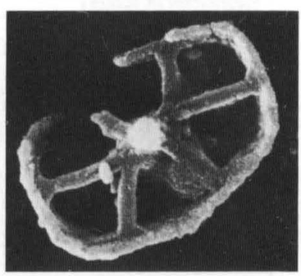

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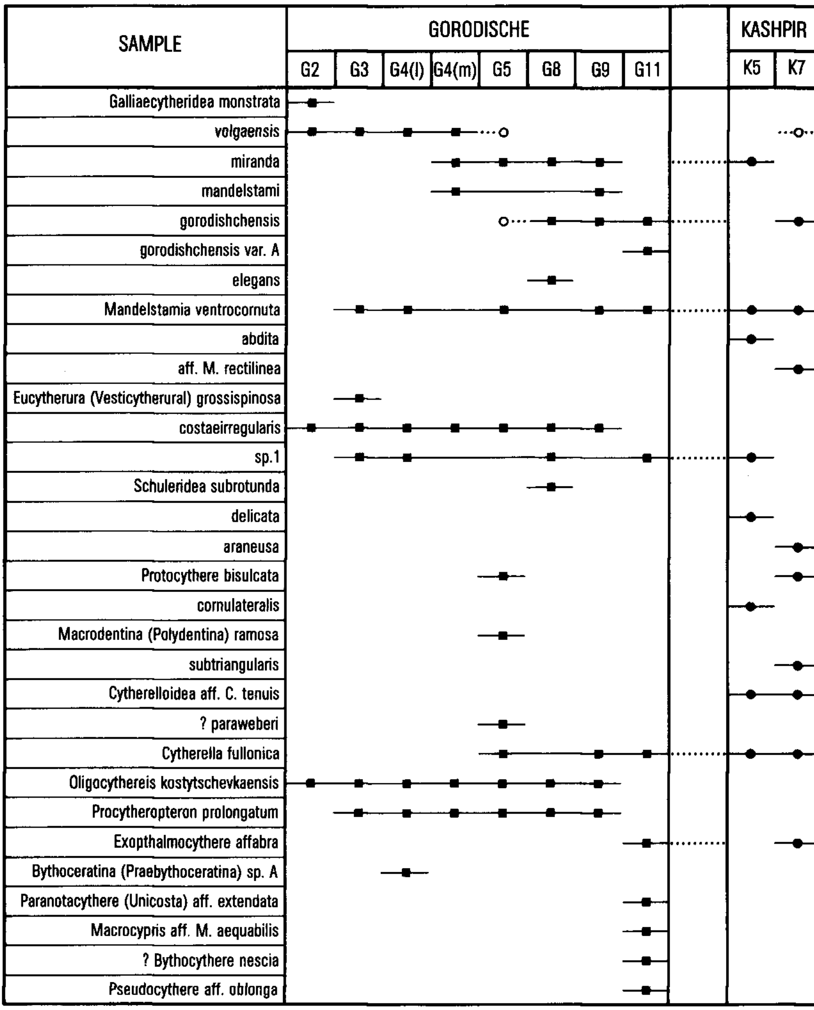


Fig. 7. Stratigraphic distribution of ostracods at Gorodishche and Kashpir.

producing the increase in species diversity and in turn reducing the dominance of the *Galliaecytheridea* species within the fauna.

In comparing the ostracods found at these two localities with those described from other regions of the USSR and areas further west, a broad similarity can be discerned at a generic level. All the genera are known in western Europe, whence most of them have been first described. Data from other localities within the USSR is sparse and difficult to obtain. Many of the identifications of material in this study are based on a publication on ostracods from the Gorodishche region produced in 1955 by LYUBIMOVA & KHABAROVA. MASUMOV (1973) published an account of ostracods from the Jurassic of Uzbekistan, but despite a similar fauna at a generic level none of the Gorodishche/Kashpir ostracods can be recognised with the single, dubious exception of *Schuleridea delicata* which MASUMOV identifies as ?*Procytheridea delicata*.

