

1 Regional correlation of Jurassic/Cretaceous boundary strata based on the Tithonian to  
2 Valanginian dinoflagellate cyst biostratigraphy of the Volga Basin, western Russia

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16

17 ABSTRACT

18

19 Precise stratal correlation of Jurassic/Cretaceous boundary successions in the Boreal  
20 Province, including the western European and Russian regions, based on ammonite  
21 biostratigraphy remain significantly problematical due to widespread faunal  
22 provincialism. In order to help clarify this situation, the marine palynology of the  
23 Tithonian (uppermost Jurassic) and the Berriasian and Valanginian (Lower Cretaceous)  
24 strata exposed on the banks of the River Volga at Gorodishche and Kashpir, near  
25 Ul'yanovsk, has been studied in detail. Over 100 dinoflagellate cyst species were  
26 recovered, and their ranges used to compile a detailed Tithonian to Valanginian  
27 palynostratigraphy for the Volga Basin. First and last appearance datums of key  
28 dinoflagellate cyst taxa are used to define ages for unreliably dated strata in the Russian  
29 successions by comparison with the stratigraphical ranges of the same taxa calibrated to  
30 ammonite zones in Boreal northwest Europe. These dinoflagellate cyst bioevents  
31 include the range bases of *Gochteodinia villosa*, *Pseudoceratium brevicornutum*,  
32 *Pseudoceratium pelliferum*, *Spiniferites primaevus* and *Spiniferites ramosus*, and the  
33 range tops of *Egmontodinium polyplacophorum*, *Pseudoceratium brevicornutum* and  
34 *Senoniasphaera jurassica*. For example, the inception of *Gochteodinia villosa* indicates  
35 a correlation between the base of the Late Tithonian Epivirgatites nikitini Zone of the  
36 Volga Basin and that of the Galbanites kerberus Zone of northwest Europe. It is clear

37 that dinoflagellate cysts have great potential for correlating between the northwest  
38 European and Russian Platform (and Siberian) ammonite zonations. Based on the  
39 successive range bases and tops of key taxa a new dinoflagellate cyst interval zonation  
40 scheme, consisting of five zones and seven subzones, has been defined for the Volga  
41 Basin. Graphic correlation of the dinoflagellate cyst range data indicate that part of the  
42 Mid Tithonian *Zaraskaites zarajskensis* Subzone is missing at Kashpir. However, the  
43 two successions were characterised by steady, coeval sedimentation up to the top of the  
44 Late Tithonian-Early Berriasian *Craspedites nodiger* Zone. There are some differences  
45 between Tithonian and Berriasian dinoflagellate cyst floras between the Volga Basin  
46 and northwest Europe, but these are relatively minor compared to the endemism  
47 displayed by molluscan faunas. Valanginian dinoflagellate cyst assemblages throughout  
48 the Northern Hemisphere, however, are significantly more similar. This scenario is also  
49 reflected globally, with the most significant floral differences being manifested between  
50 the Tithonian-Berriasian of the Southern Hemisphere and the rest of the world.

51

52 *Keywords:* Latest Jurassic; Early Cretaceous; dinoflagellate cysts; biostratigraphy;  
53 correlation; biozonation; western Russia.

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55

## 56 **1. Introduction**

57

58 Global correlation of Jurassic/Cretaceous (J/K) boundary strata has always  
59 proved highly problematical due to intense and widespread faunal provincialism  
60 throughout the Northern Hemisphere (Hoedemaeker, 1991; Wimbledon, 2007;  
61 Wimbledon et al., in press). The J/K boundary strata of the Volga Basin in western  
62 Russia represent an important succession which is difficult to correlate with other areas.  
63 In order to mitigate this, Tithonian to Valanginian dinoflagellate cyst floras from  
64 important reference sections on the banks of the River Volga have been studied in  
65 detail. These are at Gorodishche, 25 km north of Ul'yanovsk, and at Kashpir, 140 km  
66 south of that town (Fig. 1).

67 Ammonites are the primary biostratigraphical indices for the Jurassic and  
68 Cretaceous (Callomon, 1995; Zeiss, 2003); however, other fossil groups have  
69 considerable and growing significance (Torrens, 1980). The profound endemism of  
70 latest Jurassic-earliest Cretaceous ammonite faunas has led to a complex stage  
71 terminology for the terminal Jurassic stage, including junior synonyms. Thus the stages  
72 Kimmeridgian, Portlandian, Purbeckian, Tithonian and Volgian have been variously

73 applied from England/France to Poland (and Greenland), on the Russian  
74 Platform/Siberia (each with different ammonite zonation) and in the  
75 Submediterranean/Tethyan province (i.e. the Tethyan Realm) for the post-Oxfordian  
76 interval (Fig. 2). In 1990, the Tithonian was formally ratified as the terminal Jurassic  
77 stage by the International Commission on Stratigraphy, and this is used herein. This  
78 ratification has proved controversial because the Portlandian is a senior synonym of the  
79 Tithonian. Later, Cope (1993) proposed the Bolonian and the Portlandian as stages of a  
80 Tithonian Superstage. The Bolonian equates to the old Upper Kimmeridgian Stage, i.e.  
81 the Upper Kimmeridge Clay Formation of northwest Europe, spanning the *Pectinatites*  
82 *elegans* to the *Virgatopavlovia fittoni* zones; it is not illustrated in Fig. 2. A Global  
83 Stratotype Section and Point and internal divisions for the Tithonian have not been  
84 finalised. Middle and Upper Berriasian units in the Boreal Realm have been assigned to  
85 the Ryazanian (Fig. 2), but the Berriasian Stage has always been considered to be the  
86 global standard and is therefore used in preference to the Ryazanian in this paper.

87 The most complete and best documented J/K boundary successions are in the  
88 Submediterranean/Tethyan province. Consequently the Tithonian-Berriasian ammonite  
89 zonation is the primary standard for the J/K boundary, although latterly it is rivalled by  
90 the calpionellid zonation (Remane, 1998). Recently, emphasis has been placed on the  
91 base of the M18r magnetostratigraphic interval as a proxy for the lowermost Berriasian  
92 (Gradstein et al., 2004). The Tithonian and Berriasian stage nomenclature has been  
93 formally adopted by the Russian Interdepartmental Stratigraphical Committee and local  
94 stage names suppressed. However, dissident support remains for the view that the  
95 Volgian Stage should remain intact and that it must be, *a priori*, entirely Jurassic, even  
96 though it is clear that it spans the Tithonian and much of the Berriasian (Fig. 2;  
97 Zakharov and Rogov, 2008).

98 Correlations between the Submediterranean/Tethyan province and the northern  
99 Boreal region are somewhat tentative and remain uncertain by potentially as much as an  
100 entire ammonite zone. Hence the boundaries and ammonite zones of the Tithonian and  
101 Berriasian stages of the Tethyan Realm cannot be recognised precisely in Russia.  
102 However, recent palaeomagnetic research at Nordvik in Siberia by Houša et al. (2007)  
103 has shown that the base of the Berriasian, in marine and non-marine (i.e. Purbeck of  
104 Dorset) facies, can be approximately correlated with the Siberian equivalent of the  
105 *Craspedites nodiger* Zone of the Russian Platform. Thus magnetostratigraphy is proving  
106 to be a valuable tool for constraining biostratigraphical correlations and helping solve  
107 provincialism problems, but it cannot be effective in all areas due to diagenesis,  
108 incomplete sedimentary successions and weathering (Ogg et al., 1994).

109           The Portlandian (Brongniart, 1829; d'Orbigny 1842-51) was applied to supposed  
110 Portland and ?Purbeck formation equivalents in Russia (Pavlov, 1889). However a  
111 synonym, the Volgian, was proposed by Nikitin (1881). The base of the Volgian (the  
112 Subplanites klimovi Zone) is approximately equivalent to the base of the Tithonian  
113 (Gerasimov and Mikhailov, 1966). Stratigraphical breaks, indicated by phosphatites,  
114 pebble beds and winnowed horizons, within the Volgian are geographically widespread.  
115 Despite this, the term Volgian has been used extensively in the high northern latitudes  
116 outside onshore Britain, for example in the North Sea Basin (e.g. Richards et al., 1993).  
117 The Boreal or Sub-boreal nature of Oxfordian to Early Kimmeridgian and late Early  
118 Cretaceous ammonite faunas of the Russian Platform has ensured that correlation  
119 between this area and northwest Europe is now relatively well documented (Krymholts  
120 et al., 1988; Hantzpergue et al., 1998; Hoedemaeker, 1999). However, significant  
121 problems remain in the uppermost Jurassic and lowermost Cretaceous parts of these  
122 successions. Correlation of the well-known northwest European J/K boundary  
123 successions with those of the Russian Platform has proved problematical due to the  
124 geographical isolation of the Russian Platform from Kimmeridgian to Early Berriasian  
125 times, and the resultant profoundly endemic ammonite faunas (Gerasimov and  
126 Mikhailov, 1966; Casey, 1967; 1968; 1973; Wimbledon and Cope, 1978; Cope, 1978;  
127 Wimbledon, 1984; Zakharov et al., 1997; Abbink et al., 2001; Rogov and Zakharov,  
128 2008). These problems are even more acute when attempting to correlate the Russian  
129 and Tethyan ammonite zonations (Geysant, 1997). Moreover alternative  
130 stratigraphically significant microfossils such as calcareous nannofossils and  
131 calpionellids, extensively employed as precise biomarkers around the J/K boundary in  
132 the Tethyan Realm, are rare or absent in Russia. In summary, there is never likely to be  
133 a universally-accepted ammonite-based scheme that can accommodate the Lower  
134 Tithonian to Lower Berriasian of the Russian Platform, all other areas of the Boreal  
135 Realm and the Tethyan Realm. Several alternative schemes have been presented, for  
136 example Kusnetsova (1978), Lord et al. (1987), Krymholts et al. (1988), Hoedemaeker  
137 (1991; 1999) and Hantzpergue et al. (1998).

138           This study uses dinoflagellate cysts to help to resolve the aforementioned  
139 correlation problems. Motile planktonic dinoflagellates, and hence their cysts, have very  
140 wide geographical distributions (e.g. Taylor and Pollinger, 1987). Dinoflagellate cysts  
141 are thus potentially much less provincial than many other macrofossil and microfossil  
142 taxa (Riding et al., 2010; 2011). A palynological investigation has been undertaken of  
143 the Tithonian to Valanginian sections on the banks of the River Volga in order to  
144 develop an integrated biostratigraphical correlation between the Russian Platform and

145 northwest Europe. This paper reviews the Gorodishche and Kashpir sections, presents a  
146 detailed description of the dinoflagellate cyst ranges, and compares these data to those  
147 from other localities in the Russian Platform, Siberia and northwest Europe. The  
148 principal dinoflagellate cyst bioevents are discussed, thereby helping to clarify the  
149 correlation of the ammonite zonal schemes for the Russian Platform with those of  
150 northwest Europe, and a dinoflagellate cyst interval biozonation for the Russian  
151 Platform is proposed. All ammonite zones and subzones cited herein are used in the  
152 sense of biozones. The zonal index taxa are written in Roman script, and the initial  
153 letters of the words "zones" and "subzones" are capitalised. Hence the index species of  
154 the *Dorsoplanites panderi* Zone is *Dorsoplanites panderi* d'Orbigny.

155         The ammonite zonation of the Lower Tithonian to Lower Berriasian at  
156 Gorodishche was outlined by Gerasimov and Mikhailov (1966), Mikhailov (1966),  
157 Gerasimov (1969) and Mitta (1993a,b; 1994), whereas that of the reference section at  
158 Kashpir was described by Pavlov (1886), Gerasimov (1969), Mesezhnikov (1977) and  
159 Blom et al. (1984). Correlations between the Russian and English Tithonian-Early  
160 Berriasian ammonite schemes differ markedly (Lord et al., 1987). These include the  
161 schemes of Kuznetsova (1978), Sasanova and Sasanov (1979), Wimbledon (1984), Lord  
162 et al. (1987), Krymholts et al., (1988), Hoedemaeker (1991), Hantzpergue et al. (1998)  
163 and Rogov and Zakharov (2009). Lord et al. (1987) synthesised the data of Casey  
164 (1967; 1973), Cope (1967; 1978), Wimbledon and Cope (1978) and Cox and Gallois  
165 (1981). Correlations between Europe and the Volga Basin are presented as Fig. 3.

166         Lord et al. (1987) correlated the *Epivirgatites nikitini* Zone of the Volga Basin  
167 and the *Progalbanites albanii* Zone of northwest Europe as a result of the possible  
168 recognition of two specimens of *Epivirgatites nikitini* from the *Progalbanites albanii*  
169 Zone by Cope (1978). However, the correlation by Krymholts et al. (1988) of the  
170 *Zaraiskites zarajskensis* Subzone with the *Progalbanites albanii* Zone followed the  
171 suggestion by Arkell (1956) that the ammonite genera *Progalbanites* and *Zaraiskites*  
172 were synonymous. More recently, however, the base of the *Epivirgatites nikitini* Zone  
173 was deemed to be coincident with the top of the *Progalbanites albanii* Zone (e.g.  
174 Hantzpergue et al., 1998) despite Krymholts et al. (1988) having placed the base of the  
175 *Epivirgatites nikitini* Zone within the *Galbanites okusensis* Zone (Fig. 3). Ongoing  
176 studies by one of us (WAPW) have revealed no conspecific relationships between the  
177 Mid-Late Tithonian (= Portlandian) ammonites of England, France and Greenland  
178 (*Progalbanites albanii*-*Titanites anguiformis* zones) and the supposedly coeval faunas  
179 from the Volga Basin. The most recent studies on the successions at Gorodishche and  
180 Kashpir (i.e. Ruffell et al., 2002; Gröke et al., 2003; Kessels et al., 2003) all adopted the

181 ammonite zonal correlations of Hantzpergue et al. (1998). These papers illustrated  
182 sedimentary logs for the successions; despite no formal descriptions being provided,  
183 they correlate reasonably well with the logs of Hantzpergue et al. (1998) and herein  
184 (Fig. 4).

185

## 186 **2. Previous research on the Tithonian to Valanginian successions at Gorodishche** 187 **and Kashpir**

188

189 This section is an overview of previous research on the Tithonian to Valanginian  
190 successions of Gorodishche and Kashpir including their ammonite biostratigraphy and  
191 palynology. These studies are compared with the high-resolution lithological logs and  
192 ammonite data which have been compiled herein.

193

### 194 *2.1. Gorodishche*

195

196 The Tithonian and Lower Berriasian succession at Gorodishche was first  
197 described by Pavlov (1886). It was subsequently redescribed by Sasanov (1951),  
198 Mesezhnikov (1977), Blom et al. (1984), Hantzpergue et al. (1998), Ruffell et al. (2002)  
199 and Zakharov et al. (2006). A lithological log of this section is illustrated in Figs. 4 and  
200 5. Correlation of the log of the Gorodishche succession prepared by Mesezhnikov in  
201 Blom et al. (1984) with the log herein is illustrated in Fig. 5. The former log is of  
202 relatively lower resolution. Only the major lithological units were recognised, and it  
203 included vague bed thicknesses and somewhat basic sedimentological descriptions  
204 (Blom et al., 1984). Equating the lithostratigraphy of the two logs is thus problematical.  
205 However, several tie points can be identified on the basis of key lithologies, and verified  
206 using ammonite evidence.

207 Bed 11 of Blom et al. (1984) correlates with beds 1-13 herein (Fig. 5). Blom et  
208 al. (1984, p.71, 121) described the black units in Bed 11 as “pyroschist” in the key, and  
209 “bituminous, shaley dark gray brown clay (combustible shale)” in the bed descriptions.  
210 These probably equate with the laminated siltstone horizons recognised herein. The  
211 laminated lithology was described as “lime clay” by Blom et al. (1984, p. 71), and  
212 corresponds to the calcareous mudstone units (beds 1, 2, 4 and 6) herein. The  
213 substantial thickness of lenticular siltstones present in the uppermost part of the  
214 Zaraiskites zarajskensis Subzone is not represented in either the log or the  
215 sedimentological descriptions of Blom et al. (1984).

216 Beds 12 and 14 of Blom et al. (1984, p.121) were described as “phosphorite  
217 conglomerates”, and clearly equate with our beds 14 and 16 (Fig. 5). Beds 15-18 of the  
218 Russian workers were all described as grey calcareous sandstones with glauconite, but  
219 were subdivided on the basis of ammonites rather than sedimentology. This faunal  
220 information thus provides a simple means of equating this interval with our beds 17 and  
221 18; the tie-points are indicated in Fig. 5. Bed 19 of Blom et al. (1984) corresponds, by  
222 default, to the phosphorite horizon, since the adjacent units can be confidently matched.  
223 However, the description of bed 19 of Blom et al. (1984, p. 122), i.e. “sandstone,  
224 conglomerate-like yellowish-grey, ferruginated, with numerous pebbles from  
225 underlying sandstone” contrasts with the findings herein. This may suggest lateral  
226 variation within this unit, but this was not observed in the field. Bed 20 of Blom et al.  
227 (1984, p.121) was described as “clay....with numerous gypsum crystals”, and equates to  
228 our bed 20.

229 At Gorodishche, Lord et al. (1987) previously described the dinoflagellate cyst  
230 biostratigraphy of eight samples from the Upper Kimmeridgian (*Aulacostephanus*  
231 *eudoxus* Zone) to the lowermost Middle Tithonian (*Zaraskaites zarajskensis* Subzone).  
232 Only the uppermost of these eight samples, from bed 11 of Mesezhnikov (1977),  
233 overlaps with the interval examined here. The log of Lord et al. (1987) was taken from  
234 Mesezhnikov (1977), and is correlated with our log in Fig. 5. Lord et al. (1987) used the  
235 ammonite zonation of Kuznetsova (1978), and gave a log that apparently shows a  
236 generalised representation of bed 11, because it depicts many more “bituminous shale”  
237 horizons than were indicated by Blom et al. (1984). Lord et al. (1987) did not establish  
238 a dinoflagellate cyst zonation.

239 Hogg (1994) analysed 28 samples from the Upper Kimmeridgian to Upper  
240 Tithonian-Lower Berriasian (the *Aulacostephanus eudoxus* Zone to the *Craspedites*  
241 *nodiger* Zone). The log of Hogg (1994) was based on data provided by VNIGRI, Saint  
242 Petersburg, and is correlated with other logs in Fig. 5. Hogg (1994) also did not erect a  
243 dinoflagellate cyst zonation and the dinoflagellate cyst range/abundance charts were not  
244 discussed in detail. Correlation of the Russian and English ammonite successions  
245 followed that of Lord et al. (1987).

246 Riding et al. (1999) provided the most detailed account of the dinoflagellate cyst  
247 biostratigraphy of the Gorodishche succession, as part of a dinoflagellate cyst zonation  
248 for the Bathonian to Berriasian of the Russian Platform. Twenty-four samples spanning  
249 the Upper Kimmeridgian to Upper Tithonian-Lower Berriasian (*Aulacostephanus*  
250 *eudoxus* Zone to *Craspedites nodiger* Zone) were examined, and each was linked to a  
251 bed number of Blom et al. (1984). Precise comparison of the samples of Riding et al.

252 (1999) with the present work is problematical but, in general terms, the uppermost ten  
253 samples (samples RP56 to RP47) overlap with the interval studied here.

254 Riboulleau et al. (2003, p. 180) studied the palynology of the Tithonian-Lower  
255 Berriasian from the Gorodishche section as part of a geochemical and sedimentological  
256 study, but did not provide any taxonomic details.

257

## 258 2.2. *Kashpir*

259

260 The Tithonian to Valanginian succession at Kashpir was described by Pavlov  
261 (1886), Gerasimov (1969) and Blom et al. (1984). Lithological logs of the section are  
262 illustrated in Figs. 4 and 6. A correlation of the logs of Mesezhnikov in Blom et al.  
263 (1984) and Lord et al. (1987) with the log herein is illustrated in Fig. 6. There are  
264 several key lithologies which are useful markers in matching the earlier logs and the  
265 more detailed present results. Bed 6 (a “bituminous shale”) of Blom et al. (1984)  
266 correlates with our bed 2 (a laminated siltstone). Similarly the coarse-grained beds in  
267 the *Virgatites virgatus* Zone and *Epivirgatites nikitini* Zone are represented by beds 9-  
268 12 of Blom et al. (1984); these correspond to beds 4-9 herein. Bed 18, a bituminous  
269 shale horizon, herein corresponds to bed 20 of Blom et al. (1984) which is a  
270 “bituminous....combustible shale”, and beds 21-24 herein are beds 22-26 of Blom et al.  
271 (1984) on the basis of sedimentological descriptions. Bed 24 herein, the questionably  
272 Valanginian sandstone with phosphatic concretions, correlates with bed 26 of Blom et  
273 al. (1984, p.124) which was described as “conglomerate...wax-red, consists of abundant  
274 phosphorite pebbles.” The mica-rich siltstones (beds 27-30) of the current investigation  
275 were not included in the log of Blom et al. (1984).