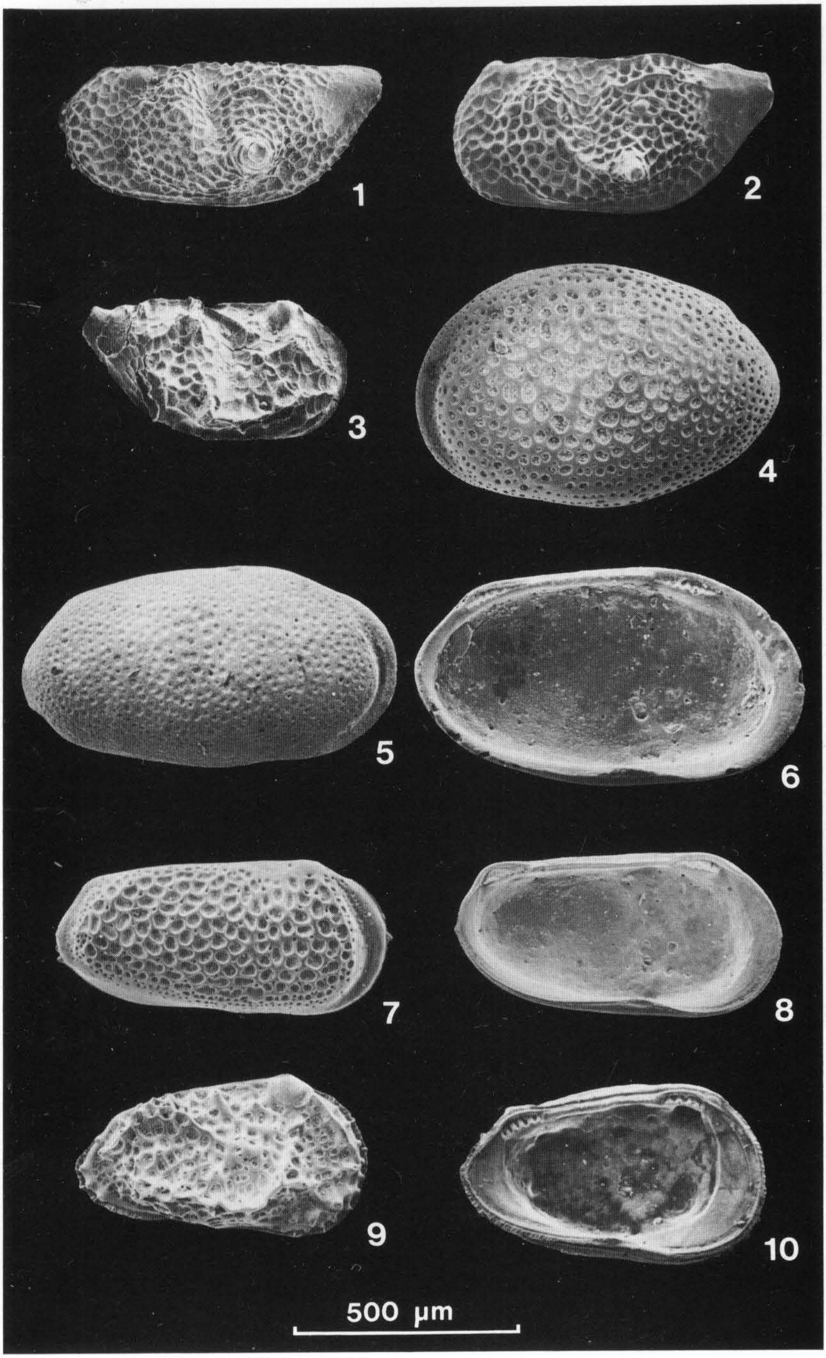
Recently KUBIATOWICZ (1983) published a paper on Upper Jurassic and Neocomian ostracods from central Poland. She recognised five of the species found in the current study: *Galliaecytheridea monstrata, G. volgaensis* and *G. mandelstami, Protocythere bisulcata,* and *Oligocythereis kostytschevkaensis* which she assigns to the genus *Pleurocythere*.

Looking further west, to Germany, Northern France and Britain, direct correlation can only be made with 3 species. *Eucytherura (Vesticytherura) costaeirregularis* is known from both England and Northern France; my topotype material appears to very closely resemble the Russian specimens and they are both illustrated in Fig. 9. *Paranotacythere (Unicosta) extendata* is also widespread in western Europe, in England, France and Germany (see Fig. 8). *Bythoceratina (Praebythoceratina)* sp. A.; this species (which is shortly to be described) has been identified from both England and Normandy, where it ranges from mid-Callovian to mid-Oxfordian, but it probably also occurs in Germany and Poland where it has not been recognised as a separate species but has been included with *Monoceratina scrobiculata* TRIEBEL & BARTENSTEIN. Comparative material is again illustrated in Fig. 8.

A number of further taxa, common and widely distributed in Europe are conspicuous by their absence from these Russian sections. They include some species of *Macrodentina* s. l., and species of the genera *Dicrorygma* and *Cytheropteron*. An explanation for their absence, when so many of the genera discussed appear to extend across Europe, would seem to lie in the small number and size of samples studied. It is to be hoped that further work in the region will produce a wider fauna containing these "missing" taxa, as it is quite reasonable to suppose that conditions existed during the period under discussion which allowed ostracod faunas to spread and link central Russia and western Europe.

Foraminifera (PWMC)

The foraminifera of the type Volgian have been the subject of a full study by DAIN & KUZNETSOVA (1976). We examined the foraminifera from our samples and recognised 64 species, a result in marked contrast with DAIN & KUZNETSOVA who recorded 233 species and subspecies of which 57 were considered new. However, the differences are in large part due to a different taxonomic perception and interpretation, and almost all our taxa were recognised by the Soviet workers.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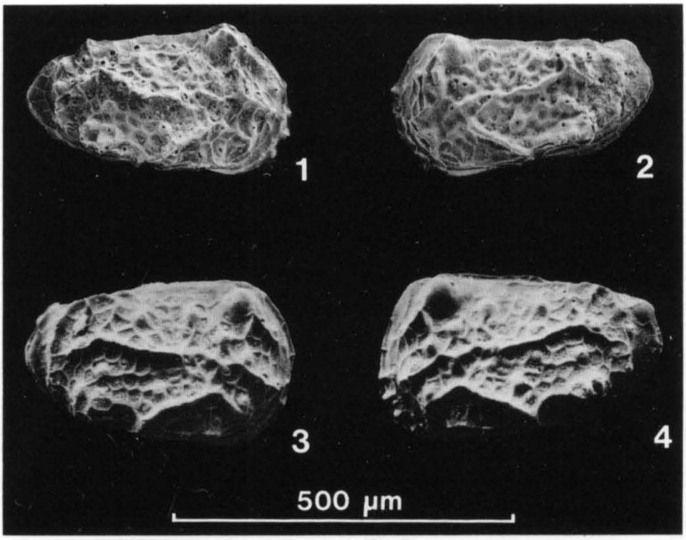

Fig. 9. Ostracoda. Scanning electron micrographs, all × 90. *Eucytherura (Vesticytherura) costaeirregularis* WHATLEY 1970.

1: RV. Gorodishche, sample G8; Lower Volgian.
2: LV. Gorodishche, sample G8; Lower Volgian.
3: RV (topotype). Melton, Yorkshire, England; Ampthill Clay, Upper Oxfordian (A. regulare Zone).
4: LV (topotype). Provenance as 9.3.

Fig. 8. Ostracoda. Scanning electron micrographs, all × 60.

1: *Bythoceratina (Praebythoceratina)* sp. A. Male LV. Gorodishche, sample G4(1); "Kimmeridgian".
2: *Bythoceratina (Praebythoceratina)* sp. A. Male LV. Warboys, Cambs. England; Lower Oxfordian (Q. mariae Zone).
3: *Paranotacythere (Unicosta) extendata* BASSIOUNI 1974. RV. Gorodishche, sample G4(m); "Kimmeridgian".
4: *Galliaecytheridea mandelstami* (LYUBIMOVA 1955). Female RV. Gorodishche, sample G2; "Kimmeridgian".
5: *Galliaecytheridea monstrata* (LYUBIMOVA 1955). Male RV. Gorodishche, sample G2; "Kimmeridgian".
6: *Galliaecytheridea monstrata* (LYUBIMOVA 1955). Female LV. Gorodishche, sample G2; "Kimmeridgian".
7: *Galliaecytheridea volgaensis* (LYUBIMOVA 1955), Male RV. Gorodishche, sample G3; "Kimmeridgian".
8: *Galliaecytheridea volgaensis* (LYUBIMOVA 1955). Male LV. Gorodishche, sample G3; "Kimmeridgian".
9: *Oligocythereis kostytschevkaensis* (LYUBIMOVA 1955). Male RV. Gorodishche, sample G3; "Kimmeridgian".
10: *Oligocythereis kostytschevkaensis* (LYUBIMOVA 1955). Female LV. Gorodishche, sample G3; "Kimmeridgian".

Broad correlations can be made to Poland by means of the foraminifera, but comparison with the Kimmeridgian of southern England is seriously hindered by poor preservation or absence of foraminifera in the upper Lower Kimmeridgian to mid Upper Kimmeridgian interval (LLOYD 1959, 1962; SHIPP & MURRAY 1981: 130). For purposes of long-range correlation the foraminifera thus have limitations to their usefulness; all are benthic forms.

Dinoflagellate cysts (AJJR)

Small quantities of the samples were prepared by standard palynological acid maceration methods. Where material permitted, additional portions of the residues were retained for SEM examination, which will provide further information on some of the more unusual species. The samples yielded rich assemblages of dinoflagellate cysts (dinocysts), associated with microforaminiferal test linings and varying amounts of angular black inertinite. Terrestrially derived spo-

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Fig. 10. Dinoflagellate cysts. Light micrographs × 350, bright-field illumination except where indicated otherwise.

1-2: *Millioudodinium "sarjeantii" sphaericum* (VOZZHENNIKOVA 1967) STOVER & EVITT 1978. Specimen 8319A:14; panderi Zone (zarasjkensis Subzone), Gorodishche. Fig. 1: dorsal focus; Fig. 2: ventral focus.

3-4: *Leptodinium subtile* KLEMENT 1960. Specimen 8314C:2; autissiodorensis Zone, Gorodishche. Fig. 3: dorsal focus; Fig. 4: ventral focus.

5: *Acanthaulax "aceras"* (*Leptodinium aceras* of GITMEZ & SARJEANT 1972). Specimen 8312A:A; eudoxus Zone, Gorodishche.

6: *Leptodinium deflandrei* (RILEY in FISHER & RILEY 1980) LENTIN & WILLIAMS 1981. Specimen 8319A:12c; panderi Zone (zarasjkensis Subzone), Gorodishche. Phase contrast.

7-8: *Leptodinium* sp.1. Specimen 8321c:3; panderi Zone, Kashpir. Fig. 7: high focus; Fig. 8: median focus.

9: *Pareodinia ceratophora* DEFLANDRE 1947, emend. GOCHT 1970. Specimen 8312B:5; eudoxus Zone, Gorodishche. Phase contrast.

10: *Hystrichodinium* sp. Specimen 8313c:1; autissiodorensis Zone, Gorodishche. Phase contrast.

11: *Gonyaulacysta fastigiata* DUXBURY 1977. Specimen 8319B:9; panderi Zone (zarasjkensis Subzone), Gorodishche.

12: *Gonyaulacysta* sp. aff. *G. helicoidea* (EISENACK & COOKSON 1960) SARJEANT 1966. Specimen 8319B:3; panderi Zone (zarasjkensis Subzone), Gorodishche.

13: *Gonyaulacysta* sp. aff. *G. longicornis* (DOWNIE 1957) SARJEANT 1969. Specimen 8315A:2; autissiodorensis Zone, Gorodishche.