276 The marine palynology of this succession was briefly considered by Lord et al.  
277 (1987), who studied two samples from the Middle Tithonian (*Zaraskaites zarajskensis*  
278 Subzone) (beds 5 and 7 of Blom et al., 1984). More recently, Riding et al. (1999)  
279 analysed nine samples from the Middle Tithonian (*Zaraskaites zarajskensis* Subzone) to  
280 the Upper Berriasian (*Riasanites rjasanensis*/*Surites spasskensis* Zone). The uppermost  
281 five samples of Riding et al. (1999) (i.e. samples RP75 to RP71) correspond to the  
282 interval examined by us.

283

284

## 285 **3. The Middle Tithonian to Lower Valanginian dinoflagellate cyst biostratigraphy** 286 **of the Gorodishche and Kashpir successions**

287

288           The dinoflagellate cyst assemblages from Gorodishche and Kashpir are rich;  
289 over 300 forms were identified from the 70 samples studied (Smith, 1999; Fig. 4;  
290 Tables 1, 2). These are all listed, with author citations where appropriate, in Appendix  
291 1. The 70 samples are listed in Appendix 2. Tables 1 and 2 comprise the ranges and  
292 relative abundance data for all dinoflagellate cysts recorded herein. The ranges of  
293 morphotypes with stratigraphically restricted occurrences are illustrated in Figs. 7-10.  
294 Selected forms are illustrated in Plates I and II. Many of the taxa recovered have also  
295 been found in coeval sections from other Boreal regions.

296           The majority of the samples yielded abundant and diverse dinoflagellate cysts.  
297 Numerous taxa range across the entire interval examined. These comprise  
298 *Ambonosphaera? staffinensis*, *Cassiculosphaeridia magna*, *Cassiculosphaeridia*  
299 *reticulata*, *Chlamydophorella nyei*, *Chytroeisphaeridia chytroeides*, *Circulodinium*  
300 *distinctum*, *Dapsilidinium multispinosum*, *Dingodinium cerviculum*, *Dingodinium*  
301 *tuberosum*, *Gonyaulacysta* spp., *Hystrichodinium pulchrum*, *Leptodinium subtile*,  
302 *Pareodinia ceratophora*, *Prolixosphaeridium parvispinum*, *Sentusidinium rioultii*,  
303 *Sirmiodinium grossii*, *Stephanelytron membranoideum*, *Tanyosphaeridium isocalamum*,  
304 *Tanyosphaeridium magneticum*, *Tenua hystrix*, *Valensiella ovulum*, *Wallodinium*  
305 *cylindricum*, *Wallodinium krutzschii* and *Wrevittia* spp. (Tables 1, 2). Four taxa,  
306 *Cribroperidinium magnificum*, *Cribroperidinium undoryensis*, *Meiourogonyaulax*  
307 *distincta* and *Thalassiphora? robusta* are apparently indigenous to the Volga Basin  
308 (Smith and Harding, 2004). The dinoflagellate cyst nomenclature of Fensome and  
309 Williams (2004) is used throughout, and all author citations of the taxa discussed can be  
310 found in this index. Further information on the informal morphotypes referred to (e.g.  
311 *Cribroperidinium* sp. 1) can be found in Smith (1999). All samples, slides and figured  
312 specimens are housed in the collections of the School of Ocean and Earth Sciences,  
313 University of Southampton, Southampton Oceanography Centre, Southampton, United  
314 Kingdom.

315

### 316 *3.1. Middle Tithonian (the Zaraskaites zarajskensis Subzone of the Dorsoplanites* 317 *panderi Zone)*

318

319           This account refers mainly to the Gorodishche succession, where 20 samples  
320 were collected. Only two samples were collected from the Zaraskaites zarajskensis  
321 Subzone at Kaspir (Fig. 4). *Dingodinium tuberosum* is the most abundant form in this  
322 subzone where it ranges from 10-36%. Other taxa which are relatively prominent  
323 include *Chytroeisphaeridia chytroeides*, *Cometodinium whitei*, *Kleithriasphaeridium*

324 *fasciatum*, *Sirmiodinium grossii*, *Systematophora daveyi* and *Trichodinium* sp. 1.  
325 *Glossodinium dimorphum*, *Gochteodinia tuberculata* and *Thalassiphora? robusta* are  
326 restricted to the *Zaraskaites zarajskensis* Subzone in both sections (Tables 1, 2).

327 The last appearance datum (LAD) or range top of *Glossodinium dimorphum*  
328 occurs stratigraphically closer to the base of the *Virgatites virgatus* Zone at Kashpir  
329 than at Gorodishche (Figs. 7, 9). This may indicate a short stratigraphical gap beneath  
330 the base of the *Virgatites virgatus* Zone at Kashpir. *Cribroperidinium magnificum* and  
331 *Trichodinium* sp. 1, both of which have LADs in this Subzone at Gorodishche, have  
332 relatively extended ranges at Kashpir with LADs at the top of the *Craspedites subditus*  
333 and the top of the *Kachpurites fulgens* zones respectively. *Cribroperidinium*  
334 *erymnoseptatum* and *Cribroperidinium* sp. 6 have LADs close to the base of the  
335 *Zaraskaites zarajskensis* Subzone at Gorodishche, but do not occur at Kashpir (Figs. 7,  
336 9). This is consistent with the contention that samples were only taken from the upper  
337 part of this subzone at Kashpir. These two forms may thus serve to separate the upper  
338 and lower parts of this subzone, although more material needs to be examined from  
339 stratigraphically lower in this subzone at Kashpir in order to verify this. The LAD of  
340 consistent abundant (i.e. 10-36 %) *Dingodinium tuberosum* is coincident with the top of  
341 the *Zaraskaites zarajskensis* Subzone in both successions (Tables 1, 2).

342 Generally, taxa with FADs in the *Zaraskaites zarajskensis* Subzone at  
343 Gorodishche also have coeval range bases at Kashpir. There are two notable exceptions,  
344 firstly *Kleithriasphaeridium corrugatum* which first appears in the *Craspedites subditus*  
345 Zone at Kashpir. The second is *Senoniasphaera jurassica*, which appears near the top of  
346 the *Zaraskaites zarajskensis* Subzone at Gorodishche, but not until the *Kachpurites*  
347 *fulgens* Zone at Kashpir (Figs. 7, 9, 10).

348

### 349 3.2. Middle to Upper Tithonian (*Virgatites virgatus* and *Epivirgatites nikitini* zones)

350

351 This summary is taken entirely from Gorodishche; no samples from the  
352 *Virgatites virgatus* and *Epivirgatites nikitini* zones were collected from Kashpir (Fig. 4).  
353 Stratigraphically restricted taxa which consistently occur throughout the Middle and  
354 Upper Tithonian succession at Gorodishche include *Cometodinium whitei*,  
355 *Hystrichosphaeridium petilum*, *Kleithriasphaeridium fasciatum*, *Lithodinia* sp. 1,  
356 *Prolixosphaeridium parvispinum*, *Systematophora daveyi*, *Tehamadinium* sp. 1,  
357 *Trichodinium* cf. *T. ciliatum*, and *Tubotuberella apatela*. In addition, *Cribroperidinium*  
358 sp. 1 and *Tenua hystrix* appear consistently within the upper part of this interval (Tables  
359 1, 2).

360           Because these zones were not sampled at Kashpir, no direct comparisons can be  
361 made. However, several of the taxa with LADs in this interval at Gorodishche occur in  
362 younger deposits at Kashpir. *Dichadogonyaulax? chondra*, which has its LAD at  
363 Gorodishche at the base of the *Virgatites virgatus* Zone is last found in the *Craspedites*  
364 *subditus* Zone at Kashpir. *Hystrichosphaeridium petilum* and *Tehamadinium sousense*,  
365 which both have LADs in the *Virgatites virgatus* Zone at Gorodishche, both extend into  
366 the *Kachpurites fulgens* Zone at Kashpir. *Stiphrosphaeridium dictyophorum* and *Tenua*  
367 *hystrix*, both of which have LADs in the *Virgatites virgatus* and *Epivirgatites nikitini*  
368 zones at Gorodishche respectively, appear last in the Middle to Upper Berriasian at  
369 Kashpir. *Tehamadinium* sp. 1, which has its LAD in the *Epivirgatites nikitini* Zone at  
370 Gorodishche, last appears at Kashpir within the *Craspedites nodiger* Zone. Additionally,  
371 *Egmontodinium polyplacophorum* first appears in the *Virgatites virgatus* Zone at  
372 Gorodishche, but has a younger FAD at Kashpir, within the *Craspedites subditus* Zone  
373 (Figs. 7, 8, 9; Tables 1, 2).

374

375 *3.3. Upper Tithonian to Lower Berriasian (Kachpurites fulgens to Craspedites nodiger*  
376 *zones)*

377

378           Stratigraphically restricted dinoflagellate cysts which occur consistently and  
379 range through the Upper Tithonian to Lower Berriasian succession at Gorodishche  
380 include *Achomosphaera neptuni*, *Cribroperidinium* spp., *Egmontodinium toryna*,  
381 *Endoscrinium granulatum*, *Gochteodinia villosa*, *Gonyaulacysta dentata*,  
382 *Kleithriasphaeridium corrugatum*, *Kleithriasphaeridium eoinodes*,  
383 *Kleithriasphaeridium fasciatum*, *Kleithriasphaeridium porosispinum*, *Lithodinia* sp. 1,  
384 *Perisseiasphaeridium ingegerdiae*, *Prolixosphaeridium parvispinum*, *Senoniasphaera*  
385 *jurassica*, *Sentusidinium* aff. *S. ?fibrillospinosum*, *Sentusidinium* sp. 3, *Sirmiodinium*  
386 *grossii*, *Stanfordella exsanguia*, *Stephanelytron membranoideum*, *Stiphrosphaeridium*  
387 *dictyophorum*, *Systematophora daveyi*, *Tehamadinium daveyi*, *Trichodinium* cf. *T.*  
388 *ciliatum*, *Tubotuberella apatela*, *Valensiella ovula* and *Wrevittia* spp. (Tables 1, 2).

389           *Tehamadinium daveyi* has its FAD in the *Kachpurites fulgens* Zone in both  
390 sections. Other taxa with FADs in this zone at Kashpir include *Endoscrinium*  
391 *granulatum* and *Scrinioidinium inritibile*. These datums both occur in the *Zaraskaites*  
392 *zarajskensis* Subzone at Gorodishche. *Cribroperidinium nuciforme*, which has its LAD  
393 in the *Kachpurites fulgens* Zone at Gorodishche, last appears in the Middle–Upper  
394 Berriasian at Kashpir (Figs. 7-10; Tables 1, 2).

395 *Circulodinium compta* and *Stiphrosphaeridium anthophorum* have FADs in the  
396 Craspedites subditus Zone of both sections although the latter appears later, at the top of  
397 this zone in Kashpir. Furthermore, *Sentusidinium rioultii* also first appears in the  
398 Craspedites subditus Zone at Kashpir; at Gorodishche, however, this species has its  
399 FAD in the Virgatites virgatus Zone. *Leptodinium subtile* has its LAD in the  
400 Craspedites subditus Zone at both localities. *Cometodinium whitei* also last occurs in the  
401 Craspedites subditus Zone at Gorodishche but ranges slightly higher, to the base of the  
402 Craspedites nodiger Zone, at Kashpir (Figs, 7-10; Tables 1, 2).

403 *Tenua* cf. *T. hystrix* is the only taxon to have its FAD in the Craspedites nodiger  
404 Zone at Gorodishche, but was first recorded stratigraphically higher, from Middle to  
405 Upper Berriasian strata, at Kashpir. At Gorodishche, the only notable taxon with its  
406 LAD in the Craspedites nodiger Zone is *Circulodinium copei*. The extent of this taxon  
407 at Gorodishche contrasts markedly to that at Kashpir, where its FAD is within the  
408 Middle–Upper Berriasian. At Kashpir, *Gonyaulacysta dentata* and *Senoniasphaera*  
409 *jurassica* have LADs in the Craspedites nodiger Zone. However, at Gorodishche these  
410 taxa both have last occurrences in the unzoned phosphorite at the Jurassic/Cretaceous  
411 boundary (Figs, 7-10; Tables 1, 2).

412

#### 413 3.4. The Jurassic/Cretaceous boundary

414

415 The Jurassic/Cretaceous boundary is markedly different in the two successions,  
416 with most of the Berriasian being entirely absent at Gorodishche (Fig. 2). Here the  
417 boundary is marked by a phosphorite horizon (sample U33) with dinoflagellate cyst  
418 assemblages dominated by long-ranging taxa such as *Chytroeisphaeridia chytrooides*,  
419 *Hystriodinium pulchrum* and an abundance of the "*Cleistosphaeridium aciculum*"  
420 taxon group. Among the taxa with ranges extending above and below this horizon,  
421 *Circulodinium compta*, *Kleithriasphaeridium* spp., *Sirmiodinium grossii*,  
422 *Stephanelytron membranoidium*, *Trichodinium ciliatum* and *Wrevittia* spp. are relatively  
423 prominent (Table 1). At Kashpir, the Jurassic/Cretaceous boundary lies within a  
424 bituminous shale horizon (sample K10), which is barren of identifiable dinoflagellate  
425 cysts (Table 2).

426

#### 427 3.5. Middle to Upper Berriasian (unzoned to the *Surites tzikwinianus* Zone)

428

429 Much of the Middle and Upper Berriasian is absent at Gorodishche, hence no  
430 meaningful comparison with Kashpir can be made. However, *Exochosphaeridium*

431 *phragmites*, *Muderongia endovata*, *Pseudoceratium pelliferum* and *Sentusidinium* sp. 4  
432 first appear in the Middle to Upper Berriasian of Kashpir, and have FADs in the base of  
433 the overlying ?Valanginian mica-rich facies at Gorodishche (Fig. 10, Tables 1, 2).

434 The dinoflagellate cyst assemblages of the unzoned Middle to Upper Berriasian  
435 succession at Kashpir contain relatively prominent *Dingodinium tuberosum*,  
436 *Chytroeisphaeridia chytroeides*, *Circulodinium compta*, *Hystrichodinium pulchrum*,  
437 *Sentusidinium* spp., *Tenua* cf. *T. hystrix* and *Trichodinium* cf. *T. ciliatum*. Important  
438 taxa that consistently occur throughout the overlying Upper Berriasian Riasanites  
439 rjasanensis/Surites spasskensis zones-Surites tzikwinianus Zone at Kashpir are similar  
440 to the marine palynofloras from the Jurassic/Cretaceous boundary beds and the Middle  
441 Berriasian (Table 2).

442

### 443 3.6. Valanginian

444

445 There is no ammonite zonation for the post-Berriasian Lower Cretaceous strata  
446 of the two sections studied, somewhat hampering the accurate comparison of the two  
447 sets of dinoflagellate cyst data. In the Kashpir section the base of this unzoned  
448 succession is represented by bed 24, a sandstone horizon which includes phosphatic  
449 concretions (Fig. 4). This bed has yielded an extremely well-preserved dinoflagellate  
450 cyst assemblage (Smith and Harding, 2004). The biostratigraphical evidence from  
451 dinoflagellate cysts strongly suggests that the entire Valanginian succession is part of  
452 the same genetic unit and hence all these strata (bed 20 at Gorodishche and beds 24-31  
453 at Kashpir) belong to the same stage.

454 Biostratigraphically significant dinoflagellate cysts which consistently occur in  
455 this interval include *Achomosphaera neptuni*, *Cassiculosphaeridia reticulata*,  
456 *Chlamydophorella nyei*, *Circulodinium compta*, *Cometodinium habibii*, *Dapsilidinium*  
457 *multispinosum*, *Dingodinium tuberosum*, *Impletosphaeridium lumectum*,  
458 *Oligosphaeridium complex*, *Phoberocysta neocomica*, *Pseudoceratium pelliferum*,  
459 *Scriniodinium campanula*, *Sentusidinium* sp. and *Spiniferites ramosus* (Figs. 7-10;  
460 Tables 1, 2).

461 *Spiniferites ramosus* and *Wallodinium cylindricum* have FADs in the lowermost  
462 sample (K17) of the unzoned Early Cretaceous interval at Kashpir, with  
463 *Impletosphaeridium lumectum*, *Spiniferites primaevus* and *Warrenia? brevispinosa*  
464 having FADs somewhat higher, in samples K18 and K19. At Gorodishche the situation  
465 is similar with *Impletosphaeridium lumectum*, *Spiniferites ramosus* and *Warrenia?*  
466 *brevispinosa* having FADs in sample U34 at the base of the mica-rich siltstone facies.

467 The succession of the FADs of *Cometodinium habibii* and *Gardodinium* sp. 1, overlain  
468 by the FAD of *Phoberocysta tabulata* is present in both sections. Other taxa  
469 characteristic of this interval in both sections include *Batioladinium radiculatum*,  
470 *Meiourogonyaaulax bulloidea* and *Systematophora* sp. 1. Neither *Cymosphaeridium*  
471 *validum*, which appears in the uppermost part of the interval sampled at Gorodishche,  
472 nor *Nelchinopsis kostromiensis* (which first appears immediately above the base of the  
473 unzoned interval in that section) were encountered at Kashpir (Figs. 8, 10; Tables 1, 2).

474

475

#### 476 **4. Comparison of this study with other investigations from the Volga Basin**

477

478 Lord et al. (1987) studied the Tithonian of the Volga Basin, overlapping with the  
479 scope of the present investigation in coverage of the Zaraskaites zarajskensis Subzone  
480 of the Dorsoplanites panderi Zone. At Gorodishche these authors noted an interval of  
481 significant palynofloral change between beds 8 and 11 of Mesezhnikov (1977; 1984),  
482 with seven new forms appearing in the upper bed. Bed 11 correlates with beds 1-13  
483 herein, although Lord et al. (1987) only collected one sample from this interval. The  
484 assemblage recovered by Lord et al. (1987) proved similar to that encountered here, if  
485 slightly less diverse. Important elements such as *Chytroeisphaeridia chytroeides*,  
486 *Glossodinium dimorphum*, *Pareodinia ceratophora*, *Systematophora daveyi* (as  
487 *Emmetrocysta sarjeantii* (Gitmez 1970) Stover & Evitt 1978) and *Tubotuberella*  
488 *apatela* are common to both studies. Lord et al. (1987) recorded *Millioudodinium*  
489 *sarjeantii* (Vozzhennikova 1967) Stover & Evitt 1978 *sphaericum* (autonym) as first  
490 appearing in Bed 11 at Gorodishche and Bed 7 of Mesezhnikov (1977) (i.e. below the  
491 current interval studied) at Kashpir. *Millioudodinium sarjeantii sphaericum* of Lord et  
492 al. (1987, fig. 10.1, 10.2) is termed *Cribroperidinium erymnoseptatum* herein. This  
493 species was recorded in the lower part of the Zaraskaites zarajskensis Subzone in this  
494 study (Fig. 7).

495 Hogg (1994) studied the dinoflagellate cyst assemblages from 28 samples of  
496 Late Kimmeridgian to Early-Mid Berriasian age, of which the upper eight overlap with  
497 the interval considered herein. The assemblages recovered by Hogg (1994) were not  
498 discussed in detail; they are of similar composition to those in the present study.

499 *Cribroperidinium erymnoseptatum* was recorded by Hogg (1994) from a single sample  
500 in the Zaraskaites zarajskensis Subzone, possibly comparable to Bed 8 herein. This  
501 horizon may thus be stratigraphically above the FAD of this taxon indicated here.

502 *Gochteodinia villosa* was recorded by Hogg (1994) only from the Kachpurites fulgens

503 Zone, and similarly *Kleithriasphaeridium porosispinum* and *Stephanelytron*  
504 *membranoidium* were only recorded in the Kachpurites fulgens and Craspedites  
505 subditus zones. The majority of other stratigraphically useful taxa encountered herein  
506 were recorded by Hogg (1994) in similar stratigraphical positions.