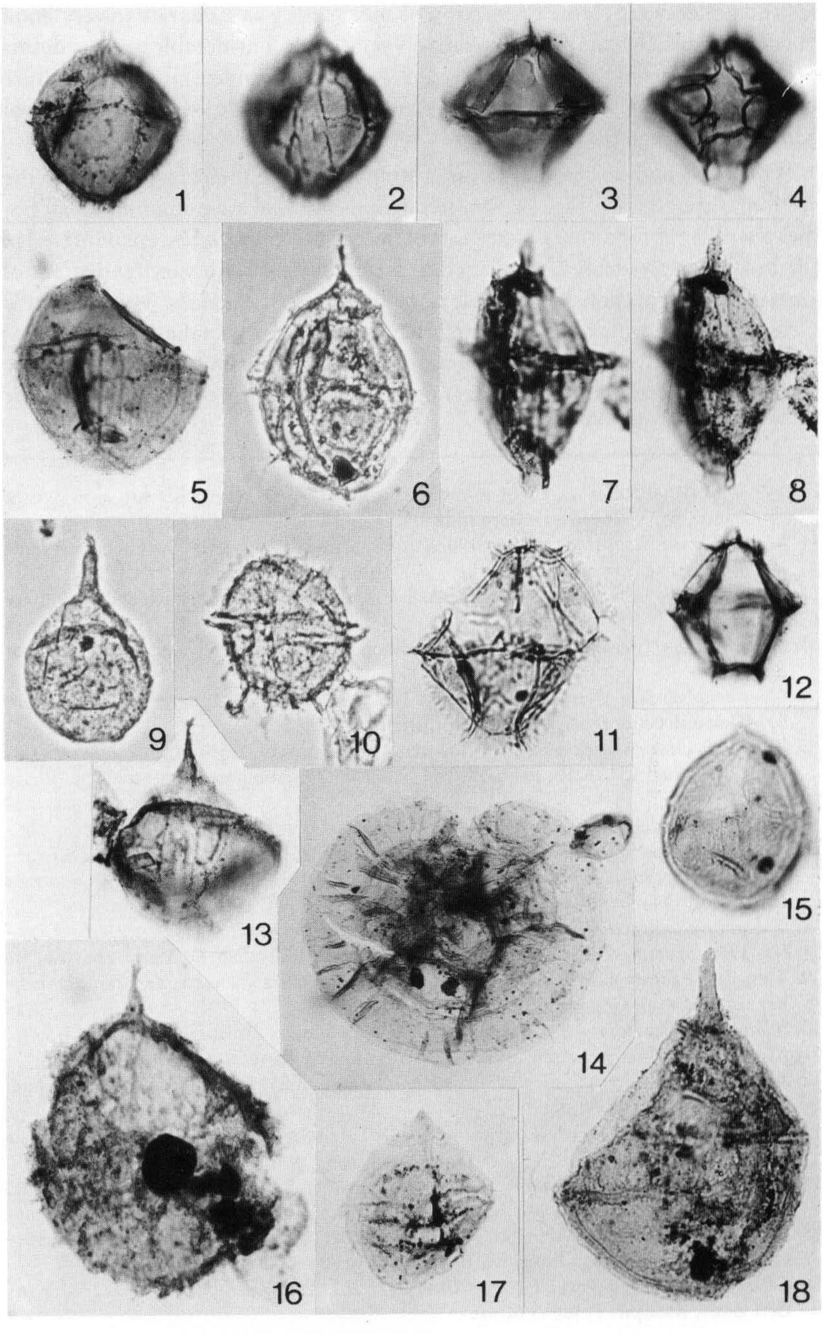
14: *Glossodinium dimorphum* IOANNIDES, STAVRINOS & DOWNIE 1976. Specimen 8312A:9; eudoxus Zone, Gorodishche.

15: *Millioudodinium* sp. aff. *M. globatum* (GITMEZ & SARJEANT 1972) STOVER & EVITT 1978. Specimen 8312c:5; eudoxus Zone, Gorodishche.

16: *Cribroperidinium* sp. Specimen 8319A:11; panderi Zone (zarasjkensis Subzone), Gorodishche.

17: *Geiselodinium paeminosum* DRUGG 1978. Specimen 8314A:9a; autissiodorensis Zone, Gorodishche.

18: *Cribroperidinium* sp. Specimen 8322c:1; panderi Zone, Kashpir.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res and pollen were rare. Preservation of specimens was moderate to very good in the Gorodishche samples but relatively poor with considerable organic debris in the material from Kashpir. This is consistent with the more bituminous nature of the latter samples and is a feature seen also, for example, in much material of Kimmeridgian age from southern Britain (eg. RILEY 1974).

Forty taxa of dinocysts have been distinguished and their ranges through the section(s) are given in Fig. 12. Omitted from this table are numerous small bodies possibly representing cavate cysts of the genus *Dingodinium*, encountered in the lower samples from Gorodishche, and small cysts with varying degrees of surface ornamentation loosely referable to *Chytroeisphaeridia* (eg. *C. pococki* GITMEZ 1970). Forms which proved difficult to identify from the available literature have been give informal designations (eg. "*Leptodinium* sp. 1"); the majority of these are illustrated in Figs. 10 and 11. Further information and taxonomic

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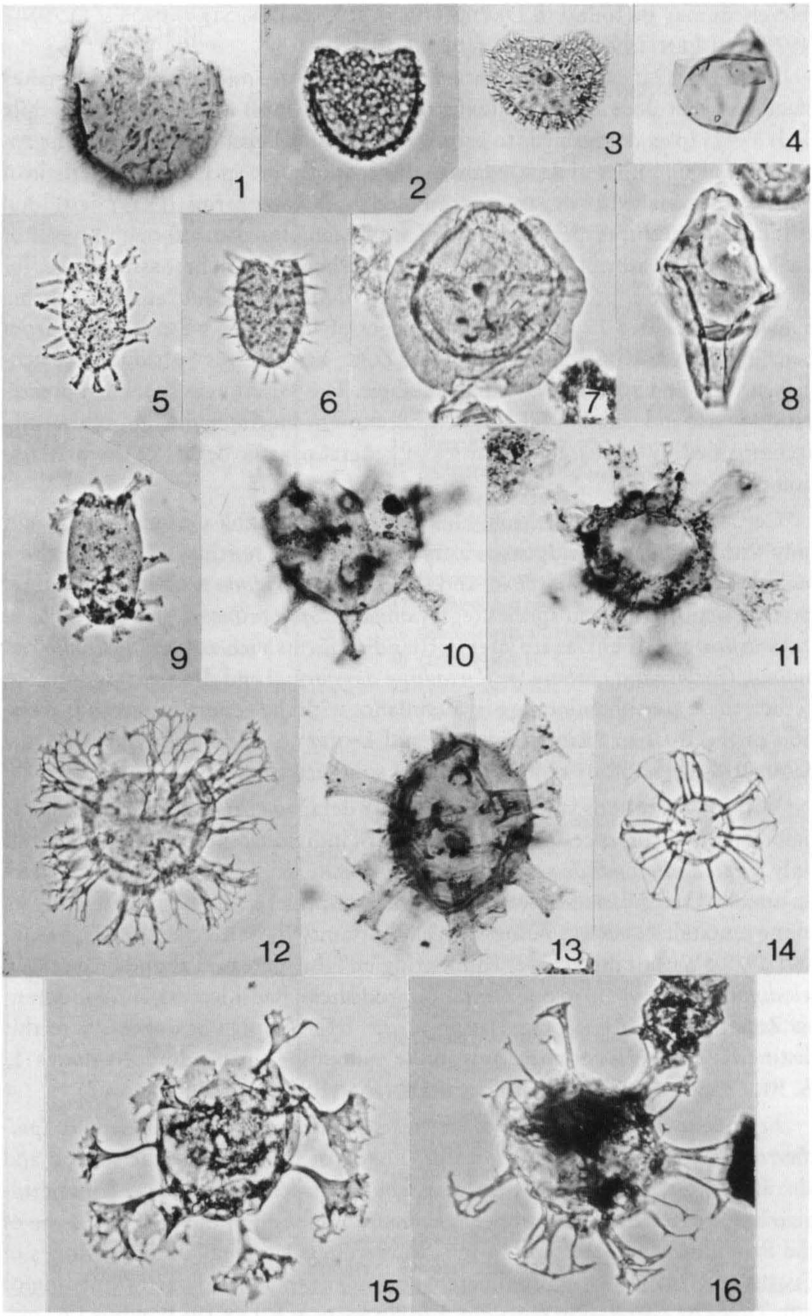
Fig. 11. Dinoflagellate cysts, Light micrographs × 350, bright-field illumination except where indicated otherwise.