507 The dinoflagellate cyst floras recorded by Riding et al. (1999) from the  
508 Tithonian to Middle Berriasian of the Russian Platform are broadly comparable to those  
509 observed here, although of somewhat lower diversity, particularly in the Virgatites  
510 virgatus and Epivirgatites nikitini zones. However, there are some significant  
511 differences between the two studies. *Cribroperidinium globatum* (Gitmez & Sarjeant  
512 1972) Helenes 1984 (considered to be 'prominent' through this interval by Riding et al.,  
513 1999), *Dichadogonyaulax? pannea* (Norris 1965) Sarjeant 1969, *Scriniodinium*  
514 *dictyotum* Cookson & Eisenack 1960 and *Tubotuberella rhombiformis* Vozzhennikova  
515 1967 were not encountered in the present study. *Tubotuberella rhombiformis* has not  
516 always been consistently distinguished from *Tubotuberella apatela* in the literature, and  
517 the present authors deem the stratigraphical value of this species to be questionable.  
518 Herein, all specimens of the *Tubotuberella apatela-rhombiformis* plexus which lack  
519 tabulation, or have weakly-expressed cingular ridges restricted to the lateral areas were  
520 assigned to *Tubotuberella apatela*. No specimens with well-developed tabulation  
521 typical of *Tubotuberella rhombiformis* were encountered herein. Several common taxa  
522 in the Tithonian to Middle Berriasian material examined herein were not discussed by  
523 Riding et al. (1999). These include *Cribroperidinium erymnoseptatum* (from the  
524 Zaraskaites zarajskensis Subzone), *Perisseiasphaeridium ingegerdiae* (which is  
525 common in the Epivirgatites nikitini to Craspedites subditus zones), and *Tehamadinium*  
526 and *Tenua* (both common in the Middle Tithonian to Middle Berriasian).

527 The palynofloras from the Middle-Upper Berriasian strata at Kashpir described  
528 by Riding et al. (1999) contrast markedly with those herein in terms of diversity and  
529 preservation. Riding et al. (1999) examined a single sample from this level, noting the  
530 most common elements of the flora to be *Cribroperidinium* spp., *Circulodinium*  
531 *distinctum* (Deflandre & Cookson 1955) Jansonius 1986, with additional  
532 *Cassiculosphaeridia* spp. In the present study *Chlamydophorella nyei*, *Dingodinium*  
533 spp., *Hystriodinium* spp. and *Sentusidinium* sp. 4, were all found to be common in  
534 this interval at Kashpir (Table 2). Other Middle to Upper Berriasian material studied by  
535 Riding et al. (1999) from the Oka Basin appears to bear closer resemblance to the  
536 assemblages studied herein. In particular, they encountered abundant *Circulodinium*  
537 *compta*, which Riding et al. (1999) noted is also common in the Middle to Upper  
538 Berriasian of northwest Europe.

539 Riding et al. (1999) considered *Muderongia endovata* (as *Muderongia simplex*  
540 Alberti 1961) and *Phoberocysta neocomica* to be indicative of the uppermost  
541 Berriasian. The taxon previously referred to as *Muderongia simplex* is now considered  
542 to be *Muderongia endovata* (see Riding et al., 2000). Some specimens of *Muderongia*  
543 *endovata* in the present study differ slightly from the species *sensu stricto*. This is  
544 because the periphragm is more closely fitting around the endocyst, the endocyst is less  
545 angular than described by Riding et al. (2000), and the lateral horns occasionally  
546 display the ‘bent’ terminations of Monteil (1991). This material is assigned to  
547 *Muderongia endovata* despite these minor morphological variations; it differs from  
548 *Muderongia tomaszowensis* in consistently having joined antapical horns (Type ATP II)  
549 instead of one axial horn (Type ATP I of Monteil, 1991). The FAD of *Muderongia*  
550 *endovata* herein is slightly older than this datum (as *Muderongia simplex*) noted by  
551 Riding et al. (1999). In this study, *Muderongia endovata* was first encountered at  
552 Kashpir in the unzoned Middle-Upper Berriasian (Fig. 10).

553 Species of *Cassiculosphaeridia* from the Volga Basin were not distinguished by  
554 Riding et al. (1999). These authors commented that although their *Cassiculosphaeridia*  
555 spp. are reminiscent of the earliest Cretaceous, their samples lacked reliable Middle-  
556 Upper Berriasian marker species. Numerous species of *Cassiculosphaeridia*, and the  
557 similar genus *Valensiella* were also encountered from the Middle-Upper Berriasian of  
558 Kashpir herein. *Cassiculosphaeridia pygmaeus* was confined to the Middle-Upper  
559 Berriasian of Kashpir, and thus may be of local stratigraphical significance in the  
560 Russian Platform (Fig. 10; Table 2).

561

562

### 563 **5. Comparison of key Tithonian-Valanginian dinoflagellate cyst ranges, principally** 564 **from northwest Europe and Russia, with those from Gorodishche and Kashpir**

565

566 There are many published latest Jurassic to earliest Cretaceous dinoflagellate  
567 cyst range data from northwest Europe (e.g. Riding and Thomas, 1992; Riding and  
568 Ioannides, 1996; Poulsen and Riding, 2003 and references therein). However,  
569 comparatively few of these studies describe dinoflagellate cyst occurrences from  
570 successions that are directly calibrated to the standard ammonite zones. This makes  
571 accurate wider stratigraphical correlations difficult. For example although Herengreen et  
572 al. (2000; 2003), Andsbjerg and Dybkjaer (2003) and Ineson et al. (2003) discussed  
573 Tithonian to Valanginian dinoflagellate cyst zonations of Denmark and the Netherlands,  
574 correlation to the standard ammonite zones is indirect. The ammonite zone boundaries

575 in these studies were based on earlier ammonite-calibrated dinoflagellate cyst zonations  
576 (K. Dybkjaer and G.F.W. Herngreen, personal communications, 2004). Nevertheless,  
577 there are several studies that have compared the dinoflagellate cyst biohorizons of  
578 northwest Europe with the Boreal standard ammonite zones throughout the Early  
579 Tithonian to Hauterivian. Several of these are mentioned below; the most recent is  
580 Poulsen and Riding (2003) for the Jurassic of Subboreal northwest Europe.

581 In this section, the ranges of the biostratigraphically significant Tithonian to  
582 Valanginian dinoflagellate cyst marker taxa recovered from Gorodishche and Kashpir  
583 are compared with ranges from other regions, principally northwest Europe and  
584 elsewhere in Russia (Figs. 11, 12). Where possible these data are used to help correlate  
585 the various Eurasian ammonite zonal schemes, or to date the Volga Basin strata which  
586 lack ammonite control.

587

#### 588 5.1. Mid to Late Tithonian (*pars*) (*Dorsoplanites panderi* to *Epivirgatites nikitini* zones)

589

590 Most of the dinoflagellate cysts in the Mid Tithonian *Zaraskaites zarajskensis*  
591 Subzone of the Volga Basin range into older strata (Lord et al., 1987; Hogg, 1994;  
592 Riding et al., 1999). These include *Egmontodinium toryna*, *Glossodinium dimorphum*,  
593 *Hystrichodinium pulchrum*, *Hystrichosphaeridium petilum*, *Leptodinium subtile*,  
594 *Rhynchodiniopsis martonense*, *Scriniodinium inritibile*, *Senoniasphaera jurassica*,  
595 *Sirmiodinium grossii*, *Systematophora daveyi*, *Tenua hystrix* and *Tubotuberella apatela*.  
596 All of these taxa are known from the Kimmeridgian and Tithonian of northwest Europe  
597 and Siberia (Woollam and Riding, 1983; Heilmann-Clausen, 1987; Poulsen, 1992;  
598 1994; 1996; Riding and Thomas, 1992; Bailey et al., 1997; Duxbury et al., 1999;  
599 Poulsen and Riding, 2003; Ilyina et al., 2005).

600 Consistent records of *Amphorula expirata* first appear in the Mid Tithonian  
601 *Pavlovia rotunda* Zone of northwest Europe (Barron, 1989). This species has its FAD in  
602 the Mid Tithonian *Dorsoplanites panderi* Zone at both Gorodishche and Kashpir (Figs.  
603 7, 9); this bioevent is within the *Zaraskaites zarajskensis* Subzone at Gorodische. This  
604 Mid Tithonian datum hence is apparently coeval and thus is of extensive correlative  
605 significance (Figs. 4, 11).

606 *Cribroperidinium erymnoseptatum* was recorded at Gorodishche from the lower  
607 part of the Mid Tithonian *Zaraskaites zarajskensis* Subzone (Fig. 7). This species is  
608 therefore likely to range below the interval examined, because it was recorded from the  
609 Kimmeridgian of the North Sea area (Bailey, 1993). *Cribroperidinium erymnoseptatum*  
610 is associated with diverse palynofloras including the *Circulodinium distinctum* group,

611 *Glossodinium dimorphum*, *Pareodinia ceratophora*, *Perisseiasphaeridium pannosum*  
612 and *Scriniodinium inritibile* (Tables 1, 2). Thus the occurrences and ranges of these taxa  
613 are similar in northwest Europe and the Volga Basin.

614 The FAD of *Gochteodinia villosa*, which was deemed to be the ‘most significant  
615 bioevent in the Portlandian’ by Stover et al. (1996, p.662), was recorded at the base of  
616 the Late Tithonian *Paracraspedites oppressus* Zone by Davey (1979), Woollam and  
617 Riding (1983), Riding (1984) and Riding and Thomas (1992). However, *Gochteodinia*  
618 *villosa* was reported from the base of the older Late Tithonian *Galbanites kerberus* Zone  
619 by Davey (1982), Heilmann-Clausen (1987) and Poulsen (1996), and from the Late  
620 Tithonian *Galbanites okusensis* Zone by Duxbury et al. (1999). The concensus thus is  
621 that this datum lies within the *Galbanites kerberus* to *Paracraspedites oppressus* zone  
622 interval. This bioevent was not discussed in relation to the Volga Basin by Riding et al.  
623 (1999), but this datum was given at the base of the Late Tithonian *Kachpurites fulgens*  
624 Zone in the Oka Basin. Herein, the oldest unequivocal specimens of *Gochteodinia*  
625 *villosa* were recorded from the lower part of the Late Tithonian *Epivirgatites nikitini*  
626 Zone at Gorodishche (Figs. 8, 11). This bioevent hence indicates a correlation of the  
627 *Epivirgatites nikitini* Zone of the Volga Basin with the *Galbanites kerberus* Zone of  
628 northwest Europe.

629 *Rhynchodiniopsis martonense* was recorded from the Mid Tithonian *Zaraskaiteis*  
630 *zarajskensis* Subzone and the lowermost part of the *Virgatites virgatus* Zone at  
631 Gorodishche (Fig. 7), and in the *Zaraskaiteis zarajskensis* Subzone by Riding et al.  
632 (1999, fig. 22). Bailey et al. (1997) described this species from the Mid Tithonian  
633 *Pectinatites hudlestoni* to *Pectinatites pectinatus* zones of northern England. Thus in the  
634 Volga Basin the stratigraphical distribution of this species is similar, perhaps ranging  
635 into slightly younger strata than in northwest Europe.

636 The range of *Athigmatocysta glabra* in the Volga Basin is significantly older  
637 than previously thought. It was recorded herein from the Mid Tithonian to latest  
638 Berriasian at Kashpir (Table 2). However in northwest Europe this taxon characterises  
639 the latest Berriasian to Hauterivian-Barremian interval (Duxbury, 1977; Davey, 1982).

640 The range top of *Glossodinium dimorphum* is within the Late Tithonian *Titanites*  
641 *anguiformis* Zone in northwest Europe (Riding and Thomas, 1992), although LADs of  
642 this taxon have been recorded within the Mid to Late Tithonian *Virgatopavlovia fittoni*,  
643 *Progalbanites albani*, *Galbanites okusensis* and *Paracraspedites oppressus* zones  
644 (Raynaud, 1978; Fisher and Riley, 1980; Haq et al., 1987; Heilmann-Clausen, 1987;  
645 Poulsen, 1996; Duxbury et al., 1999). Comparing the present study with that of Riding  
646 et al. (1999), it is clear that the LAD of *Glossodinium dimorphum* occurs at the top of

647 the Mid Tithonian Zaraskaites zarajskensis Subzone across the Russian Platform (Figs.  
648 7, 11), which is hence significantly older than this bioevent in northwest Europe.

649 *Isthmocystis distincta* has its range base at or near the base of the Late Tithonian  
650 Galbanites kerberus Zone in northwest Europe (Heilmann-Clausen, 1987; Riding and  
651 Thomas, 1992; Duxbury et al., 1999). Herein the FAD of this taxon was recorded from  
652 the middle of the Mid to Late Tithonian Virgatites virgatus Zone at Gorodishche (Fig.  
653 8); this datum lies within the Late Tithonian Kachpurites fulgens Zone at Kashpir (Fig.  
654 10). This means that the FAD of *Isthmocystis distincta* is slightly older in the  
655 Volga Basin than in northwest Europe, but it is a regional biomarker for the Mid to Late  
656 Tithonian in the Northern Hemisphere (Fig. 11).

657 *Scriniodinium pharo* has its FAD at the base of the Mid Tithonian Progalbanites  
658 albani Zone (Davey, 1982; Riding and Thomas, 1992; Poulsen, 1996). However, the  
659 FAD of consistent/common occurrences are within the earliest Berriasian  
660 Subcraspedites preplicomphalus Zone (Woollam and Riding, 1983; Duxbury et al.,  
661 1999). *Scriniodinium pharo* was reported from the uppermost Tithonian-Mid Berriasian  
662 of northeast Siberia by Nikitenko et al. (2008). This species was encountered near the  
663 base of the Mid Tithonian Zaraskaites zarajskensis Subzone in the present study (Figs.  
664 7, 9), which is broadly consistent with the record in northwest Europe (Fig. 11). This  
665 indicates that the FAD of *Scriniodinium pharo* is slightly older in the Volga Basin than  
666 in northwest Europe.

667 The range base of *Egmontodinium polyplacophorum* in northwest Europe is  
668 within the Early Tithonian Pectinatites elegans Zone (Woollam and Riding, 1983;  
669 Riding and Thomas, 1992; Poulsen, 1996). Other studies such as Riding and Thomas  
670 (1988) and Barron (1989) placed the FAD of consistent records of this species  
671 somewhat younger, within the Mid Tithonian. *Egmontodinium polyplacophorum* is rare  
672 in the Volga Basin, having its FAD in the Mid-Late Tithonian Virgatites virgatus Zone  
673 at Gorodishche (Fig. 8). By contrast, it first appears at Kashpir in the Late Tithonian  
674 Craspedites subditus Zone (Table 2). Due to the rarity of this species, further work may  
675 reveal older specimens from the Volga Basin, however the present study suggests that  
676 this range base is younger in Russia than in northwest Europe.

677 *Kleithriasphaeridium porosispinum*, which has its FAD in the Mid Tithonian  
678 Pectinatites pectinatus Zone in northwest Europe (Davey, 1982), was not noted below  
679 the Mid Tithonian, specifically the latest part of the Pavlovia pavlovi Subzone (of the  
680 Dorsoplanites panderi Zone) by Riding et al. (1999, fig. 26). These authors encountered  
681 "significant numbers" of *Kleithriasphaeridium porosispinum* in the Mid Tithonian  
682 Zaraskaites zarajskensis Subzone of the Dorsoplanites panderi Zone. This taxon was not

683 encountered below the Mid-Late Tithonian *Virgatites virgatus* Zone at Gorodishche  
684 herein (Figs. 8, 11). Therefore this bioevent appears to be younger in Russia than in  
685 northwest Europe.

686 The LAD of *Leptodinium subtile* has been variously placed between the top of  
687 the Progalbanites *albani* Zone (Woollam and Riding, 1983; Riding and Thomas, 1992)  
688 and the top of the Galbanites *okusensis* Zone (Davey, 1982) close to the Mid-Late  
689 Tithonian transition of northwest Europe. Riding et al. (1999) noted the last occurrence  
690 of this species from the top of the Mid Tithonian *Zaraskaites zarajskensis* Subzone at  
691 Gorodishche, and they suggested that this datum may have stratigraphical significance  
692 in the Russian Platform. By contrast, Lord et al. (1987) recorded the LAD of  
693 *Leptodinium subtile* significantly older, within the Early Tithonian *Ilowaiskya klimovi*  
694 Zone at Gorodishche. Herein this taxon was recorded in the Late Tithonian to Mid  
695 Berriasian, up to the *Craspedites subditus* Zone at both localities studied (Figs. 7, 9),  
696 although it is extremely rare above the Mid-Late Tithonian *Virgatites virgatus* Zone  
697 (Tables 1, 2). Thus *Leptodinium subtile* may range into slightly younger strata in the  
698 Volga Basin than has previously been recorded in northwest Europe (Fig. 11).

699 *Scriniodinium irritibile* has its LAD in northwest Europe in the Mid-Late  
700 Tithonian between the top of the Progalbanites *albani* Zone (Woollam and Riding,  
701 1983; Riding and Thomas, 1988; 1992; Poulsen, 1996), and the top of the Galbanites  
702 *okusensis* Zone (Davey, 1982). Riding et al. (1999) noted the LAD of this taxon at the  
703 top of the Mid Tithonian *Zaraskaites zarajskensis* Subzone in the Russian Platform.  
704 However, *Scriniodinium irritibile* was recovered in small proportions herein from  
705 stratigraphically higher, within the Upper Tithonian to Middle Berriasian succession (in  
706 the *Kachpurites fulgens* Zone at Gorodishche and the *Craspedites nodiger* Zone at  
707 Kashpir) (Figs. 7, 9, 11). Thus *Scriniodinium irritibile* ranges into younger strata in the  
708 Volga Basin than in northwest Europe (Fig. 11).

709 The FAD of *Senoniasphaera jurassica* is within the Mid Tithonian *Zaraskaites*  
710 *zarajskensis* Subzone at Gorodishche (Figs. 7, 11). This range base was also reported  
711 from the Mid-Late Tithonian of northeast Siberia by Nikitenko et al. (2008, fig. 5). In  
712 northwest Europe, the range base of significant numbers of this distinctive species is  
713 within the earliest Mid Tithonian *Pectinatites pectinatus* Zone (Riding and Thomas,  
714 1988, fig. 3). Hence this bioevent appears to be slightly younger in the Volga Basin.

715 Riding et al. (1999, fig. 26) noted the LAD of *Perisseiasphaeridium pannosum*  
716 at the top of the Late Tithonian *Epivirgatites nikitini* Zone in the Russian Platform.  
717 These authors commented that the range top of this species and that of the closely  
718 related taxon *Oligosphaeridium patulum* are thus younger than their earliest Mid

719 Tithonian LADs (*Pavlovia pallasoides* and *Pectinatites pectinatus* zones respectively)  
720 in England (Riding and Thomas, 1988). In Riding et al. (1999), *Oligosphaeridium*  
721 *patulum* was recorded only from the base of the Mid Tithonian *Zaraskaites zarajskensis*  
722 Subzone, whilst *Perisseiasphaeridium pannosum* was equally rare, and not recorded  
723 above this subzone. Ilyina et al. (2005, fig. 8) reported *Oligosphaeridium patulum* from  
724 the Mid and Late Tithonian of western Siberia. These taxa were both not encountered  
725 herein.

726 Riding et al. (1999) stated that the LAD of *Prolixosphaeridium parvispinum* is  
727 of stratigraphical significance in the Russian Platform at the top of the Late Tithonian  
728 Epivirgatites nikitini Zone. Herein *Prolixosphaeridium parvispinum* exhibits significant  
729 variations in the number and morphology of the processes. Specimens close to the  
730 holotype were recorded from the lower part of the Lower Cretaceous mica-rich  
731 siltstones in both sections herein (Tables 1, 2). Since these morphological variations  
732 appear to be gradational, all the specimens in this study were assigned to  
733 *Prolixosphaeridium parvispinum*. Thus the Late Tithonian Epivirgatites nikitini Zone  
734 LAD of Riding et al. (1999) appears not to be a reliable biomarker.