1. *Sentusidinium ?rioultii* (SARJEANT 1968) SARJEANT & STOVER 1978. Specimen 8314A:6; autissiodorensis Zone, Gorodishche.
2. *?Cassiculosphaeridia* sp. Specimen 8314B:8; autissiodorensis Zone, Gorodishche. Phase contrast.
3: *Sentusidinium/Cleistosphaeridium* sp. Specimen 8314A:2; autissiodorensis Zone, Gorodishche.
4: *Chytroeisphaeridia chytroeides* (SARJEANT 1962a) DOWNIE & SARJEANT 1965. Specimen 8314C:3; autissiodorensis Zone, Gorodishche.
5: *Tanyosphaeridium isocalamum* (DEFLANDRE & COOKSON 1955) DAVEY & WILLIAMS 1969. Specimen 8319A:1b; panderi Zone (zarasjkensis Subzone), Gorodishche. Phase contrast.
6: *Prolixosphaeridium mixtispinosum* (KLEMENT 1960) DAVEY, DOWNIE, SARJEANT & WILLIAMS 1969. Specimen 8314c:5; autissiodorensis Zone, Gorodishche. Phase contrast.
7: *Sirmiodinium grossii* ALBERTI 1961, emend. WARREN 1973. Specimen 8312B:2; eudoxus Zone, Gorodishche. Phase contrast.
8: *Tubotuberella apatela* (COOKSON & EISENACK 1960b) IOANNIDES, STAVRINOS & DOWNIE 1976. Specimen 8314A:7; autissiodorensis Zone, Gorodishche. Phase contrast.
9: *Tanyosphaeridium magneticum* DAVIES 1983. Specimen 8319B:3a; panderi Zone (zarasjkensis Subzone), Gorodishche. Phase contrast.
10. *?Compositosphaeridium* sp. 1. Specimen 8312c:1; eudoxus Zone, Gorodishche.
11: *Kleithriasphaeridium* sp. Specimen 8321A:10; panderi Zone, Kashpir.
12: *Systematophora fasciculigera* KLEMENT 1960. Specimen 8313c:2; autissiodorensis Zone, Gorodishche. Phase contrast.
13: *Compositosphaeridium/Perissiasphaeridium* sp. Specimen 8314B:5; autissiodorensis Zone, Gorodishche.
14: *Hystrichosphaeridium petilum* GITMEZ 1970. Specimen 8314B:2; autissiodorensis Zone, Gorodishche. Phase contrast.
15: *Oligosphaeridium "pulcherrimum"* sensu IOANNIDES, STAVRINOS & DOWNIE 1976. Specimen 8321A:5; panderi Zone, Kashpir. Phase contrast.
16: *Emmetrocysta sarjeantii* (GITMEZ 1970) STOVER & EVITT 1978. Specimen 8322A:2; panderi Zone, Kashpir. Phase contrast.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references may be found in DAVIES (1983), IOANNIDES, STAVRINOS & DOWNIE (1976) and LENTIN & WILLIAMS (1981).

From Fig. 12 it can be seen that comparatively little microfloral change takes place between Beds 2 — 5 (eudoxus to klimovi Zones) at Gorodishche, while Beds 8 — 11 (pseudoscythicus to panderi Zone, zarasjkensis Subzone) see the appearance of a number of new taxa with the loss of some species characteristic of the lower levels. Bed 11 in particular yielded some 7 new forms; it has microfloral affinities in certain respects with the Kashpir samples also, although several of the Kashpir taxa are not represented at Gorodishche. The richest assemblages recovered were from Beds 3 and 4 (lower) (autissiodorensis Zone) at Gorodishche, which each yielded 19 species. Assemblages of 15 species were recorded from Beds 2 (eudoxus Zone) and 11 (panderi Zone, zarasjkensis Subzone) at Gorodishche and Bed 5 (panderi Zone) at Kashpir. The variation in specimen preservation is also indicated in Fig. 12; deterioration in specimen quality was usually accompanied by increased quantities of general organic debris in the preparation.

Certain species found throughout the sections in the present study occur only within the Kimmeridgian or early Portlandian in north-west Europe; these include *Glossodinium dimorphum* and *Hystrichosphaeridium petilum.* In addition, characteristic Oxfordian species (eg. *Nannoceratopsis pellucida* and *Gonyaulacysta jurassica)* are absent, as are later Portlandian forms such as *Ctenidodinium culmulum, Gochteodinia villosa* (= *Pareodinia dasyforma)* and *Muderongia* spp. Together, these considerations are in accordance with the generally agreed correlation of the Russian "Kimmeridgian" and Lower to Middle Volgian with the Kimmeridgian and Lower Portlandian of southern England.

Within the sections studied, several more detailed correlations may be made based on the occurrence and/or abundance of individual species in certain levels only. *Leptodinium subtile* and (possibly) *Systematophora fasciculigera* are characteristically Oxfordian or Lower Kimmeridgian species, *L. subtile* ranging only up to the mutabilis/eudoxus Zones with any certainty (LAM & PORTER 1977, SARJEANT 1979). Within the "Upper Kimmeridgian" the increased abundance of *Geiselodinium paeminosum* in one sample (Gorodishche Bed 4(lower), autissiodorensis Zone) affords a good correlation to the UK — North Sea area where this distinctive species is common only in the eudoxus — autissiodorensis Zones (L. A. RILEY, pers. comm.; cf. GITMEZ & SARJEANT 1972, and DRUGG 1978).

Leptodinium (formerly *Gonyaulacysta*) *deflandrei* and *Oligosphaeridium "pulcherrimum"*, which are found towards the top of the Gorodishche section and also at Kashpir, are species of restricted range characteristic of Upper Kimmeridgian levels in north-west Europe: *L. deflandrei* is found in the upper subzone of the Pareodinia mutabilis and in the "Muderongia simplex" dinocyst Zones of FISHER & RILEY (1980: approximately equivalent to pallasioides-fittoni ammonite Zones by correlation with Fig. 3 in RAWSON & RILEY 1982), while *O. "pul-*

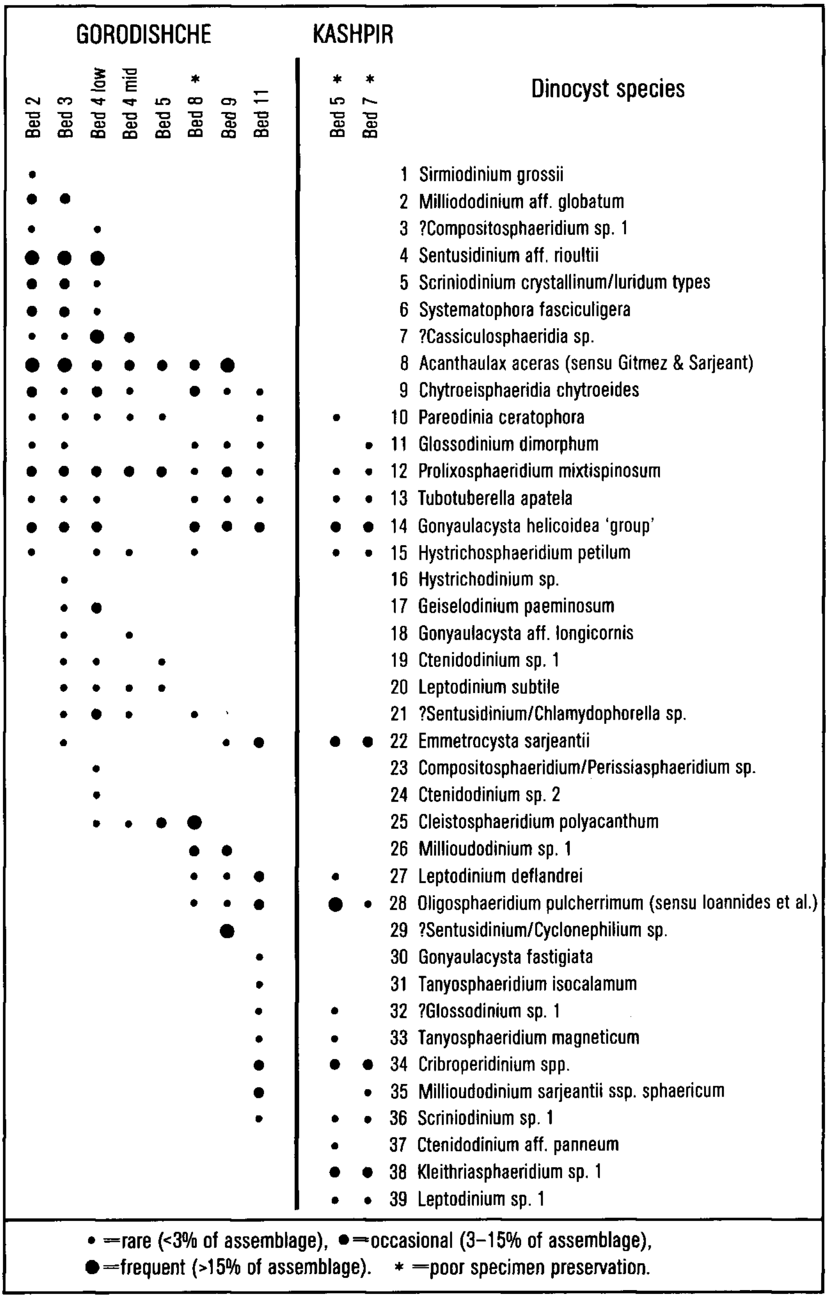

Fig. 12. Stratigraphic distribution of dinocysts at Gorodishche and Kashpir.

cherrimum" is most characteristic of the pectinatus-hudlestoni Zones in the North Sea although it may range up to the pallasioides and possibly rotunda Zones (L. A. RILEY, pers. comm.; cf. RAYNAUD 1978). Taken together, these taxa would suggest a pallasioides-rotunda Zone age for Bed 11 at Gorodishche and Bed 5 at Kashpir, and possibly also a similar age for the two preceding Gorodishche samples although the evidence is based on only a small number of specimens. The much reduced abundance of *O. "pulcherrimum"* in Bed 7 at Kashpir suggests a stratigraphically higher position than that of Bed 11 at Gorodishche.