735 The Mid-Late Tithonian occurrences of *Apteodinium spinosum*, *Avellodinium*  
736 *falsificum*, *Cassiculosphaeridia magna*, *Cassiculosphaeridia reticulata*,  
737 *Chlamydophorella nyei*, *Cometodinium whitei*, *Dapsilidinium multispinosum*,  
738 *?Downiesphaeridium? aciculare*, *Exiguosphaera phragma*, *Kleithriasphaeridium*  
739 *corrugatum*, *Kleithriasphaeridium eoinodes*, *Kleithriasphaeridium fasciatum*,  
740 *Oligosphaeridium pulcherrimum*, *Stanfordella exsanguia*, *Stanfordella fastigiata*,  
741 *Stiphrosphaeridium dictyophorum*, *Tanyosphaeridium magneticum* and *Tehamadinium*  
742 *sousense* are recorded from significantly older strata in the Volga Basin than in reports  
743 from other Northern Hemisphere localities (e.g. Davey, 1974; Duxbury, 1977; 1979;  
744 Davies, 1983).

745 Similarly, the Mid-Late Tithonian and younger records of *Chytroeisphaeridia*  
746 *cerastes*, *Chytroeisphaeridia chytrooides*, *Circulodinium copei*, *Cribroperidinium*  
747 *nuciforme*, *Dichadogonyaulax? chondra*, *Gochteodinia tuberculata*, *Gonyaulacysta*  
748 *dentata* and *Perisseiasphaeridium ingegerdiae* from the Volga Basin (Tables 1, 2) are  
749 also anomalously young when compared to records from elsewhere in the Northern  
750 Hemisphere (Drugg, 1978; Raynaud, 1978; Nøhr-Hansen, 1986; Riding and Thomas,  
751 1988; Below, 1990; Bailey, 1993; Poulsen, 1996; Bailey et al., 1997). The disparity in  
752 the Callovian-Oxfordian stratigraphical ranges of *Chytroeisphaeridia cerastes*,  
753 *Cribroperidinium nuciforme* and *Gonyaulacysta dentata* (see Deflandre, 1938; Riding,  
754 1987; Riding and Thomas, 1997) between northwest Europe and the Volga Basin means

755 that the reports of these species from Gorodishche and Kashpir (Tables 1, 2) probably  
756 represent reworking.

757

758 *5.2. Late Tithonian (pars) to Early Berriasian (Kachpurites fulgens to Craspedites*  
759 *nodiger zones)*

760

761 The Upper Tithonian and Lower Berriasian successions at Gorodishche and  
762 Kashpir produced abundant and diverse marine palynofloras (Tables 1, 2). There are  
763 relatively few stratigraphically significant dinoflagellate cyst bioevents in this interval  
764 in northwest Europe (e.g. Riding and Thomas, 1992, fig. 2.14).

765 The range top of *Egmontodinium polyplacophorum* in northwest Europe is  
766 within the Late Tithonian Paracraspedites oppressus Zone (Davey, 1979; 1982;  
767 Woollam and Riding, 1983; Partington et al., 1993; Duxbury et al., 1999). However,  
768 this bioevent was subsequently revised to within the Subcraspedites preplicomphalus  
769 Zone of the Early Berriasian by Abbink et al. (2001, fig. 11). The Paracraspedites  
770 oppressus to Subcraspedites preplicomphalus Zone interval is equivalent to the  
771 Tithonian-Berriasian transition of the Russian Platform (Figs. 1, 3). *Egmontodinium*  
772 *polyplacophorum* was recorded from both sections herein. Its LAD is in the Craspedites  
773 nodiger Zone at Kashpir (Fig. 10); at Gorodishche, this species ranges from the Mid-  
774 Late Tithonian Virgatites virgatus Zone to the Late Tithonian Kachpurites fulgens Zone  
775 (Fig. 8). Hence, this important bioevent at Kashpir represents evidence for the  
776 correlation of the Subcraspedites preplicomphalus Zone of northwest Europe with the  
777 Craspedites nodiger Zone of the Volga Basin (Figs. 1, 3, 11).

778 The LAD of *Senoniasphaera jurassica* is within the Early Berriasian in the  
779 Volga Basin (Figs. 7, 9, 11). This bioevent in northwest Europe is somewhat equivocal  
780 (Poulsen and Riding, 1992, p. 29, 30). Several authors placed it within the Progalbanites  
781 albani Zone of the Mid Tithonian (Raynaud, 1978; Davey, 1979; Woollam and Riding,  
782 1983). Subsequently, this bioevent was assigned to within the Galbanites kerberus and  
783 Titanites anguiformis zones, i.e. stratigraphically younger in the Late Tithonian  
784 (Wimbledon and Hunt, 1983; Poulsen and Riding, 1992; Riding and Thomas, 1992;  
785 Poulsen, 1996; Duxbury et al., 1999). However, more recently Hunt (2004, fig. 3)  
786 reported *Senoniasphaera jurassica* from the Subcraspedites preplicomphalus Zone close  
787 to the Tithonian-Berriasian transition. Interestingly, Abbink et al. (2001) did not record  
788 *Senoniasphaera jurassica* from the Subcraspedites preplicomphalus Zone in the North  
789 Sea, hence it appears to be relatively rare in the latest Tithonian-Early Berriasian of  
790 northwest Europe. In the Russian Platform, the LAD of *Senoniasphaera jurassica* was

791 encountered by Riding et al. (1999) within the *Craspedites nodiger* Zone, and these  
792 authors suggested that this bioevent is a reliable marker for the Mid Tithonian to Early  
793 Berriasian in the Volga Basin. This is consistent with this bioevent recorded herein from  
794 Gorodishche and Kashpir (Figs 7, 9). Consequently, its reliability as a marker in the  
795 Russian Platform is confirmed. Despite the aforementioned lack of consensus on the  
796 precise LAD of *Senoniasphaera jurassica*, and its relative scarcity in the Late Tithonian  
797 and Early Berriasian in northwest Europe, this bioevent appears to be broadly coeval  
798 throughout the Northern Hemisphere based on the record of Hunt (2004). This provides  
799 strong evidence for the correlation of the *Craspedites nodiger* Zone with the  
800 *Subcraspedites preplicomphalus* Zone (Figs. 1, 3, 11). Nikitenko et al. (2008, fig. 5)  
801 reported sporadic occurrences of *Senoniasphaera jurassica* from the Mid-Late  
802 Berriasian of northeast Siberia. These isolated occurrences may represent reworking;  
803 this species is known to be somewhat prone to stratigraphical recycling (Poulsen and  
804 Riding, 1992, fig. 2).

805 *Circulodinium compta* has its FAD close to the base of the *Craspedites subditus*  
806 Zone in both sections (Figs. 8, 10). This datum is consistent with northwest Europe,  
807 where the range base of this species is typically in the Late Tithonian (Davey, 1982;  
808 Heilmann-Clausen, 1987; Abbink et al., 2001). The occurrence of *Ellipsoidictyum*  
809 *cinctum* in the Late Tithonian (*Craspedites subditus* Zone) of Kashpir (Table 2) is  
810 consistent with the Mid-Late Jurassic range of this taxon (Riding et al., 1985; Barron,  
811 1989; Riding, 2005). Similarly, the range base of *Hystrichodinium voigtii* was observed  
812 in the Late Tithonian (*Kachpurites fulgens* Zone) of Kashpir (Table 2). This bioevent  
813 was reported from the Mid and Late Tithonian of Denmark by Davey (1982), hence this  
814 datum can help to recognise this interval.

815 *Tehamadinium daveyi* ranges from the Late Tithonian *Kachpurites fulgens* Zone  
816 to the Late Berriasian of the Volga Basin (Figs. 8, 10). This taxon has been recorded  
817 from the Mid-Late Berriasian and Valanginian in northwest Europe (Jan du Chêne et  
818 al., 1986, fig. 8). Costa and Davey (1992) reported the FAD of this species from the  
819 latest Berriasian (*Peregrinoceras albidum* Zone). Hence the Late Tithonian occurrences  
820 from Gorodishche and Kashpir are the oldest records known.

821 The LAD of *Scriniodinium inritibile* lies in the latest Tithonian-Early Berriasian  
822 at Gorodishche and Kashpir (Figs. 7, 9). By contrast, this bioevent in northwest Europe  
823 is of Mid Tithonian age (*Virgatopavlovia fittoni* and *Progalbanites albani* zones) (Fisher  
824 and Riley, 1980; Riding and Thomas, 1992; Riding and Fensome, 2002; Poulsen and  
825 Riding, 2003). Similarly, *Stiphrosphaeridium anthophorum* first occurs in the Late  
826 Tithonian (*Craspedites subditus* Zone) of the Volga Basin (Tables 1, 2); however, this

827 species has a Mid Tithonian range base in Europe (Heilmann-Clausen, 1987).  
828 *Systematophora areolata* was recorded at Kashpir from the Late Tithonian (Craspedites  
829 subditus Zone) to the Late Berriasian (Table 2). In northwest Europe, this distinctive  
830 chorate species ranges from the Oxfordian to the Late Tithonian (Raynaud, 1978;  
831 Riding, 1987), hence the reports from Kashpir are significantly younger.

832 The Early Berriasian and younger records of *Gonyaulacysta eisenackii*, *Kalyptea*  
833 *diceras* and *Kleithriasphaeridium telaspinosum* from Kashpir (Table 2) are also  
834 anomalously young when compared to records from elsewhere (Cookson and Eisenack,  
835 1960; Fisher and Riley, 1980; Poulsen, 1996). The disparity in the Callovian-Oxfordian  
836 range of *Gonyaulacysta eisenackii* (see Riding, 1987; Riding and Thomas, 1997)  
837 between northwest Europe and the Volga Basin means that the reports of this species  
838 from Kashpir (Table 2) probably represent reworking. By contrast, the occurrences of  
839 *Gonyaulacysta speciosa* in the Early Berriasian of the Volga Basin (Tables 1, 2) are  
840 anomalously old compared to the Early Barremian records of this taxon in western  
841 Europe (Harding, 1990).

842

843 *5.3. Late Berriasian (Riasanites rjasanensis/Surites spasskensis and Surites*  
844 *tzikwinianus zones)*

845

846 Upper Berriasian strata are best developed at Kashpir, and this succession has  
847 yielded abundant and diverse marine palynofloras (Tables 1, 2).

848 The LAD of *Amphorula expirata* is within the Mid to Late Berriasian at Kashpir  
849 (Table 2); this is consistent with the Late Berriasian (Hectoroceras kochi Zone) range  
850 top in northwest Europe (Abbink et al., 2001). The FAD of *Batioladinium? gochtii*  
851 occurs at the base of the Late Berriasian Riasanites rjasanensis/Surites spasskensis  
852 zones at Kashpir (Fig. 10). Iosifova (1996) also reported the range base of this species  
853 in the lower part of the Riasanites rjasanensis/Surites spasskensis zones of the Moscow  
854 Basin. Thus this datum appears to be a reliable marker for the Late Berriasian  
855 throughout western Russia. The range of *Batioladinium radiculatum* is from the Late  
856 Berriasian (Riasanites rjasanensis/Surites spasskensis zones) to the Valanginian at  
857 Gorodishche and Kashpir (Figs. 8, 10). This is broadly consistent with Davey (1982),  
858 Poulsen (1996) and Duxbury et al. (1999) who reported the FAD of this species from  
859 the Mid-Late Berriasian. The range base of *Cribroperidinium volkovae* is in the upper  
860 part of the Riasanites rjasanensis/Surites spasskensis zones (Iosifova, 1996).  
861 *Cribroperidinium* cf. *C. volkovae* herein differs slightly from *Cribroperidinium*  
862 *volkovae sensu stricto* in having intratabular tuberculae and numerous penitabular

863 features (Smith, 1999). The FAD of *Cribroperidinium* cf. *C. volkovae* at Kashpir is  
864 within the Surites tzikwinianus Zone (Fig. 10). The range bases of *Cribroperidinium*  
865 *volkovae* and *Cribroperidinium* cf. *C. volkovae* are thus broadly similar across the  
866 Russian Platform, and are reliable markers for the latest Berriasian in this area. The  
867 range of *Lagenorhysis delicatula* is latest Berriasian/earliest Valanginian  
868 (*Peregrinoceras albidum* and *Paratollia* zones) to earliest Hauterivian (*Endemoceras*  
869 *amblygonium* Zone) in northwest Europe (Duxbury, 1977; 2001; Davey, 1982; Costa  
870 and Davey, 1992). At Kashpir, the range of rare *Lagenorhysis delicatula* is within the  
871 Valanginian mica-rich siltstones (Fig. 10). Hence this distinctive species appears to be a  
872 reliable Valanginian marker throughout the Northern Hemisphere.

873         The range bases of *Muderongia endovata*, *Phoberocysta neocomica*,  
874 *Phoberocysta tabulata*, *Pseudoceratium brevicornutum* and *Pseudoceratium pelliferum*  
875 are all within the latest Berriasian (*Surites stenomphalus* and *Peregrinoceras albidum*  
876 zones) of northwest Europe (e.g. Duxbury, 1977; Davey, 1979; Woollam and Riding,  
877 1983; Heilmann-Clausen, 1987; Costa and Davey, 1992; Poulsen and Riding, 2003).  
878 Because of their close morphological resemblance to the extant motile dinoflagellate  
879 genus *Ceratium*, these have been termed ‘pseudoceratioid’ cysts (Wall and Evitt, 1975;  
880 Woollam and Riding, 1983, p. 14). Riding et al. (1999, fig. 31) recorded the FADs of  
881 *Muderongia endovata* and *Phoberocysta neocomica* within the Riasanites  
882 rjasanensis/Surites spasskensis zones, and *Pseudoceratium pelliferum* at the top of the  
883 Surites tzikwinianus Zone in the Russian Platform. Herein, the FAD of *Muderongia*  
884 *endovata* at Kashpir is at the top of the unzoned Middle-Upper Berriasian succession  
885 (Table 2), hence is slightly stratigraphically older than in northwest Europe.  
886 Furthermore, the inceptions of *Phoberocysta neocomica* and *Pseudoceratium pelliferum*  
887 are in the upper part of the Late Berriasian Surites tzikwinianus Zone, and the FAD of  
888 *Phoberocysta tabulata* is stratigraphically younger (Figs. 8, 10). The FAD of  
889 *Phoberocysta neocomica* herein is therefore slightly later than noted by Riding et al.  
890 (1999). The FAD of *Phoberocysta tabulata* apparently occurs in the Valanginian of the  
891 Volga Basin (Fig. 12), i.e. stratigraphically younger than in northwest Europe.  
892 However, the range bases of ‘pseudoceratioid’ cysts such as *Phoberocysta neocomica*  
893 and *Pseudoceratium pelliferum* are reliable markers for the Late Berriasian throughout  
894 northwest Europe and the Russian Platform (Fig. 12).

895         The range of *Pseudoceratium brevicornutum* is latest Berriasian (*Peregrinoceras*  
896 *albidum* Zone) to Early Valanginian (*Polyptychites* Zone) (Heilmann-Clausen (1987;  
897 Herngreen et al., 2000; Davey, 2001). Late Valanginian and Early Hauterivian records  
898 were interpreted as reworking by Herngreen et al. (2000, p. 50). This species was

899 recorded herein from the Late Berriasian (*Surites tzikwinianus* Zone) to within the  
900 earliest Valanginian at Kashpir (Figs. 10, 12). This means that the range base of  
901 *Pseudoceratium brevicornutum* at Kashpir in the Volga Basin is a reliable tie-point  
902 between the *Surites tzikwinianus* Zone and the *Peregrinoceras albidum* Zone. The LAD  
903 of this form at the base of the mica-rich siltstones at Kashpir is consistent with a  
904 Valanginian age; this bioevent indicates a correlation with the *Paratollia* and  
905 *Polyptychites* zones of northwest Europe.

906 In northwest Europe, *Systematophora daveyi* ranges from the Kimmeridgian to  
907 the Late Berriasian (*Hectoroceras kochi* Zone) (Davey, 1982; Riding and Thomas,  
908 1988; Abbink et al., 2001; Poulsen and Riding, 2003). In the Volga Basin, the LAD of  
909 *Systematophora daveyi* is within the unzoned Middle-Upper Berriasian succession  
910 (Figs. 7, 9), thus this datum is comparable in both regions. *Systematophora palmula* is  
911 confined to the Mid-Late Berriasian (samples K13-K16) at Kashpir (Fig. 10). In  
912 northwest Europe, this species is typical of the latest Berriasian and Early Valanginian  
913 (*Surites stenomphalus* to *Polyptychites* zones) (Davey, 1982; Costa and Davey, 1992;  
914 Duxbury, 2001). However, Heilmann-Clausen (1987) reported *Systematophora palmula*  
915 from the Late Berriasian (*Hectoroceras kochi* Zone), hence this taxon appears to be a  
916 reliable marker for the Mid-Late Berriasian in the Northern Hemisphere.

917 The FAD of *Achomosphaera neptuni* was recorded from the Mid Tithonian to  
918 Mid Berriasian at Gorodishche and Kashpir respectively (Figs. 7, 9). By contrast, the  
919 range base of *Achomosphaera neptuni* is a reliable marker for the latest Berriasian  
920 (*Peregrinoceras albidum* Zone) in northwest Europe (Davey, 1979; Heilmann-Clausen,  
921 1987; Costa and Davey, 1992; Duxbury et al., 1999). Riding et al. (1999, fig. 23)  
922 recorded a single, questionable specimen of *Achomosphaera?* sp. from the unzoned  
923 Middle-Upper Berriasian succession at Kashpir. The specimens assigned to  
924 *Achomosphaera neptuni* in this study from the Mid Tithonian to Mid Berriasian have  
925 thinner cyst walls than are typical for this species. Unequivocal specimens of  
926 *Achomosphaera neptuni* were encountered herein from within the unzoned Middle  
927 Berriasian succession into the Valanginian. The Mid-Late Tithonian occurrences from  
928 Gorodishche hence represent the oldest known examples of *Achomosphaera*. Therefore  
929 the FAD of *Achomosphaera neptuni* (*sensu lato*) in the Mid-Late Tithonian in the Volga  
930 Basin is significantly earlier than in northwest Europe.

931 The range of *Wallothinium anglicum* at Kashpir is Late Berriasian (*Surites*  
932 *spasskensis* Zone) to Valanginian (Table 2). This is not consistent with the significantly  
933 younger Late Albian-Early Cenomanian range reported by Cookson and Hughes (1964).

934 Previous reports of *Tehamadinium evittii* are Kimmeridgian-Early Berriasian  
935 (Dodekova, 1969; Jan du Chêne et al., 1986). This species was recorded in small  
936 numbers from the Late Berriasian (Surites spasskensis Zone) to Valanginian at Kashpir  
937 (Table 2), hence these occurrences represent an extension of the range of this taxon into  
938 the Valanginian. Similarly, the Mid-Late Berriasian to Valanginian occurrences of  
939 *Cribroperidinium venustum*, *Endoscrinium granulatum* and *Lithodinia arcanitabulata*  
940 (Tables 1, 2) are also anomalously young compared to the Mid Oxfordian-Early  
941 Tithonian, Tithonian and Late Oxfordian-Early Kimmeridgian ranges respectively of  
942 these species in Europe (Klement, 1960; Raynaud, 1978; Brenner, 1988; Feist  
943 Burkhardt and Wille, 1992; Poulsen, 1996).

944 The FAD of rare *Walloodinium luna* is within the Surites spasskensis Zone of  
945 Kashpir (Table 2); this is consistent with its Berriasian range base in Australia (Morgan,  
946 1980). Similarly, *Cassiculosphaeridia pygmaeus* may be a good biomarker. The range  
947 of this species in Australia is Berriasian (Stevens, 1987), and it is present in the Mid-  
948 Late Berriasian and Valanginian at Kashpir (Table 2). *Apteodinium spongiosum* is  
949 present in the Late Berriasian to Valanginian at Kashpir (Table 2). This species was  
950 reported from the Valanginian of arctic Canada by McIntyre and Brideaux (1980),  
951 hence may be a reliable long-range marker for the earliest Cretaceous.

952

#### 953 5.4. Valanginian (unzoned)

954

955 Sandstones and siltstones of Valanginian age are present at Kashpir and  
956 Gorodishche; these beds are significantly thicker at Kashpir (Fig. 4). These successions  
957 have produced abundant and diverse dinoflagellate cyst associations (Tables 1, 2).

958 The cosmopolitan species *Egmontodinium toryna* was recorded from the Mid  
959 and Late Tithonian to the Early Cretaceous of Gorodishche and Kashpir (Figs. 7, 9). At  
960 Kashpir, the LAD of this taxon is in Bed 29, within the Valanginian mica-rich  
961 siltstones. The range top of *Egmontodinium toryna* is within the earliest Valanginian  
962 Paratollia Zone in northwest Europe (Duxbury, 1977; 2001; Davey, 1979; Heilmann-  
963 Clausen, 1987; Costa and Davey, 1992). This bioevent is thus considered to be a key  
964 marker for the earliest Valanginian in Europe and Russia.

965 The LAD of *Gochteodinia villosa* was noted by Riding et al. (1999, figs. 24, 26,  
966 31) within the Late Berriasian Riasanites rjasanensis/Surites spasskensis zones in the  
967 Russian Platform. However in this study, this datum was recorded in the earliest  
968 Valanginian at Kashpir (Fig. 9). In northwest Europe, the range top of *Gochteodinia*  
969 *villosa* is highly characteristic of the Berriasian/Valanginian transition (Peregrinoceras

970 albidum and Paratollia zones) (Davey, 1982; Heilmann-Clausen, 1987; Costa and  
971 Davey, 1992). Therefore, this datum is a reliable regional marker in the Northern  
972 Hemisphere for the Berriasian/Valanginian boundary.

973 *Scriniodinium campanula* has its FAD in the Valanginian of the Volga Basin  
974 (Figs. 8, 10). The range base of this species has been recorded from the latest Berriasian  
975 in northwest Europe (Riding and Fensome, 2002, fig. 2). Hence this bioevent is of  
976 widespread biostratigraphical significance for the Berriasian-Valanginian transition.  
977 The large and distinctive species *Scriniodinium pharo* is present in the Mid and Late  
978 Tithonian to Valanginian of both Gorodishche and Kashpir. The LAD is in the lower  
979 part of the Valanginian mica-rich siltstones in both sections (Figs. 8, 10, Tables 1, 2).  
980 The range top of this taxon is well-established, and lies within the Early Valanginian  
981 Paratollia Zone in northwest Europe (Duxbury, 1977; 2001; Davey, 1982; Woollam and  
982 Riding, 1983; Heilmann-Clausen, 1987; Costa and Davey, 1992). This datum is  
983 therefore considered to be a reliable regional marker for the earliest Valanginian  
984 throughout the Northern Hemisphere.

985 *Spiniferites primaevus* is confined to the Valanginian at Gorodishche and  
986 Kashpir (Figs. 8, 10, 12; Tables 1, 2). In northwest Europe, the FAD of this species lies  
987 within the Early Valanginian, in the earliest Paratollia Zone (Duxbury, 1977; Heilmann-  
988 Clausen, 1987; Costa and Davey, 1992). This means that the range base of this species  
989 has widespread correlative significance for the Early Valanginian in the Northern  
990 Hemisphere. The FAD of *Spiniferites ramosus* was noted herein from the earliest  
991 Valanginian. This is the base of the mica-rich siltstone (Bed 20) at Gorodishche, and  
992 within the phosphatic concretion-bearing siltstone unit (Bed 24) at Kashpir (Figs. 8, 10,  
993 12). The range base of this distinctive and important species is within the Paratollia  
994 Zone of the Early Valanginian in northwest Europe (Davey, 1979; 1982; Heilmann-  
995 Clausen, 1987; Costa and Davey, 1992). It hence is clear that this bioevent has  
996 widespread correlative significance. *Tanyosphaeridium magneticum* was reported from  
997 the Valanginian of the Arctic by Davies (1983), hence the records in the Volga Basin  
998 (Tables 1, 2) are broadly consistent with this range.

999 The FADs of *Cymosphaeridium validum*, *Nelchinopsis kostromiensis* and  
1000 *Oligosphaeridium complex*, and the LADs of *Kleithriasphaeridium porosipinum* and  
1001 *Tubotuberella apatela* are of Early Valanginian age in northwest Europe (Davey, 1979;  
1002 1982; Heilmann-Clausen, 1987; Costa and Davey, 1992; Duxbury, 2001). In the Volga  
1003 Basin, these datums are present in the Valanginian mica-rich siltstones (Figs. 7-10).  
1004 These data confirm the utility of these bioevents as regional biomarkers for the Early  
1005 Valanginian of northwest Europe and the Russian Platform.

1006 Several taxa recorded from the Early Cretaceous of the Volga Basin herein are  
1007 typical of this interval in western Europe. Some of these forms have ranges which  
1008 extend stratigraphically younger than the Valanginian in Europe. These include  
1009 *Achomosphaera neptuni*, *Aprobolocysta trycheria*, *Cymosphaeridium validum*,  
1010 *Kleithriasphaeridium corrugatum*, *Kleithriasphaeridium eoinodes*, *Isthmocystis*  
1011 *distincta*, *Nelchinopsis kostromiensis*, *Phoberocysta neocomica*, *Phoberocysta tabulata*,  
1012 *Pseudoceratium pelliferum*, *Spiniferites ramosus* and *Trichodinium ciliatum* (Figs. 7-10;  
1013 Tables 1, 2). Others, such as *Exochosphaeridium phragmites*, are characteristic of  
1014 younger intervals within the Early Cretaceous of northwest Europe (Davey, 1982; Costa  
1015 and Davey, 1992).

1016 *Aprobolocysta galeata* was recorded in the Valanginian of Gorodishche (Table  
1017 1). This species was originally reported from the Valanginian to earliest Hauterivian of  
1018 Western Australia (Backhouse, 1987), hence may be a reliable long-range index taxon.  
1019 *Meiourogonyaulax bulloidea* is another typically Australian species present in the  
1020 Volga Basin (Tables 1, 2). Its range in the Southern Hemisphere is Early-Mid Tithonian  
1021 to earliest Valanginian (Riding and Helby, 2001), hence the range top may be a reliable  
1022 marker for the Valanginian.

1023 The range of rare *Batioladinium jaegeri* at Gorodishche is Valanginian (Table  
1024 2). This is inconsistent with the significantly younger latest Hauterivian to Cenomanian  
1025 range in northwest Europe (Duxbury, 1977; Costa and Davey, 1992). The Valanginian  
1026 mica-rich siltstones at Gorodishche and Kashpir yield several taxa noted by Iosifova  
1027 (1996) from the Hauterivian of Tchernaya Retchka in the Moscow Basin. These include  
1028 *Batioladinium? gochtii*, *Cribroperidinium cf. C. volkovae*, *Sentusidinium* sp. 4,  
1029 *Spiniferites* sp. 2 and *Warrenia? brevispinosa* (Figs. 8, 10). Iosifova (1996) did not  
1030 report any typical marker species for the Late Valanginian-Hauterivian of northwest  
1031 Europe from the Moscow region.

1032 By contrast, the Valanginian occurrences of *Dingodinium tuberosum*,  
1033 *Gochteodinia mutabilis*, *Gonyaulacysta pectinigera*, *Impletosphaeridium lumectum* and  
1034 *Mendicodinium reticulatum* from Gorodishche and Kashpir (Tables 1, 2) are  
1035 significantly younger when compared to their records from northwest Europe (Sarjeant,  
1036 1960; Morgenroth, 1970; Fisher and Riley, 1980; Woollam and Riding, 1983; Riding et  
1037 al., 1985). The particularly large disparity in the Late Pliensbachian range of  
1038 *Mendicodinium reticulatum* (see Morgenroth, 1970) between northwest Europe and the  
1039 Volga Basin records means that the occurrences of this species from Kashpir (Table 2)  
1040 may represent reworking.

1041

1042 5.5. Important Tithonian to Valanginian dinoflagellate cyst bioevents in the Volga  
1043 Basin and their correlation to ammonite zones

1044

1045 Six dinoflagellate cyst events were identified as prime markers for stratal  
1046 correlations between the Tithonian to Valanginian successions in the Volga Basin and  
1047 northwest Europe. These key bioevents provide strong evidence for establishing  
1048 equivalencies between the ammonite zones in both these regions. These are:

1049

- 1050 • The FAD of *Gochteodinia villosa*. This bioevent occurs at the base of the Late  
1051 Tithonian Epivirgatites nikitini Zone in the Volga Basin (Fig. 11). It has been  
1052 reported from the base of the Late Tithonian Galbanites okusensis, Galbanites  
1053 kerberus and Paracraspedites oppressus zones in northwest Europe. This  
1054 important datum strongly indicates a correlation of the bases of the Late  
1055 Tithonian Epivirgatites nikitini Zone and the Galbanites kerberus Zone, and  
1056 hence that the Mid-Late Tithonian ammonite zonal correlations of Krymholts et  
1057 al. (1988) are more accurate than those of Hantzpergue et al. (1998) (Fig. 3).  
1058
- 1059 • The LAD of *Egmontodinium polyplacophorum*. This biomarker is within the  
1060 Late Tithonian-Early Berriasian Craspedites nodiger Zone at Kashpir. In  
1061 northwest Europe, this range top lies within the earliest Berriasian  
1062 Subcraspedites preplicomphalus Zone (Abbink et al., 2001). This biomarker at  
1063 Kashpir thus supports the correlation of the Subcraspedites preplicomphalus  
1064 Zone of northwest Europe with the Craspedites nodiger Zone of the Volga Basin  
1065 (Fig. 3).  
1066
- 1067 • The LAD of *Senoniasphaera jurassica*. This bioevent was noted in the Late  
1068 Tithonian-Early Berriasian Craspedites nodiger Zone by Riding et al. (1999, fig.  
1069 26) and at both Gorodishche and Kashpir herein (Fig. 9). This bioevent is  
1070 characteristic of the earliest Berriasian Subcraspedites preplicomphalus Zone in  
1071 northwest Europe (Hunt, 2004). This datum in the Volga Basin is thus consistent  
1072 with the correlation of the Subcraspedites preplicomphalus Zone of northwest  
1073 Europe with the Craspedites nodiger Zone of the Volga Basin (Fig. 3).  
1074
- 1075 • The FAD of *Pseudoceratium pelliferum*. This study and Riding et al. (1999)  
1076 established this datum within the upper part of the Late Berriasian Surites  
1077 tzikwinianus Zone of the Volga Basin (Fig. 10). In northwest Europe, this datum

1078 occurs at the base of the latest Berriasian *Peregrinoceras albidum* Zone (e.g.  
1079 Davey, 1979; Heilmann-Clausen, 1987; Poulsen, 1996). Thus this important  
1080 bioevent provides additional evidence for the correlation of the upper part of the  
1081 *Surites tzikwinianus* Zone with the *Peregrinoceras albidum* Zone (Fig. 3).

1082

1083 • The entire range of *Pseudoceratium brevicornutum*. The range base and range  
1084 top of *Pseudoceratium brevicornutum* are excellent biomarkers for the latest  
1085 Berriasian to Early Valanginian of the Northern Hemisphere respectively. In the  
1086 Volga Basin, this species ranges from the upper part of the Late Berriasian  
1087 *Surites tzikwinianus* Zone to immediately above the base of the unzoned  
1088 Valanginian strata (Fig. 12). In northwest Europe, this species is present in the  
1089 *Peregrinoceras albidum* to *Polyptychites* Zone interval (e.g. Heilmann-Clausen,  
1090 1987). Thus the range base of this taxon confirms the equivalence of the upper  
1091 part of the *Surites tzikwinianus* Zone with the *Peregrinoceras albidum* Zone.

1092

1093 • The FADs of *Spiniferites primaevus* and *Spiniferites ramosus*. These datums  
1094 occur at the base of the unzoned Valanginian strata in the Volga Basin (Fig. 12),  
1095 and from within the earliest Valanginian *Paratollia* Zone in northwest Europe  
1096 (e.g. Duxbury, 1977; Davey, 1979). These markers thus support the Early  
1097 Valanginian age for these horizons at Gorodishche and Kashpir. Other  
1098 biomarkers for the Early Valanginian of the Volga Basin include the LADs of  
1099 *Scriniodinium pharo* and *Tubotuberella apatela*, and the FAD of  
1100 *Oligosphaeridium complex*.

1101

1102 Three dinoflagellate cyst bioevents have been identified herein that appear to be  
1103 useful for stratal correlation across the Volga Basin and the wider Russian Platform.

1104 These are:

1105

1106 • The LAD of *Glossodinium dimorphum*. This datum marks the top of the Mid  
1107 Tithonian *Zaraskaites zarajskensis* Subzone in the Russian Platform based on  
1108 Riding et al. (1999, figs. 26, 31) and herein (Fig. 7).

1109

1110 • The FAD of *Batioladinium? gochtii*. This range base occurs at the base of the  
1111 Late Berriasian *Riasanites rjasanensis*/*Surites spasskensis* Zone in the Volga and  
1112 Moscow Basins (Fig. 10 and Iosifova, 1996 respectively). Hence this bioevent is  
1113 a reliable index for the base of the Late Berriasian in western Russia.

1114

1115 • The FAD of *Cribroperidinium* cf. *C. volkovae*. This datum of this form occurs  
1116 within the Late Berriasian *Surites tzikwinianus* Zone at Kashpir in the Volga  
1117 Basin (Fig. 10). The range base of *Cribroperidinium volkovae sensu stricto* is  
1118 known from the upper part of the Late Berriasian *Riasanites rjasanensis*/*Surites*  
1119 *spasskensis* Zone in the Moscow Basin (Iosifova, 1996). This datum is closely  
1120 correlative in both areas, and is thus a useful marker for the Late Berriasian of  
1121 western Russia.

1122

1123

## 1124 **6. The ages of the non ammonite-bearing strata at Gorodishche and Kashpir**

1125

1126 In this section, the ages of five intervals at Gorodishche and Kashpir which have  
1127 not yielded ammonites are discussed based on dinoflagellate cyst stratigraphy.

1128

### 1129 *6.1. The age of Bed 19 at Gorodishche*

1130

1131 Bed 19 at Gorodishche is a phosphorite unit which was assigned to the  
1132 Valanginian by Blom et al. (1984). One sample, number U33, was taken from this unit  
1133 (Fig. 4), which yielded a diverse dinoflagellate cyst assemblage (Table 1). Many long-  
1134 ranging taxa such as *Chlamydotheca nyei*, *Sirmiodinium grossii* and *Tubotuberella*  
1135 *apatela* are present. Some forms which are somewhat reminiscent of the Early  
1136 Cretaceous such as *Cassiculosphaeridia reticulata*, *Kleithriasphaeridium corrugatum*,  
1137 *Stanfordella fastigiata* and *Tehamadinium daveyi* were observed. However, no  
1138 unequivocal Berriasian/Valanginian markers are present in Bed 19. The most  
1139 stratigraphically diagnostic taxon in sample U33 is *Senoniasphaera jurassica*. The  
1140 range top of this species is indicative of the earliest Berriasian *Subcraspedites*  
1141 *preplicomphalus* Zone in northwest Europe (Hunt, 2004), which equates to the  
1142 *Craspedites nodiger* Zone of the Volga Basin. The occurrence of *Dingodinium*  
1143 *tuberosum* in this sample is consistent with a latest Tithonian-Early Berriasian age  
1144 (Woollam and Riding, 1983). Furthermore, the lack of any significant change in the  
1145 flora of Bed 19 compared to horizons sampled immediately below it strongly suggests  
1146 that sample U33 belongs to the *Craspedites nodiger* Zone (Table 1).

1147

### 1148 *6.2. The age of beds 18 to 22 at Kashpir*

1149

1150           These strata are presumed to belong to the Mid-Late Berriasian Garniericeras  
1151 subclypeiforme-Hectoroceras kochi zone interval of the Russian Platform, although  
1152 whether this includes a hiatus in the Volga Basin is not known. The LADs of  
1153 *Amphorula expirata* and *Systematophora daveyi* occur in samples K13 and K11  
1154 respectively (Table 2). These datums are characteristic of the Late Berriasian  
1155 Hectoroceras kochi Zone (e.g. Davey, 1982; Abbink et al., 2001). Furthermore, the  
1156 FAD of *Systematophora palmula* is in sample K13 (Table 2). This range base is known  
1157 to be within the Hectoroceras kochi Zone (Heilman-Clausen, 1987). One apparently  
1158 anomalous occurrence is the FAD of *Muderongia endovata* in sample K13 (Table 2).  
1159 This bioevent is normally characteristic of the latest Berriasian (e.g. Duxbury, 1977;  
1160 Davey, 1979), hence the Mid-Late Berriasian age of of K13 is arguably somewhat  
1161 questionable. Other taxa such as *Cassiculosphaeridia reticulata*, *Stiphrosphaeridium*  
1162 *dictyophorum* and *Tehamadinium daveyi* are consistent with a Mid-Late Berriasian age.

1163

### 1164 6.3. The age of Bed 24 at Kashpir

1165

1166           The phosphatic concretion-bearing Bed 24, and the overlying strata, at Kashpir  
1167 were assigned to the Hauterivian by Blom et al. (1984). However no characteristically  
1168 Hauterivian dinoflagellate cyst taxa such as *Aprobolocysta eilema* Duxbury 1977,  
1169 *Canningia duxburyi* Harding 1990 or *Oligosphaeridium abaculum* Davey 1979 were  
1170 found from sample K17, which was taken from this unit (Fig. 4).

1171           The occurrences of *Circulodinium compta*, *Pseudoceratium brevicornutum*,  
1172 *Scriniodinium pharo*, *Spiniferites ramosus* and *Tubotuberella apatela* (Fig. 10; Table  
1173 2), in the absence of any reliable Late Valanginian or Hauterivian markers, indicates  
1174 that Bed 24 at Kashpir is of Early Valanginian age. The range tops of *Circulodinium*  
1175 *compta*, *Pseudoceratium brevicornutum*, *Scriniodinium pharo* and *Tubotuberella*  
1176 *apatela* and the range base of *Spiniferites ramosus* are all within the earliest  
1177 Valanginian Paratollia Zone (e.g. Davey, 1982; Heilman-Clausen, 1987; Costa and  
1178 Davey, 1992). Sample K17 represents the range base of *Spiniferites ramosus* and the  
1179 range top of *Tubotuberella apatela* at Kashpir (Fig. 10; Table 2), which provides  
1180 especially compelling biostratigraphical evidence. Further evidence for an earliest  
1181 Valanginian age is that sample K17 lies within the range of *Egmontodinium toryna* at  
1182 Kashpir (Fig. 10; Table 2). The range of *Egmontodinium toryna* is Mid-Late Tithonian  
1183 to earliest Valanginian (Duxbury, 1977; Riding and Thomas, 1988). The occurrences of  
1184 forms in sample K17 with latest Berriasian range bases such as *Muderongia endovata*,

1185 *Pseudoceratium pelliferum* and *Scriniodinium campanula* (Fig. 10; Table 2) are  
1186 consistent with this earliest Valanginian age assessment.

1187 In summary, Bed 24 is attributed to the lower part of the Paratollia Zone of  
1188 northwest Europe. Using the correlation scheme of Hoedemaeker (1991), the Paratollia  
1189 Zone correlates with the Pseudogarnieria undulatoplicatilis Zone of the Russian  
1190 Platform.

1191

1192

#### 1193 6.4. The age of Bed 20 at Gorodishche and beds 27 to 30 at Kashpir

1194

1195 Samples U34 to U40 inclusive were collected from Bed 20 at Gorodishche, and  
1196 samples K19 to K30 inclusive were taken from beds 27 to 30 at Kashpir (Appendix 2).  
1197 These mica-rich siltstone beds represent the youngest intervals studied herein (Fig. 4),  
1198 and have yielded relatively abundant and diverse dinoflagellate cyst associations  
1199 (Tables 1, 2).

1200 Bed 20 at Gorodishche yielded several key dinoflagellate cysts which are  
1201 indicative of an earliest Valanginian age. The cooccurrences of *Circulodinium compta*,  
1202 *Cymosphaeridium validum*, *Oligosphaeridium complex*, *Scriniodinium pharo*,  
1203 *Spiniferites primaevus* and *Spiniferites ramosus* is indicative of the the Paratollia Zone.  
1204 Similarly, beds 27 to 30 at Kashpir also yielded taxa characteristic of the earliest  
1205 Valanginian Paratollia Zone. These are *Circulodinium compta*, *Egmontodinium toryna*,  
1206 *Lagenorhytis delicatula*, *Oligosphaeridium complex*, *Scriniodinium pharo*, *Spiniferites*  
1207 *primaevus* and *Spiniferites ramosus* (see Duxbury, 1977; 2001; Davey, 1979; 1982;  
1208 Heilmann-Clausen, 1987; Costa and Davey, 1992). At both localities, the presence of  
1209 taxa such as *Achomosphaera neptuni*, *Exiguisphaera phragma*, *Meiourogonyaulax*  
1210 *bulloidea*, *Muderongia endovata*, *Phoberocysta neocomica*, *Phoberocysta tabulata*,  
1211 *Pseudoceratium pelliferum* and *Scriniodinium campanula* is entirely consistent with the  
1212 Early Valanginian; no Late Valanginian or Hauterivian markers were observed (Figs. 7-  
1213 10; Tables 1, 2).