Assemblages comparable to those found in the present samples have not prevously been reported from the USSR. VOZZHENNIKOVA (1967) described a slightly younger assemblage (including the stratigraphically important species *Pareodinia dasyforma*, = *Gochteodinia villosa*) from the Upper Volgian of the Moscow region, but recorded no dinoflagellates from the Kimmeridgian. The closest equivalents would appear to be assemblages of "Lower Kimmeridgian" and Middle Volgian age described by BIRKELUND et al. (1978) from Arctic Norway, which characteristically include a "*Gonyaulacysta* complex" and a species of *Prolixosphaeridium* close to *P. mixtispinosum*. Much original data on Kimmeridgian and Portlandian sediments in North-West Europe remains to be properly published, but the information available (e. g. RAYNAUD 1978, FISHER & RILEY 1980, WOOLLAM & RIDING 1983) suggests that the Russian assemblages contain little-known or new taxa (reflected in the difficulty of naming many species in Fig. 12), together with representatives of some genera (*Compositosphaeridium, Ctenidodinium, Scriniodinium*) unexpected at these levels. It is hoped that further study of the material available will allow resolution of some taxonomic problems and enable additional points of stratigraphic interest to be identified.

Concluding discussion

In our study, only samples from the "Kimmeridgian" and Lower to Middle Volgian (up to panderi Zone) of the Volga Basin have been available for micropalaeontological investigation, thus we have not been able to contribute to current debate regarding the presence of considerable non-sequences in upper parts of the Volgian succession in the type area. Correlation of the levels studied here is suggested in Fig. 3 on the basis of ammonite evidence, largely after the work of CASEY and COPE et al. (see discussion above on ammonite correlations). The microfossil assemblages described here provide support for this scheme in a general way, and several details of the nannofossil and dinocyst distributions support the correlation of individual zones more closely, in particular the Soviet and British eudoxus and autissiodorensis Zones, and the basal panderi Zone (base Middle Volgian) with the British pallasioides Zone. The sample from the zarasjkensis Subzone, panderi Zone would appear on dinocyst evidence to be no younger than rotunda Zone age in equivalent British terminology, although

KUZNETSOVA (1978) would correlate this level with the albani Zone of the British Portlandian.

The calcareous nannoflora shows the closest comparability with equivalent North-West European Boreal assemblages and the ostracods and foraminifera the least, although the validity of the latter may be lessened by the paucity of comparable material due to preservational effects in the type-Kimmeridgian. We also recognise the limitations of the present study in terms of sampling frequency and quantities of material studied but present the main features of the microfossil distributions in the expectation that further study will be stimulated.