1214 To conclude, these micaceous siltstones are correlated to the Paratollia Zone of  
1215 northwest Europe; according to Hoedemaeker (1991), this zone is equivalent to the  
1216 Pseudogarnieria undulatoplicatilis Zone of the Russian Platform.

1217

1218

## 1219 **7. The Tithonian to Early Valanginian dinoflagellate cyst zonation of the Volga** 1220 **Basin**

1221

1222 Five dinoflagellate cyst zones are erected for the Tithonian to Early Valanginian  
1223 of the Volga Basin herein, two of which are further divided into seven subzones. These  
1224 are defined below and illustrated in Fig. 13. All the zones and subzones are interval  
1225 zones of Salvador (1994). The zone and subzone boundaries are defined on first or last  
1226 occurrences of selected taxa. Existing zonal index taxa and other important marker taxa  
1227 known from northwest Europe were used where possible. First appearances were  
1228 chosen in preference to last occurrences, due to the potential significance of reworking  
1229 in condensed sections such as Gorodishche and Kashpir. First appearance datums  
1230 (FADs) or range bases which have similar stratigraphical positions across the Russian  
1231 Platform or in northwest Europe are used to augment and extend the dinoflagellate cyst  
1232 zonation proposed by Riding et al. (1999). The biozonation proposed here for the Volga  
1233 Basin is the most detailed hitherto, although its regional applicability has yet to be  
1234 tested. The key datums in the proposed zonation is compared with those in Riding et al.  
1235 (1999) for the Russian Platform, and other schemes of biozones for northwest Europe  
1236 (Figs. 11, 12).

1237

#### 1238 7.1. *The Glossodinium dimorphum (Gdi) Zone*

1239

1240 Definition. The interval from the LAD of *Subtilisphaera? inaffecta* (Drugg 1978) Bujak  
1241 and Davies 1983 (see Riding et al., 1999, figs. 26, 31), to the LAD of *Glossodinium*  
1242 *dimorphum* and the FAD of *Perisseiasphaeridium ingegerdiae* (Figs. 11, 13).

1243 Age. Late Jurassic, Early to Mid Tithonian (Ilowaiskya sokolovi, Ilowaiskya  
1244 pseudoscythica and Dorsoplanites panderi zones).

1245 Reference section. Gorodishche.

1246 Typical dinoflagellate cyst assemblages. The lower part of the Gdi Zone is characterised  
1247 by abundant *Batiacasphaera* spp., *Dingodinium* spp.,

1248 *Downiesphaeridium/Impletosphaeridium* spp. and *Systematophora daveyi*, with

1249 common *Chytroeisphaeridia chytroeides*, *Circulodinium* spp., *Kleithriasphaeridium*  
1250 *fasciatum* and *Pareodinia* spp. Forms which are sporadically present are *Cometodinium*

1251 *whitei*, *Cribroperidinium* spp., *Lithodinia* sp. 1, *Prolixosphaeridium parvispinum*,

1252 *Sentusidinium* sp. 3, *Sirmiodinium grossii* and *Tehamadinium* sp. 1. Rare, but

1253 characteristic floral elements include *Gochteodinia tuberculata*, *Glossodinium*

1254 *dimorphum*, *Rhynchodiniopsis martonense*, *Tehamadinium sousense* and

1255 *Thalassiphora?* sp. Additionally, *Cribroperidinium erymnoseptatum* and *Trichodinium*

1256 sp. 1 are rare but typical of the lower part of the zone (Figs. 7-10, Tables 1, 2).

1257 Remarks. The *Glossodinium dimorphum* Zone broadly follows the definition of Riding  
1258 et al. (1999, p. 68, 69), but the upper boundary is additionally defined by the FAD of  
1259 *Perisseiasphaeridium ingegerdiae*. The base of the *Glossodinium dimorphum* Zone  
1260 (RPJ15) Zone of Riding et al. (1999) extends stratigraphically below the base of the  
1261 *Zaraskaites zarajskensis* Subzone, and hence below the base of the interval studied  
1262 herein. Therefore the lowermost marker of this zone, the LAD of *Subtilisphaera?*  
1263 *inaffecta*, was not observed in this study, but follows Riding et al. (1999, fig. 31).  
1264 Herein the LAD of *Glossodinium dimorphum* occurs below the top of the *Zaraskaites*  
1265 *zarajskensis* Subzone at Gorodishche, and at the top of this subzone at Kashpir (Figs. 7,  
1266 9). The absence of the lenticular-bedded facies at the top of this subzone at Kashpir  
1267 suggests the presence of a short stratigraphical gap at this level, which may be  
1268 responsible for this minor incoherence (Fig. 4). For this reason, the upper limit of the  
1269 zone is defined by the LAD of *Glossodinium dimorphum* and the FAD of  
1270 *Perisseiasphaeridium ingegerdiae*, which occurs at the base of the *Virgatites virgatus*  
1271 Zone at Gorodishche (Fig. 8).

1272 The definition of the upper boundary of the *Glossodinium dimorphum* Zone is  
1273 slightly emended herein, but the interval is as originally defined by Riding et al. (1999)  
1274 for the entire Russian Platform. The zone corresponds to the *Pectinatites wheatleyensis*  
1275 to *Virgatopavlovia fittoni* zones of the standard Boreal ammonite scheme (Fig. 11). The  
1276 LAD of *Glossodinium dimorphum* in the Russian Platform is apparently significantly  
1277 stratigraphically lower than in northwest Europe, where the range top is reported within  
1278 the *Titanites anguiformis* Zone (Davey, 1979; Woollam and Riding, 1983). However,  
1279 Raynaud (1978) and Fisher and Riley (1980) recorded this bioevent within the  
1280 *Progalbanites albani* Zone, i.e. virtually coeval with the Russian Platform. No  
1281 equivalent interval has been recorded in the Arctic provinces of the Boreal Realm.

1282

## 1283 7.2. *The Perisseiasphaeridium ingegerdiae (Pin) Zone*

1284

1285 Definition. The interval from the LAD of *Glossodinium dimorphum* and the FAD of  
1286 *Perisseiasphaeridium ingegerdiae*, to the FAD of *Gochteodinia villosa* (Figs. 11, 13).  
1287 Age. Late Jurassic, Mid to Late Tithonian (*Virgatites virgatus* Zone).

1288 Reference section. Gorodishche.

1289 Typical dinoflagellate cyst assemblages. This interval is characterised by abundant  
1290 *Systematophora daveyi* and common *Chlamydophorella nyei*, *Circulodinium* spp.,  
1291 *Cribroperidinium* spp., *Tenua hystrix* and *Trichodinium* cf. *T. ciliatum*. *Dingodinium*  
1292 spp., *Kleithriasphaeridium fasciatum* and *Sirmiodinium grossii* are sporadically

1293 significant (Figs. 7-10, Tables 1, 2). The *Perisseiasphaeridium ingegerdiae* Zone is  
1294 distinguished from the underlying *Glossodinium dimorphum* Zone by the relatively low  
1295 abundances of *Batiacasphaera* spp. and *Dingodinium* spp., and by the increased  
1296 abundance of *Chlamydothorella nyei* and *Trichodinium* cf. *T. ciliatum*, together with  
1297 the presence of *Achomosphaera neptuni*, *Impletosphaeridium* sp. 1 and  
1298 *Perisseiasphaeridium ingegerdiae*. It is distinguishable from the overlying Gvi Zone by  
1299 the absence of *Gochteodinia villosa* (Figs. 7-10, Tables 1, 2).

1300 Remarks. The *Perisseiasphaeridium ingegerdiae* Zone is intercalated between the  
1301 *Glossodinium dimorphum* and *Gochteodinia villosa* zones, and is hence comparable to  
1302 the *Senoniasphaera jurassica* Zone of Riding et al. (1999, p. 69). The latter zone was  
1303 not used herein as *Senoniasphaera jurassica* was not recovered from the *Virgatites*  
1304 *virgatus* Zone (Figs. 7-10, Tables 1, 2). *Perisseiasphaeridium ingegerdiae* was not  
1305 recorded by Riding et al. (1999). Poulsen (1996) stated that *Perisseiasphaeridium*  
1306 *ingegerdiae* ranges from the *Aulacostephanus mutabilis* to *Aulacostephanus*  
1307 *autissiodorensis* zones in Denmark. Nøhr-Hansen (1986) recorded this species from the  
1308 *Aulacostephanus mutabilis* and *Aulacostephanus eudoxus* zones. In the Volga Basin,  
1309 however, the range extends into the Valanginian at Gorodishche; it is unequivocally  
1310 present in the Late Berriasian *Surites tzikwinianus* Zone (Fig. 9). Thus the FAD of  
1311 *Perisseiasphaeridium ingegerdiae* may be of local significance in the Volga Basin, and  
1312 its range appears to be markedly different to that in northwest Europe.

1313

### 1314 7.3. The *Gochteodinia villosa* (Gvi) Zone

1315

1316 Definition. The interval between the FAD of *Gochteodinia villosa*, and the FADs of  
1317 *Cribroperidinium* cf. *C. volkovae* and *Pseudoceratium pelliferum* (Figs. 11-13).

1318 Age. Late Jurassic, Late Tithonian (*Epivirgatites nikitini* Zone) to Early Cretaceous,  
1319 Late Berriasian (lower part of the *Surites tzikwinianus* Zone).

1320 Reference sections. Gorodishche and Kashpir.

1321 Typical dinoflagellate cyst assemblages. This interval is characterised by abundant  
1322 *Systematophora daveyi* with common *Batiacasphaera* spp., ?*Downiesphaeridium*?  
1323 *aciculare*, *Gochteodinia villosa*, *Perisseiasphaeridium ingegerdiae*, *Tehamadinium*  
1324 *daveyi* and *Trichodinium* cf. *T. ciliatum*. Also sporadically significant are *Dingodinium*  
1325 *tuberosum*, *Hystrichodinium pulchrum*, *Impletosphaeridium* sp. 1, *Kleithriasphaeridium*  
1326 *porosispinum* and *Stephanelytron membranoidium*. The Early Cretaceous assemblages  
1327 contain abundant to common *Batiacasphaera* spp., *Chytroeisphaeridia chytroeides*,

1328 *Circulodinium compta*, *Dingodinium tuberosum* and *Hystriodinium pulchrum*. *Tenua*  
1329 cf. *T. hystrix* is sporadically important (Figs. 7-10, Tables 1, 2).  
1330 Remarks. This zone is broadly equivalent to the *Pareodinia dasyforma* Zone of Davey  
1331 (1979, p. 66) for northwest Europe except that the upper limit is additionally defined by  
1332 the FAD of *Cribroperidinium* cf. *C. volkovae*. It is not possible to locate the upper limit  
1333 of this zone with accuracy in this study because only one sample was taken from the top  
1334 of the *Surites tzikwinianus* Zone at Kashpir (Fig. 3). This top of the zone is hence  
1335 tentatively placed within the *Surites tzikwinianus* Zone, between samples K15  
1336 (uppermost *Riasanites rjasanensis*/*Surites spasskensis* Zone) and K16 (uppermost  
1337 *Surites tzikwinianus* Zone).

1338 The Gvi zone as defined herein differs from the *Gochteodinia villosa* Zone of  
1339 Riding et al. (1999, fig. 31) in that the first appearance of the index, and thus the base of  
1340 the interval, is within the *Epivirgatites nikitini* Zone at Gorodishche (Fig. 8). This is  
1341 stratigraphically lower than previously recorded (Fig. 11). In northwest Europe, the  
1342 base of the *Gochteodinia villosa* Zone is normally taken as at the base of the  
1343 *Paracraspedites oppressus* Zone (Davey, 1979; Woollam and Riding, 1983; Riding and  
1344 Thomas, 1992, Poulsen and Riding, 2003). Other studies have reported *Gochteodinia*  
1345 *villosa* from the underlying *Galbanites okusensis* and *Galbanites kerberus* zones (e.g.  
1346 Davey, 1982; Heilmann-Clausen, 1987). Therefore the regional FAD of *Gochteodinia*  
1347 *villosa* supports the correlation of the base of the *Epivirgatites nikitini* Zone of the  
1348 Volga Basin with the *Galbanites okusensis* Zone of northwest Europe of Krymholts et  
1349 al. (1988) (Fig. 3).

1350 The upper limit of the zone herein is slightly higher than that of Riding et al.  
1351 (1999) since the range base of *Pseudoceratium pelliferum* was recorded in the upper  
1352 part of the *Surites tzikwinianus* Zone at Gorodishche (Fig. 10). However this may not  
1353 reflect the true FAD due to a sampling gap (see above). The FAD of *Pseudoceratium*  
1354 *pelliferum* in the Volga Basin thus correlates well with this bioevent in northwest  
1355 Europe at the base of the *Peregrinoceras albidum* Zone (e.g. Davey, 1979, Woollam and  
1356 Riding, 1983; Heilmann-Clausen, 1987). Other authors have placed this range base  
1357 within the underlying *Surites stenomphalus* Zone (Costa and Davey, 1992; Duxbury et  
1358 al., 1999). Both these bioevents are consistent with the correlation of the *Surites*  
1359 *tzikwinianus* Zone of the Russian Platform with the *Surites stenomphalus* and  
1360 *Peregrinoceras albidum* zones of the Boreal standard (Krymholts et al., 1988) (Fig. 3).  
1361 Subzones. The *Gochteodinia villosa* Zone is subdivided into four interval subzones.  
1362 These are based on dinoflagellate cyst data of local and regional stratigraphical

1363 importance in the Russian Platform, but they are not comparable to the subdivisions of  
1364 this zone in northwest Europe.

1365

1366 Subzone a

1367 Definition. The interval from the FAD of *Gochteodinia villosa* to the FAD of  
1368 *Circulodinium compta* (Figs. 11, 13).

1369 Age. Late Jurassic, Late Tithonian (*Epivirgatites nikitini* and *Kachpurites fulgens*  
1370 zones).

1371 Reference section. Gorodishche.

1372

1373 Subzone b

1374 Definition. The interval from the FAD of *Circulodinium compta*, to the FADs of  
1375 *Cassiculosphaeridia pygmaeus* and *Muderongia endovata* (Figs. 11-13).

1376 Age. Late Jurassic, Late Tithonian (*Craspedites subditus* Zone) to Early Cretaceous,  
1377 Mid-Late Berriasian, within the earliest part of the Berriasian unzoned interval. The  
1378 latter is equivalent to the Mid to Late Berriasian interval (*Garniericeras subclypeiforme*-  
1379 *Hectoroceras kochi* zones) of the Russian Platform, and the Mid to Late Berriasian  
1380 *Praetollia* (*Runctonia*) *runctoni* and *Hectoroceras kochi* zones of the Boreal standard.

1381 Reference section. Kashpir.

1382

1383 Subzone c

1384 Definition. The interval from the FADs of *Cassiculosphaeridia pygmaeus* and  
1385 *Muderongia endovata*, to the FAD of *Batioladinium? gochtii* (Figs. 12, 13).

1386 Age. Early Cretaceous, Mid to Late Berriasian, the Berriasian unzoned interval to  
1387 earliest Late Berriasian, the lowermost part of the *Riasanites rjasanensis*/*Surites*  
1388 *spasskensis* Zone.

1389 Reference section. Kashpir.

1390

1391 Subzone d

1392 Definition. The interval from the FAD of *Batioladinium? gochtii*, to the FADs of  
1393 *Cribroperidinium* cf. *C. volkovae* and *Pseudoceratium pelliferum* (Figs. 12, 13).

1394 Age. Early Cretaceous, Late Berriasian, the lowermost part of the *Riasanites*  
1395 *rjasanensis*/*Surites spasskensis* Zone to the lower part of the *Surites tzikwinianus* Zone).

1396 Reference section. Kashpir.

1397 Remarks. Subzones c and d can be distinguished from subzones a and b by the  
1398 increased abundances of *Achomosphaera neptuni*, *Circulodinium compta*,

1399 *Sentusidinium* sp. 4 and *Tenua* cf. *T. hystrix*, and by the absence of *Systematophora*  
1400 *daveyi*. The FADs of *Batioladinium?* *gochtii* and *Muderongia endovata* are comparable  
1401 to bioevents noted by Iosifova (1996) from the Moscow Basin, and are therefore of  
1402 regional stratigraphical significance in the Russian Platform. The FADs of  
1403 *Cassiculosphaeridia pygmaeus* and *Circulodinium compta* are at different levels in  
1404 other parts of the Russian Platform, and hence are of local stratigraphical significance in  
1405 the Volga Basin.

1406

#### 1407 7.4. *The Pseudoceratium pelliferum (Ppe) Zone*

1408

1409 Definition. The interval from the FADs of *Cribroperidinium* cf. *C. volkovae* and  
1410 *Pseudoceratium pelliferum*, to the FAD of *Spiniferites ramosus* and the LAD of  
1411 *Gochteodinia villosa* (Figs. 12, 13).

1412 Age. Early Cretaceous, Late Berriasian (upper part of the *Surites tzikwinianus* Zone).

1413 Reference section. Kashpir.

1414 Typical dinoflagellate cyst assemblages. The single horizon examined from the Ppe

1415 Zone, sample K16, contains abundant *Dingodinium* spp., and common

1416 *Chlamydotheca nyei*, *Chytroesphaeridia chytroeides*, *Circulodinium compta*,

1417 *?Downiesphaeridium? aciculare*, *Impletosphaeridium* sp. 1, *Kleithriasphaeridium*

1418 *corrugatum* and *Sentusidinium* sp. 4. Rare, but stratigraphically important forms are

1419 *Cribroperidinium* cf. *C. volkovae*, *Phoberocysta neocomica*, *Pseudoceratium*

1420 *brevicornutum* and *Pseudoceratium pelliferum* (Figs. 7-10, Tables 1, 2).

1421 Remarks. The Ppe Zone herein corresponds to the upper part of the unnamed zone

1422 (RPK1) of Riding et al. (1999, p. 70). RPK1 is the interval from the LAD of

1423 *Gochteodinia villosa* to the FAD of *Pseudoceratium pelliferum*. The base of the Ppe

1424 Zone as defined herein correlates with the base of the *Pseudoceratium pelliferum* Zone

1425 in northwest Europe (e.g. Davey, 1979; Woollam and Riding, 1983). The FAD of

1426 *Pseudoceratium pelliferum* is an important bioevent providing independent evidence for

1427 the correlation of the Russian *Surites tzikwinianus* Zone with the *Surites stenomphalus*

1428 and *Peregrinoceras albidum* zones of the Boreal standard. Davey (1979; 1982) placed

1429 the FAD of *Spiniferites ramosus* within the *Paratollia* Zone, and thus positioned the top

1430 of the *Pseudoceratium pelliferum* Zone at this level. This important FAD also allows

1431 correlation between the earliest Valanginian of northwest Europe and the Russian

1432 Platform.

1433

#### 1434 7.5. *The Spiniferites ramosus (Sra) Zone*

1435

1436 Definition. The interval from the FAD of *Spiniferites ramosus* and the LAD of  
1437 *Gochteodinia villosa*, to the top of the interval studied (Figs. 12, 13).

1438 Age. Early Cretaceous, Early Valanginian.

1439 Reference sections. Gorodishche and Kashpir for the Early Valanginian, and various  
1440 sections in northwest Europe described by Davey (1979) for the Late Valanginian.

1441 Typical dinoflagellate cyst assemblages. *Achomosphaera neptuni*, *Chlamydomphorella*  
1442 *neyi*, *Circulodinium compta*, *Dapsilidinium multispinosum*, *Dingodinium* spp.,

1443 *Impletosphaeridium lumectum*, *Impletosphaeridium* sp. 1, *Kleithriasphaeridium*

1444 *corrugatum*, *Sentusidinium* sp. 4 and *Stephanelytron membranoidium* are common to

1445 abundant. Sporadically significant forms include *Cassiculosphaeridia reticulata*,

1446 *Chytroeisphaeridia chytrooides*, *Circulodinium* spp., *Cometodinium habibii*,

1447 *?Downiesphaeridium? aciculare*, *Nelchinopsis kostromiensis*, *Oligosphaeridium*

1448 *complex*, *Phoberocysta neocomica*, *Spiniferites ramosus*, *Spiniferites* sp. 2, *Tenua* cf. *T.*

1449 *hystrix* and *Warrenia? brevispinosa*. Other rare but stratigraphically important elements

1450 are *Cymososphaeridium validum*, *Exochosphaeridium phragmites*, *Meiourogonyaulax*

1451 *bulloidea*, *Phoberocysta tabulata*, *Spiniferites primaevus* and *Wallogodinium cylindricum*

1452 (Figs. 7-10, Tables 1, 2).

1453 Remarks. The *Spiniferites ramosus* Zone is directly comparable to this biozone in

1454 northwest Europe (Davey, 1979; 1982). No taxa characteristic of the Late Valanginian

1455 to Hauterivian of northwest Europe were encountered in this study. There is hence no

1456 evidence for the *Spiniferites ramosus* Zone herein to range into the Hauterivian.

1457 Subzones. The Sra Zone is subdivided into three interval subzones.

1458

1459 Subzone a

1460 Definition. The interval from the FAD of *Spiniferites ramosus* and the LAD of

1461 *Gochteodinia villosa*, to the FADs of *Oligosphaeridium complex*, *Spiniferites*

1462 *primaevus* and *Warrenia? brevispinosa* (Figs. 12, 13).

1463 Age. Early Cretaceous, earliest part of the Valanginian unzoned interval, possibly

1464 equivalent to the *Pseudogarnieria undulatoplicatilis* Zone of the Russian Platform and

1465 the early part of the *Paratollia* Zone of the Boreal standard.

1466 Reference section. Kashpir.

1467 Remarks. This subzone comprises Bed 24, a phosphatic concretion-bearing sandstone,

1468 at Kashpir. An extremely well-preserved palynoflora with three-dimensional

1469 preservation was recovered from this bed, including taxa apparently confined to it

1470 (Smith and Harding, 2004); these include *Meiourogonyaulax distincta*.

1471

1472 Subzone b

1473 Definition. The interval from the FADs of *Oligosphaeridium complex*, *Spiniferites*  
1474 *primaevus* and *Warrenia? brevispinosa*, to the FAD of *Phoberocysta tabulata* (Figs. 12,  
1475 13).

1476 Age. Early Cretaceous, middle part of the Early Valanginian unzoned interval, possibly  
1477 equivalent to the *Temnoptychites hoplitoides* Zone of the Russian Platform and the  
1478 upper part of the *Paratollia* Zone of the Boreal standard.

1479 Reference sections. Gorodishche and Kashpir.

1480

1481 Subzone c

1482 Definition. The interval from the FAD of *Phoberocysta tabulata* to the top of the  
1483 interval studied (Figs. 12, 13).

1484 Age. Early Cretaceous, upper part of the Early Valanginian unzoned interval, possibly  
1485 equivalent to the *Polyptychites michalskii* Zone of the Russian Platform and the  
1486 *Polyptychites* Zone of the Boreal standard, to the top of the interval studied.

1487 Reference sections. Gorodishche and Kashpir.

1488 Remarks. The FAD of *Phoberocysta tabulata* in northwest Europe is latest Berriasian  
1489 (Heilmann-Clausen, 1987; Costa and Davey, 1992), hence this FAD in the Volga Basin  
1490 is of local stratigraphical significance. The top of this subzone cannot be defined herein.

1491

1492

## 1493 **8. Graphic correlation**

1494

1495         Graphic correlation of the ammonite zone boundaries and the dinoflagellate cyst  
1496 distributions in the Gorodishche and Kashpir successions is equivocal, perhaps partly  
1497 due to the low dinoflagellate cyst sample densities in certain of the beds (Fig. 14).

1498 However, the dinoflagellate cyst data indicate that significant levels of Middle

1499 Tithonian (*Zaraskaites zarajskensis* Subzone) strata are missing at Kashpir, probably

1500 due to erosional truncation at the base of Bed 4. There are no discontinuities suggested

1501 by the dinoflagellate cyst data through the sedimentologically complex Middle-Upper

1502 Tithonian (*Virgatites virgatus* and *Epivirgatites nikitini* zones) succession, but this may

1503 be an artefact of sample density, because the FADs of several taxa in sample K3 at

1504 Kashpir indicates hiatuses. The two successions demonstrate steady, coeval

1505 sedimentation up to the top of the Upper Tithonian-Lower Berriasian (*Craspedites*

1506 *nodiger* Zone) sequence (Fig. 14). The dinoflagellate cyst data indicate that the

1507 phosphoritic Bed 19 at Gorodishche may represent a significantly condensed horizon  
1508 equivalent to the Upper Berriasian (*Riasanites rjasanensis*/*Surites spasskensis*-*Surites*  
1509 *tzikwinianus* zones) succession as developed at Kashpir. However resolution of this  
1510 question may be achieved by denser sampling through the phosphorite at Gorodishche  
1511 and in the coeval succession at Kashpir.

1512

1513

## 1514 **9. Provincialism of Tithonian to Valanginian dinoflagellate cyst assemblages with** 1515 **emphasis on the Volga Basin**

1516

1517 The vast majority of the dinoflagellate cyst taxa recovered from the Tithonian to  
1518 Valanginian successions at Gorodishche and Kashpir are characteristic of northwest  
1519 Europe. This study has clearly demonstrated the overall similarities between these  
1520 regions both in terms of the relative proportions of taxa and their biostratigraphy. Some  
1521 stratigraphical differences were perceived (see above), and several minor provincial  
1522 differences were noted. In this section, the Tithonian to Valanginian dinoflagellate cyst  
1523 assemblages from Gorodishche and Kashpir are compared to coeval floras from  
1524 northwest Europe and elsewhere.

1525

### 1526 *9.1. Comparison of Tithonian and Berriasian marine palynofloras of the Volga Basin* 1527 *and northwest Europe*

1528

1529 Generally, the Tithonian and Berriasian marine palynofloras of the Volga Basin  
1530 and northwest Europe are substantially similar both in terms of stratigraphical ranges,  
1531 taxonomical spectra and relative proportions. For example *Circulodinium compta*,  
1532 *Cribroperidinium* spp., *Dingodinium* spp., *Gochteodinia villosa*, *Hystrichodinium*  
1533 *pulchrum*, *Senoniasphaera jurassica*, *Sentusidinium* spp., *Sirmiodinium grossii*,  
1534 *Systematophora daveyi*, *Systematophora* spp. and *Tubotuberella apatela* are prominent  
1535 in the Tithonian and Berriasian of both the Volga Basin and northwest Europe (Tables  
1536 1, 2; Davey, 1982; Riding and Thomas, 1988; Riding et al., 1999, fig. 26; Abbink et al,  
1537 2001, figs 10, 11). This means that dinoflagellates had relatively wide geographical  
1538 distributions during this interval of profound provincialism among macrofaunas (e.g.  
1539 Hoedemaeker, 1991; Wimbledon, 2007). Moreover, it confirms that dinoflagellate cysts  
1540 are extremely important biomarkers over extensive geographical areas, and that they  
1541 can help to resolve correlation problems where other fossil groups are affected by  
1542 endemism (Riding et al., 2010; 2011).

1543 Dinoflagellate cyst species typical of the Tithonian and Berriasian of northwest  
1544 Europe which were not recorded in the Volga Basin include *Cribroperidinium? gigas*  
1545 (Raynaud 1978) Helenes 1984, *Dichadogonyaulax culmula* (Norris 1965) Loeblich Jr.  
1546 & Loeblich III 1968, *Dichadogonyaulax? pannea* (Norris 1965) Sarjeant 1969,  
1547 *Dingodinium? spinosum* (Duxbury 1977) Davey 1979, *Gochteodinia virgula* Davey  
1548 1982, *Hystrichodinium voigtii* (Alberti 1961) Davey 1974, *Mendicodinium*  
1549 *groenlandicum* (Pocock & Sarjeant 1972) Davey 1979, *Muderongia simplex* Alberti  
1550 1961 (i.e. *Muderongia* sp. A of Davey, 1979), *Pareodinia halosa* (Filatoff 1975) Prauss  
1551 1989 and *Rotosphaeropsis thule* (Davey 1982) Riding & Davey 1989. The absence of  
1552 *Rotosphaeropsis thule* in the Volga Basin is perhaps the most marked difference. This  
1553 species is a persistent Tithonian-Berriasian element in northwest Europe (Davey, 1979;  
1554 Riding, 1984; Costa and Davey, 1992). *Rotosphaeropsis thule* is especially common in  
1555 the latest Tithonian to Late Berriasian interval (Riding and Davey, 1989). Similarly,  
1556 *Glossodinium dimorphum* is far more common in the Tithonian of northwest Europe  
1557 than it is in the Volga Basin (Riding and Thomas, 1988, fig. 3). By contrast, species of  
1558 *Kleithriasphaeridium* appear to be more diverse and common in the Tithonian of the  
1559 Volga region than in northwest Europe (Tables 1, 2; Riding and Thomas, 1988).  
1560 Likewise, there are relatively few dinoflagellate cyst taxa in this interval which are  
1561 endemic within the Volga Basin (Smith and Harding, 2004).

1562

## 1563 9.2. Comparison of Valanginian marine palynofloras of the Volga Basin and northwest 1564 Europe

1565

1566 Dinoflagellate cysts from the Valanginian (and younger Cretaceous stages)  
1567 across the Russian Platform and northwest Europe are significantly more cosmopolitan  
1568 than their Tithonian and Berriasian counterparts; this reflects more widespread marine  
1569 connections at this time. Forms such as *Achomosphaera neptuni*, *Aprobolocysta*  
1570 *trycheria*, *Batioladinium* spp., *Cassiculosphaeridia magna*, *Cassiculosphaeridia*  
1571 *reticulata*, *Chlamydophorella nyei*, *Cribroperidinium* spp., *Cymososphaeridium*  
1572 *validum*, *Dingodinium* spp., *Exiguosphaera phragma*, *Exochosphaeridium phragmites*,  
1573 *Hystrichodinium* spp., *Isthmocystis distincta*, *Kleithriasphaeridium* spp., *Lagenorhytis*  
1574 *delicatula*, *Muderongia simplex*, *Nelchinopsis kostromiensis*, *Oligosphaeridium*  
1575 *complex*, *Phoberocysta neocomica*, *Phoberocysta tabulata*, *Pseudoceratium*  
1576 *brevicornutum*, *Pseudoceratium pelliferum*, *Scriniodinium campanula*, *Scriniodinium*  
1577 *pharo*, *Spiniferites primaevus*, *Spiniferites ramosus*, *Stanfordella exsanguia*,  
1578 *Tanyosphaeridium* spp., *Trichodinium ciliatum* and *Wallodinium* spp. are present in

1579 both areas (e.g. Davey, 1979; 1982; Heilmann-Clausen, 1987). The ranges and relative  
1580 proportions are also substantially similar. Species typical of the Valanginian of  
1581 northwest Europe which were not recorded in the Volga Basin include *Cantulodinium*  
1582 *speciosum* Alberti 1961, *Ctenidodinium elegantulum* Millioud 1969, *Discorsia nannus*  
1583 (Davey 1974) Duxbury 1977, *Heslertonia heslertonensis* (Neale & Sarjeant 1962)  
1584 Sarjeant 1966, *Hystrichosphaerina schindewolfii* Alberti 1961, *Nematosphaeropsis*  
1585 *scala* Duxbury 1977 and *Systematophora palmula* Davey 1982. Despite the apparent  
1586 absence of the latter species in the Valanginian of the Volga Basin, there are no major  
1587 floral differences with assemblages of this age from northwest Europe.

1588

### 1589 9.3. Comparison of Tithonian to Valanginian marine palynofloras of other regions and 1590 the Volga Basin/northwest Europe

1591

1592 In this subsection, Tithonian to Valanginian marine palynofloras from southern  
1593 Europe, the Arctic, the North Atlantic and the Southern Hemisphere are briefly  
1594 described, and the differences between these and coeval associations from the Volga  
1595 Basin and northwest Europe highlighted. Dinoflagellate cyst assemblages from this  
1596 interval in North Africa and surrounding regions are substantially similar to their  
1597 equivalents from western Russia and northwest Europe (e.g. Thusu and Vigran, 1985;  
1598 Thusu et al., 1988; Ibrahim and El-Beialy, 1995; Baioumi, 2002).

1599 During the Tithonian and Berriasian, biotic provincialism was at its maximum.  
1600 Despite this, species such as *Pareodinia ceratophora*, *Scriniodinium crystallinum*,  
1601 *Sirmiodinium grossii* and *Tubotuberella apatela* are present worldwide during this  
1602 interval. Valanginian dinoflagellate cyst associations globally include significantly less  
1603 endemic taxa.

1604

#### 1605 9.3.1. Southern Europe

1606 The Tithonian to Valanginian dinoflagellate cyst record of southeast France,  
1607 southeast Spain and western Switzerland was studied by Jardiné et al. (1984), Leereveld  
1608 (1989; 1997), Monteil (1992a,b; 1993) and Hoedemaeker and Leereveld, 1995).

1609 Although some species in the latter area are present throughout the Northern  
1610 Hemisphere, the Tithonian and Berriasian associations from this part of southern  
1611 Europe are significantly different to coeval floras from northwest Europe and the  
1612 Russian Platform, with many endemic forms present. Clearly, this is a reflection of the  
1613 profound provincialism of biotas at this time. By contrast, dinoflagellate cysts of the

1614 Valanginian (and younger stages) across Europe and the Russian Platform are much  
1615 more cosmopolitan, reflecting relatively widespread open marine settings at this time.  
1616 This situation is best illustrated by Monteil (1992b) and Leereveld (1997). These  
1617 authors recorded several endemic species from the Mid Tithonian to Late Berriasian  
1618 interval of southeast France and southeast Spain. These taxa include *Amphorula*  
1619 *metaelliptica* Dodekova 1969, *Biorbifera johnewingii* Habib 1972, *Cirrusphaera*  
1620 *dissimilis* Monteil 1992, *Cometodinium habibii* Monteil 1991, *Diacanthum hollisteri*  
1621 Habib 1972, *Dichadogonyaulax bensonii* Monteil 1992, *Foucheria modesta* Monteil  
1622 1992, *Lanterna bulgarica* Dodekova 1969, *Prolixosphaeridium basifurcatum* Dodekova  
1623 1969, *Protobatioladinium lunare* Monteil 1992, *Pyxidinosphaeridium challengerensis* Habib  
1624 1976 and *Warrenia californica* Monteil 1992 (see Monteil, 1992b, table 1; Leereveld,  
1625 1997, figs. 2, 3). None of these species were recorded in the Volga Basin. Mid  
1626 Tithonian to Late Berriasian taxa which are present throughout Europe and western  
1627 Russia include *Achomosphaera neptuni*, *Pseudoceratium pelliferum*, *Spiniferites*  
1628 *ramosus*, *Systematophora areolata*, *Tubotuberella apatela* and *Wallodinium*  
1629 *cylindricum* (see Monteil, 1992b, table 1; Leereveld, 1997, figs. 2, 3). By contrast, the  
1630 Valanginian of southeast France and southeast Spain is dominated by forms which are  
1631 present in the Volga Basin and north and south Europe. These include  
1632 *Cassiculosphaeridia magna*, *Hystrichodinium pulchrum*, *Kleithriasphaeridium*  
1633 *corrugatum*, *Kleithriasphaeridium fasciatum*, *Nelchinopsis kostromiensis*,  
1634 *Oligosphaeridium complex* and *Spiniferites primaevus* (see Jardiné et al., 1984, fig.  
1635 6.16; Monteil, 1992b, table 1; Leereveld, 1997, figs. 2, 3). Endemic subtropical forms  
1636 such as *Amphorula metaelliptica*, *Biorbifera johnewingii*, *Druggidium apicopaucicum*  
1637 Habib 1973, *Druggidium deflandrei* (Millioud 1969) Habib 1973 and *Foucheria*  
1638 *modesta* are present but they are relatively minor components (Monteil, 1992b, table 1;  
1639 Leereveld, 1997, figs. 2, 3). The partitioning of Tethyan/Atlantic taxa such as  
1640 *Biorbifera johnewingii* from more Arctic/Boreal forms such as *Gochteodinia* spp. was  
1641 illustrated by Leereveld (1989, fig. 2).

1642 Dodekova (1994) described Tithonian dinoflagellate cysts from northern  
1643 Bulgaria. According to this author, the majority of the taxa recognised are typical of  
1644 northwest Europe and the Russian Platform (Dodekova, 1994, fig. 2). These are hence  
1645 more similar to the Volga Basin floras than the coeval material from southeast France  
1646 and Switzerland. Dodekova (1994), however, recorded several species which are typical  
1647 of the northwest part of Tethys. These include *Amphorula dodekovae* Zotto et al. 1987,  
1648 *Amphorula metaelliptica*, *Amphorula? monteilii* Dodekova 1974, *Atlantodinium*  
1649 *jurassicum* Zotto et al. 1987, *Biorbifera johnewingii*, *Lanterna bulgarica* Dodekova

1650 1969, *Lanterna sportula* Dodekova 1969 and *Meiourogonyaulax bejui* Zotto et al. 1987  
1651 (see Dodekova, 1994, fig. 2).

1652

### 1653 9.3.2. The Arctic region

1654 Davies (1983) reported relatively low diversity floras dominated by endemic  
1655 forms from the Tithonian and Berriasian of the Canadian Arctic. Relatively few taxa are  
1656 present in the Volga Basin and northwest Europe. These typically high latitude species  
1657 include *Paragonyaulacysta? borealis* (Brideaux & Fisher 1976) Stover & Evitt 1978,  
1658 *Paragonyaulacysta capillosa* (Brideaux & Fisher 1976) Stover & Evitt 1978 and  
1659 *Tetrachacysta spinosigibberosa* (Brideaux & Fisher 1976) Backhouse 1988. In the  
1660 Valanginian (the *Tanyosphaeridium magneticum* Opper-Zone of Davies, 1983), there is  
1661 a significant increase in diversity. The base of this biozone, is characterised by  
1662 significant numbers of inceptions including several typically European taxa such as  
1663 *Heslertonia heslertonensis*, *Nelchinopsis kostromiensis* and *Odontochitina operculata*  
1664 (Wetzel 1933) Deflandre & Cookson 1955 (see Davies, 1983, fig. 4). This confirms that  
1665 widespread marine connections became reestablished, following Tithonian-Berriasian  
1666 restricted depocentres, in the Valanginian. Other studies on the Arctic region which  
1667 report characteristically high latitude taxa in the latest Jurassic-earliest Cretaceous  
1668 include Brideaux and Fisher (1976), Håkansson et al. (1981), Smelror et al. (1998),  
1669 Lebedeva and Nikitenko (1999) and Smelror and Dypvik (2005).

1670

### 1671 9.3.3. The North Atlantic

1672 The Tithonian to Valanginian succession from offshore eastern U.S.A. in the  
1673 North Atlantic was studied by Habib (1972; 1973; 1975) and Habib and Drugg (1983;  
1674 1987). These assemblages, from offshore Florida to New Jersey, are extremely  
1675 reminiscent of coeval floras from southeast France, southeast Spain and western  
1676 Switzerland (see above). Relatively low numbers of dinoflagellate cyst species in this  
1677 interval in the North Atlantic are common to the Russian Platform and northwest  
1678 Europe, particularly in the Tithonian and Berriasian. Characteristic species of the North  
1679 Atlantic region include *Amphorula metaelliptica*, *Biorbifera johnewingii*, *Druggidium*  
1680 *apicopaucicum*, *Druggidium deflandrei*, *Druggidium rhabdoreticulatum* Habib 1973,  
1681 *Histiophora* sp. and *Pyxidinosia challengerensis* (see Habib, 1975, fig. 3; Habib and  
1682 Drugg, 1987, fig. 2). These associations are typically southern European/western  
1683 Tethyan and constitute a provincial flora which is centered on the early North Atlantic  
1684 and adjacent areas (Smith and Briden, 1977, maps 8, 9). This phytoprovince is  
1685 relatively widespread; van Helden (1986) recorded *Amphorula metaelliptica* from

1686 offshore Newfoundland. The relatively geographically isolated nature of the North  
1687 Atlantic at this time may have prevented the free passive dispersal of, for example,  
1688 *Druggidium* spp. However, latitudinal and/or climatic controls may also have controlled  
1689 the distribution of these apparently highly geographically restricted taxa. *Biorbifera*  
1690 *johnewingii* has also been reported from the Berriasian and Valanginian of California  
1691 (Habib and Warren, 1973).