Acknowledgements

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Appendix 1

Nannofossil species

Actinozygus fragilis ROOD & BARNARD 1972

Actinozygus geometricus (GÓRKA 1957) ROOD, HAY & BARNARD 1971

Anfractus harrisonii MEDD 1979

Axopodorhabdus cylindratus (NOËL 1965) WISE & WIND 1977

Biscutum dubia (NOËL 1965) GRÜN & ZWEILI 1980

Biscutum ellipticum (GÓRKA 1957) GRÜN & ALLEMANN 1976

Chiastozygus leptostauros COOPER 1987

Cretarhabdus conicus BRAMLETTE & MARTINI 1964

Cyclagelosphaera margereli NOËL 1965

Cyclagelosphaera tubulatum (GRÜN & ZWEILI 1980) COOPER 1987

Diadorhombus horrelli ROOD and BARNARD 1972

Ellipsagelosphaera britannica (STRADNER 1963) PERCH-NIELSEN 1968

Ellipsagelosphaera fossacincta BLACK 1971

Ellipsagelosphaera keftalrempti GRÜN & ALLEMANN 1976

Ellipsagelosphaera ovata (BUKRY 1969) BLACK 1973

Ellipsagelosphaera reinhardti (ROOD, HAY & BARNARD 1971) NOËL 1973

Ethmorhabdus anglicus ROOD, HAY and BARNARD 1971

Ethmorhabdus gallicus NOËL 1965

Hexapodorhabdus cuvillieri NOËL 1965

Paractinozygus gorodishchensis COOPER 1987

Parhabdolithus embergeri (NOËL 1958) STRADNER 1963

Podorhabdus grassei NOËL 1965, emend. WISE & WIND 1977

Polypodorhabdus escaigi NOËL 1965

Retecapsa schizobrachiata (GARTNER 1968) GRÜN & ALLEMANN 1976

Rotelapillus radians NOËL 1973

Staurorhabdus quadriarcullus (NOËL 1965) NOËL 1973

Stephanolithion atmetros COOPER 1987

Stephanolithion bigoti DEFLANDRE 1939

Stephanolithion helotatus (WISE & WIND 1977) COOPER 1987

Stradnerlithus bifurcatus NOËL 1973

Stradnerlithus comptus BLACK 1971

Stradnerlithus delftensis (STRADNER & ADAMIKER 1966) BLACK 1971

Stradnerlithus rhombicus (STRADNER & ADAMIKER 1966) NOËL 1973

Stradnerlithus senarius (WISE & WIND 1977) GALLOIS & MEDD 1979

Stradnerlithus tortuosus NOËL 1973

Tubirhabdus patulus PRINS 1969

Vekshinella dibrachiata GARTNER 1968

Watznaueria barnesae (BLACK 1959) PERCH-NIELSEN 1968

Zygodiscus erectus (DEFLANDRE 1951) MANIVIT 1971

Zygodiscus noelae (ROOD, HAY & BARNARD 1971) TAYLOR 1978

Appendix 2

Ostracod species

Bythoceratina (Praebythoceratina) sp. A
?*Bythocythere nescia* LYUBIMOVA 1955
Cytherella fullonica JONES & SHERBORN 1888
Cytherelloidea ?paraweberi OERTLI 1959
Cytherelloidea aff. *C. tennis* SHARAPOVA 1939
Eucytherura (Vesticytherura) grossospinosa FULLER ms.
Eucytherura (Vesticytherura) costaeirregularis WHATLEY 1970
Eucytherura (Vesticytherura) sp. 1
Exopthalmocythere affabra LYUBIMOVA 1955
Galliaecytheridea elegans (SHARAPOVA 1937)
Galliaecytheridea gorodishchensis FULLER & LORD 1979
Galliaecytheridea gorodishchensis var. A
Galliaecytheridea mandelstami (LYUBIMOVA 1955)
Galliaecytheridea miranda (LYUBIMOVA 1955)
Galliaecytheridea monstrata (LYUBIMOVA 1955)
Galliaecytheridea volgaensis (MANDELSTAM 1955)
Macrocypris aff. *M. aquabilis* OERTLI 1959
Macrodentina (Polydentina) ramosa (LYUBIMOVA 1955)
Macrodentina (Polydentina) subtriangularis (SHARAPOVA 1937)
Mandelstamia abdita LYUBIMOVA 1955
Mandelstamia aff. *M. rectilinea* MALZ 1958
Mandelstamia ventrocornuta (SHARAPOVA 1939)
Oligocythereis kostytschevkaensis (LYUBIMOVA 1955)
Paranotacythere (Unicosta) aff. *P. (U.) extendata* BASSIOUNI 1974
Procytheropteron prolongatum (SHARAPOVA 1939)
Protocythere bisulcata (SHARAPOVA 1939)
Protocythere cornulateralis LYUBIMOVA 1955
Pseudocythere aff. *P. oblonga* FULLER ms.
Schuleridea araneusa (LYUBIMOVA 1955)
Schuleridea delicata (LYUBIMOVA 1955)
Schuleridea subrotunda (LYUBIMOVA 1955)

Appendix 3

Dinoflagellate cysts

The number preceding each taxon relates to its order of appearance on the range chart (Fig. 12).

(8) *Acanthaulax "aceras"* (= *Leptodinium aceras* of GITMEZ & SARJEANT 1972). Fig. 10:5.
(7) ?*Cassiculosphaeridia* sp. Fig. 11:2.
(9) *Chytroeisphaeridia chytroeides* (SARJEANT 1962a) DOWNIE & SARJEANT 1965. Fig. 11:4
(25) *Cleistosphaeridium polyacanthum* GITMEZ 1970.
(3) ?*Compositosphaeridium* sp. 1. Fig. 11:10.
(23) *Compositosphaeridium* sp. 2./*Perissiasphaeridium* sp. Fig. 11:13.
(34) *Cribroperidinium* spp. Fig. 10:16, 18.
(37) *Ctenidodinium* aff. *C. panneum* (NORRIS 1965) LENTIN & WILLIAMS 1973.
(19) *Ctenidodinium* sp. 1.
(24) *Ctenidodinium* sp. 2.

(22) *Emmetrocysta sarjeantii* (GITMEZ 1970) STOVER & EVITT 1978. Fig. 11:16.
(17) *Geiselodinium paeminosum* DRUGG 1978. Fig. 10:17.
(15) *Glossodinium dimorphum* IOANNIDES, STAVRINOS & DOWNIE 1976. Fig. 10:14.
(32) *?Glossodinium* sp. 1.
(30) *Gonyaulacysta fastigiata* DUXBURY 1977. Fig. 10:11.
(14) *Gonyaulacysta.* aff. *G. helicoidea* (EISENACK & COOKSON 1960) SARJEANT 1966. Fig. 10:12.
(18) *Gonyaulacysta* aff. *G. longicornis* (DOWNIE 1957) SARJEANT 1969. Fig. 10:13.
(16) *Hystrichodinium* sp. Fig. 10:10.
(15) *Hystrichosphaeridium petilum* GITMEZ 1970. Fig. 11:14.
(38) *Kleithriasphaeridium* sp. 1. Fig. 11:11.
(27) *Leptodinium deflandrei* (RILEY in FISHER & RILEY 1980) LENTIN & WILLIAMS 1981. Fig. 10:6.
(20) *Leptodinium subtile* KLEMENT 1960. Fig. 10:3, 4.
(39) *Leptodinium* sp. 1. Fig. 10:7, 8.
(2) *Millioudodinium* aff. *M. globatum* (GITMEZ & SARJEANT 1972) STOVER & EVITT 1978. Fig. 10:15.
(35) *Millioudodinium "sarjeantii" sphaericum* (VOZZHENNIKOVA 1967) STOVER & EVITT 1978. Fig. 10:1, 2.
(26) *Millioudodinium* sp. 1.
(28) *Oligosphaeridium "pulcherrimum" of* IOANNIDES, STAVRINOS & DOWNIE 1976. Fig. 11:15.
(10) *Pareodinia ceratophora* DEFLANDRE 1947c, emend. GOCHT 1970b (sens. lat.). Fig. 10:9.
(12) *Prolixosphaeridium mixtispinosum* (KLEMENT 1960) DAVEY, DOWNIE, SARJEANT & WILLIAMS 1979. Fig. 11:6.
(5) *Scriniodinium* spp.
(36) *Scriniodinium* sp.1.
(4) *Sentusidinium* aff. *rioultii* (SARJEANT 1968) SARJEANT & STOVER 1978. Fig. 11:1.
(21) *?Sentusidinium/Chlamydophorella* sp.
?Sentusidinium/Cleistosphaeridium sp. Fig. 11:3.
(29) *?Sentusidinium/Cyclonephilium* sp.
(1) *Sirmiodinium grossii* ALBERTI 1961, emend WARREN 1973. Fig. 11:7.
(6) *Systematophora fasciculigera* KLEMENT 1960. Fig. 11:12.
(31) *Tanyosphaeridium isocalamum* (DEFLANDRE & COOKSON 1955) DAVEY & WILLIAMS 1969. Fig. 11:5.
(33) *Tanyosphaeridium magneticum* DAVIES 1983. Fig. 11:9.
(13) *Tubotuberella apatela* (COOKSON & EISENACK 1960b) IOANNIDES, STAVRINOS & DOWNIE 1976. Fig. 11:8.