1692

#### 1693 9.3.4. The Southern Hemisphere

1694 The Tithonian dinoflagellate cyst floras of the Northwest Shelf of Australia,  
1695 New Zealand, Papua New Guinea and the Antarctic Peninsula are profoundly different  
1696 to their counterparts from Europe and western Russia. These Southern Hemisphere  
1697 floras were described by Davey (1987), Helby et al. (1987; 1988), Riding et al. (1992),  
1698 Snape (1992), Bint and Marshall (1994), Riding and Helby (2001) and Riding et al.  
1699 (2010). The Austral floras are overwhelmingly dominated by endemic forms, however  
1700 small proportions of cosmopolitan taxa such as *Imbatodinium kondratjevii*,  
1701 *Nannoceratopsis pellucida*, *Sirmiodinium grossii* and *Tubotuberella apatela* are present  
1702 (Snape, 1992, fig. 2; Bint and Marshall, 1994, fig. 4). The intensity of this provincialism  
1703 was slightly lessened in the Berriasian and Valanginian. Typically Australasian  
1704 Tithonian species such as *Broomea simplex* Cookson & Eisenack 1958, *Nummus similis*  
1705 (Cookson & Eisenack 1960) Burger 1980 and *Omatia montgomeryi* Cookson &  
1706 Eisenack 1958 are also present in the Tithonian of northeast India (Garg et al., 2003).  
1707 This is similar to the Tithonian of Kenya, East Africa where Jiang et al. (1992) reported  
1708 Austral species such as *Broomea ramosa* Cookson & Eisenack 1958,  
1709 *Carnarvonodinium morganii* Parker 1988, *Komewuia glabra* Cookson & Eisenack 1960  
1710 and *Mombasadinium parvelatum* (Jiang in Jiang et al. 1992) Riding & Helby 2001.  
1711 Similarly, Schrank (2005) recorded several typically Australian species, for example  
1712 *Endoscrinium attadalense* (Cookson & Eisenack 1958) Riding & Fensome 2003 from  
1713 the Tithonian of Tanzania, East Africa. By contrast, Tithonian dinoflagellate cyst  
1714 associations from Argentina are low in diversity and appear to lack any of the typically  
1715 Australasian endemic elements (Quattrocchio and Sarjeant, 1992, fig. 6). This is despite  
1716 the Tethys circumglobal current (TCC), which flowed westwards in the tropics during  
1717 the Mesozoic. Hence the TCC could have potentially dispersed planktonic organisms  
1718 from eastern to western Tethys at this time. However, north-south currents tend to be  
1719 relatively weak during greenhouse conditions (Bush, 1997). This factor may have  
1720 prevented the passive dispersal of dinoflagellate cysts from Gondwana northwards into  
1721 Eurasia (Riding et al., 2011). Similarly, the latest Jurassic-earliest Cretaceous interval;

1722 of China is not, apparently, characterised by typically Australasian taxa (e.g. He and  
1723 Zhu, 2003; Zhu and He, 2007).

1724

#### 1725 9.3.5. Synthesis

1726 Based on an analysis of global reports of Tithonian and Berriasian marine  
1727 palynofloras, it is clear that significant endemism operated during this interval. The  
1728 most significant differences are between Australasia and elsewhere in the world. This  
1729 provincialism is interpreted as being largely due largely to geographical isolation  
1730 (Riding et al., 2010; 2011). Specifically, latitudinal and/or palaeotemperature barriers  
1731 probably prevented passive dispersal of dinoflagellate cysts from Australasia to Eurasia  
1732 northwards across Tethys. Similar palaeoclimatic interfaces, together with geographical  
1733 barriers apparently prevented the mixing of dinoflagellate cyst floras from the Volga  
1734 Basin and northwest Europe, with their counterparts in the Arctic and southern Europe.  
1735 The North Atlantic region was somewhat geographically isolated at this time (Smith  
1736 and Briden, 1977, map 9), and this factor may have at least partially controlled  
1737 prevented the relatively restricted distributions of forms such as *Druggidium* spp.

1738 Therefore, it appears that the extents of the various phytoplanktonic provinces  
1739 were controlled by several factors during the Tithonian and Berriasian. By contrast,  
1740 Valanginian dinoflagellate cyst associations include more cosmopolitan taxa than their  
1741 Tithonian and Berriasian counterparts. This indicates the re-establishment of open  
1742 marine connections at this time.

1743

1744

## 1745 10. Conclusions

1746

1747 Correlation of Jurassic/Cretaceous boundary successions between the Volga  
1748 Basin, and northwest and southern Europe based on ammonite biostratigraphy is  
1749 hampered by intense and widespread molluscan provincialism. The dinoflagellate cyst  
1750 biostratigraphy of the Tithonian to Valanginian successions at Gorodishche and Kashpir  
1751 in the Volga Basin, western Russia have been investigated in detail in order to attempt  
1752 to help with these longstanding correlation problems.

1753 Both the Gorodishche and Kashpir sections produced abundant, diverse and  
1754 well-preserved dinoflagellate cyst floras which were used to construct a detailed  
1755 Tithonian to Valanginian palynostratigraphy applicable to western Russia. The  
1756 stratigraphical ranges of all dinoflagellate cyst taxa recognised have been assessed and  
1757 the key datums used to effect correlations to the northwest European Boreal ammonite

1758 biostratigraphy. The most important bioevents include the inceptions of *Gochteodinia*  
1759 *villosa*, *Pseudoceratium* spp. and *Spiniferites* spp., and the apparent extinctions of  
1760 *Egmontodinium polyplacophorum*, *Pseudoceratium brevicornutum* and *Senoniasphaera*  
1761 *jurassica*. Examples of these are the range tops of *Egmontodinium polyplacophorum*  
1762 and *Senoniasphaera jurassica* which are in the Late Tithonian-Early Berriasian  
1763 *Craspedites nodiger* Zone at Gorodishche and Kashpir. These bioevents support the  
1764 correlation of the *Craspedites nodiger* Zone with the *Subcraspedites preplicomphalus*  
1765 Zone of northwest Europe. The range base of *Spiniferites* spp. at the base of the  
1766 unzoned Valanginian strata in the Volga Basin is consistent with an earliest Valanginian  
1767 age. Other datums confirm this earliest Valanginian age assessment, and other  
1768 dinoflagellate cyst bioevents established in northwest Europe have allowed the dating of  
1769 the Middle-Upper Berriasian strata from the Volga River sections which are devoid of  
1770 ammonites. Thus it is evident that dinoflagellate cysts have substantial potential for the  
1771 correlation of the northwest European and Russian Platform ammonite biozonations,  
1772 thereby refining the work of authors such as Krymholts et al. (1988) and Hantzpergue et  
1773 al. (1998). Selected important dinoflagellate cyst bioevents were used to construct a  
1774 Tithonian to Valanginian dinoflagellate cyst zonation comprising five interval zones  
1775 and seven interval subzones and which is applicable to the Volga Basin. This  
1776 palynozonation markedly refines the biozonal scheme of Riding et al. (1999) for the  
1777 Russian Platform. Moreover this new zonal scheme is partially comparable to the  
1778 dinoflagellate cyst zonation for northwest Europe of Riding and Thomas (1992), despite  
1779 some minor apparent differences in the ranges of several taxa.

1780         Graphic correlation of the ammonite zonal boundaries using the dinoflagellate  
1781 cyst data has provided some interesting conclusions. It appears that a significant part of  
1782 the Middle Tithonian (*Zaraskaites zarajskensis* Subzone) succession is missing at  
1783 Kashpir, probably due to erosional truncation. There are apparently no discontinuities  
1784 indicated by the dinoflagellate cyst data in the Middle-Upper Tithonian (*Virgatites*  
1785 *virgatus* and *Epivirgatites nikitini* zones) sequence. The two successions were  
1786 characterised by steady, coeval sedimentation up to the top of the Upper Tithonian-  
1787 Lower Berriasian (*Craspedites nodiger* Zone) (Fig. 14).

1788         The majority of the Tithonian to Valanginian dinoflagellate cyst taxa from  
1789 Gorodishche and Kashpir are present in northwest Europe. The marked endemism  
1790 which affected molluscan populations, especially in the Tithonian-Berriasian interval,  
1791 was not manifested in the marine phytoplankton. Some apparent differences in  
1792 taxonomical spectra and stratigraphical ranges were observed. For example the  
1793 prominent Early Tithonian to Mid-Late Berriasian species *Rotosphaeropsis thule* was

1794 not recorded in the Volga Basin, despite being prominent in the North Sea and  
1795 surrounding regions. However, the floras in both areas are substantially similar, offering  
1796 the potential for robust correlations to be made. The Tithonian to Berriasian interval  
1797 exhibits most differences. By contrast, however, Valanginian dinoflagellate cyst  
1798 assemblages throughout the Northern Hemisphere, however, are markedly more similar.  
1799 These associations are relatively diverse and include many geographically widespread  
1800 markers such as *Lagenorhysis delicatula*, *Nelchinopsis kostromiensis*, *Oligosphaeridium*  
1801 *complex* and *Spiniferites* spp.

1802 Tithonian to Valanginian dinoflagellate cyst associations are, however,  
1803 demonstrably provincial at the global scale. Cosmopolitan taxa in the Tithonian to  
1804 Berriasian interval are relatively rare, especially in the Arctic and the the Southern  
1805 Hemisphere. Jurassic-Cretaceous boundary beds in southern Europe and the North  
1806 Atlantic region include significant proportions of taxa which are present in northwest  
1807 Europe and the Volga Basin. However the former areas are typified by several  
1808 apparently provincial forms such as species of *Amphorula*, *Druggidium*, *Lanterna* and  
1809 *Warrenia*. As mentioned above, the Tithonian to Valanginian of the Arctic region is  
1810 typified by endemic high latitude taxa such as *Paragonyaulacysta* spp. The Tithonian of  
1811 Australasia and the Antarctic Peninsula is dominated by endemic taxa, and some of  
1812 these forms have been reported from East Africa and India. This provincialism was  
1813 most likely to have been due to a number of factors including the absence of open  
1814 marine connections, interruptions in shelfal seas, lithofacies control, nutrient levels,  
1815 ocean currents, salinity, seasonality, temperature and water stratification.

1816 This study has significantly advanced the understanding of the Tithonian to  
1817 Valanginian dinoflagellate cyst biostratigraphy of the important outcrop sections at  
1818 Gorodishche and Kashpir, and how this can advance stratal correlations, particularly  
1819 with northwest Europe. Future studies on the Jurassic-Cretaceous boundary strata of the  
1820 Volga Basin could include the more detailed study of beds not extensively sampled  
1821 here, detailed taxonomic assessments of forms here placed in open nomenclature and  
1822 work on the dinoflagellate cyst concentrations.

1823

1824

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2484 assemblage zones in eastern Heilongjiang Province, northeast China. *Cretaceous*  
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2486

2487

2488 **Display material captions:**

2489

2490 Fig. 1. The locations of the sections sampled at Gorodishche and Kashpir near  
2491 Ul'yanovsk in the Volga Basin, western Russia. a – regional map of western Russia and  
2492 surrounding regions. b – the location of the section at Gorodishche on the west bank of  
2493 the River Volga, to the south of Undory. c – the location of the section at Kashpir on the  
2494 west bank of the River Volga, to the to the south of Stroetyel. The stippled areas in b  
2495 and c represent the River Volga.

2496

2497 Fig. 2. Latest Jurassic (Tithonian) to Early Cretaceous (Valanginian) standard Tethyan  
2498 stage nomenclature adjacent to the Jurassic/Cretaceous boundary. The British/French  
2499 and Russian Platform (Boreal) stages and the regional ammonite zones are plotted  
2500 against the standard.

2501

2502 Fig. 3. Correlation of the Late Jurassic to earliest Cretaceous ammonite zonation for  
2503 eastern England with the ammonite zonation for the Volga Basin. The scheme of  
2504 Hanzpergue et al. (1998) is the Volga Basin zonation used herein.

2505

2506 Fig. 4. The numbers and positions of the samples in this study on the summary  
2507 lithological logs of the Middle Tithonian to Valanginian successions at Gorodishche

2508 (samples U1-U40) and Kashpir (K1-K30). The logs were produced by Giles A. Smith  
2509 and Vladimir Efimov.

2510

2511 Fig. 5. Correlation of the lithological logs for the Middle Tithonian to Valanginian  
2512 succession at Gorodishche. 1 – the log of Lord et al. (1987) after Mesezhnikov (1977). 2  
2513 – the log of Hogg (1994) based on data supplied by VNIGRI, Saint Petersburg. 3 – the  
2514 log of Mesezhnikov in Blom et al. (1984). 4 – the present study; the log was produced  
2515 by Giles A. Smith and Vladimir Efimov. The correlation lines are based on lithological  
2516 criteria and the ammonite zone boundaries indicated in Lord et al. (1987), Hogg (1994)  
2517 and Mesezhnikov in Blom et al. (1984).

2518

2519 Fig. 6. Correlation of the lithological logs for the Middle Tithonian to Valanginian  
2520 succession at Kashpir. 1 – the log of Lord et al. (1987). 2 – the log of Mesezhnikov in  
2521 Blom et al. (1984). 3 – the present study; the log was produced by Giles A. Smith and  
2522 Vladimir Efimov. The correlation lines are based on lithological criteria and the  
2523 ammonite zone boundaries indicated in Lord et al. (1987) and Mesezhnikov in Blom et  
2524 al. (1984).

2525

2526 Fig. 7. The ranges of selected stratigraphically-significant dinoflagellate cysts from the  
2527 Middle Tithonian to Lower Valanginian succession of Gorodishche (1 of 2).

2528

2529 Fig. 8. The ranges of selected stratigraphically-significant dinoflagellate cysts from the  
2530 Middle Tithonian to Lower Valanginian succession of Gorodishche (2 of 2).

2531

2532 Fig. 9. The ranges of selected stratigraphically-significant dinoflagellate cysts from the  
2533 Middle Tithonian to Lower Valanginian succession of Kashpir (1 of 2).

2534

2535 Fig. 10. The ranges of selected stratigraphically-significant dinoflagellate cysts from the  
2536 Middle Tithonian to Lower Valanginian succession of Kashpir (2 of 2).

2537

2538 Fig. 11. A comparison of biostratigraphically significant dinoflagellate cyst first and last  
2539 appearance datums in the Tithonian (latest Jurassic) to Early Berriasian of the Volga  
2540 Basin and Western Europe.

2541

2542 Fig. 12. A comparison of biostratigraphically significant dinoflagellate cyst first and last  
2543 appearance datums in the Mid-Late Berriasian to Valanginian/Hauterivian (Early  
2544 Cretaceous) of the Volga Basin and Western Europe.

2545

2546 Fig. 13. The dinoflagellate cyst biozonation proposed herein with the defining  
2547 biostratigraphically significant dinoflagellate cyst bioevents. The biozonation herein is  
2548 compared with those of Riding et al. (1999) for the Russian Platform and by other  
2549 authors for northwest Europe.

2550

2551 Fig. 14. Graphic correlation. **Need a caption from ICH. We need to explain the**  
2552 **significance of the circles, squares and crosses**

2553

2554

2555 Table 1. The stratigraphical distribution and relative abundance data of dinoflagellate  
2556 cysts from the Middle Tithonian to Valanginian of the Gorodishche section. The  
2557 numbers represent actual numbers of specimens counted. Forms recorded outside of the  
2558 formal count are indicated by an "X".

2559

2560 Table 2. The stratigraphical distribution and relative abundance data of dinoflagellate  
2561 cysts from the Middle Tithonian to Valanginian of the Kashpir section. The numbers  
2562 represent actual numbers of specimens counted. Forms recorded outside of the formal  
2563 count are indicated by an "X". \* = Upper Jurassic/Lower Cretaceous. \*\* = Upper  
2564 Tithonian/Lower Berriasian.

2565

2566

2567 Plate I

2568 Transmitted light photomicrographs of selected dinoflagellate cysts from the Middle-  
2569 Upper Tithonian, Upper Tithonian and Valanginian strata of Gorodishche and Kashpir.  
2570 The sample number, slide number and England Finder (EF) coordinates are quoted for  
2571 all specimens.

2572

2573 1, 2. *Achomosphaera neptuni* (Eisenack 1958) Davey & Williams 1966. Valanginian  
2574 (unzoned) of Kashpir. Sample/slide K17-0/300-2, EF R43/0. Dorsal and ventral focus  
2575 respectively.

2576 3. *Batioladinium? gochtii* (Alberti 1961) Lentin & Williams 1977. Valanginian  
2577 (unzoned) of Kashpir. Sample/slide K17, EF E41/3. Oblique lateral focus.

2578 4, 10. *Scrinodinium pharo* (Duxbury 1977) Davey 1982. Valanginian (unzoned) of  
2579 Kashpir. Sample/slide K17-0/300-2, EF K41/4. Dorsal and ventral focus respectively.  
2580 5. *Egmontodinium polyplacophorum* Gitmez & Sarjeant 1972. Upper Tithonian  
2581 (Craspedites subditus Zone) of Kashpir. Sample/slide K8, EF G24/4. Lateral focus.  
2582 6, 11. *Cribooperidinium* cf. *C. volkovae* Iosifova 1996. Valanginian (unzoned) of  
2583 Kashpir. Sample/slide K17-0/300, EF J35/3. Ventral and dorsal focus respectively.  
2584 7. *Gochteodinia villosa* (Vozzhennikova 1967) Norris 1978. Upper Tithonian  
2585 (Craspedites subditus Zone) of Kashpir. Sample/slide K8, EF P53/0. Left lateral focus.  
2586 8. *Senoniasphaera jurassica* (Gitmez & Sarjeant 1972) Lentin & Williams 1976. Upper  
2587 Tithonian (Craspedites subditus Zone) of Kashpir. Sample/slide K8, EF H39/0. Dorsal  
2588 focus.  
2589 9. *Spiniferites ramosus* (Ehrenberg 1838) Mantell 1854. Valanginian (unzoned) of  
2590 Kashpir. Sample/slide K17-0/300-2, EF J44/0. Ventral-lateral focus.  
2591 12. *Oligosphaeridium complex* (White 1842) Davey & Williams 1966. Valanginian  
2592 (unzoned) of Kashpir. Sample/slide K27, EF J34/3. Ventral focus.  
2593 13, 14. *Tehamadinium daveyi* Jan du Chêne et al. 1986. Upper Tithonian (Craspedites  
2594 subditus Zone) of Kashpir. Sample/slide K8-2, EF O31/0. Ventral and dorsal focus  
2595 respectively.  
2596 15, 19. *Isthmocystis distincta* Duxbury 1979. Valanginian (unzoned) of Kashpir.  
2597 Sample/slide K17-0/300-3, EF E34/2. Ventral focus on epitract and dorsal focus on  
2598 hypotract respectively.  
2599 16. *Tubotuberella* cf. *apatela* (Cookson & Eisenack 1960) Ioannides et al. 1976.  
2600 Middle-Upper Tithonian (*Virgatites virgatus* Zone) of Gorodishche. Sample/slide U23-  
2601 2, EF N29/0. Ventral focus.  
2602 17, 18. *Kleithriasphaeridium eoinodes* (Eisenack 1958) Davey 1974. Valanginian  
2603 (unzoned) of Kashpir. Sample/slide K17-0/300-2, EFM62/3. Ventral and dorsal focus  
2604 respectively.  
2605  
2606  
2607 Plate II  
2608 Scanning electron photomicrographs of selected dinoflagellate cysts from the Upper  
2609 Tithonian and Valanginian strata of Kashpir. The sample number, SEM stub number  
2610 and the grid square coordinates are quoted for all specimens.  
2611

- 2612 1. *Gochteodinia villosa* (Vozzhennikova 1967) Norris 1978. Upper Tithonian  
 2613 (Craspedites subditus Zone) of Kashpir. Sample K8, SEM stub 9, grid square 2/II.  
 2614 Dorsal view.
- 2615 2. *Gochteodinia villosa* (Vozzhennikova 1967) Norris 1978. Upper Tithonian  
 2616 (Craspedites subditus Zone) of Kashpir. Sample K8, SEM stub 9, grid square 4/II.  
 2617 Dorsal view, note that one opercular plate has been lost, and another remains lodged  
 2618 within the archaeopyle.
- 2619 3. *Isthmocystis distincta* Duxbury 1979. Valanginian (unzoned) of Kashpir. Sample  
 2620 K21, SEM stub 11, grid square 4/I. Ventral view.
- 2621 4. *Senoniasphaera jurassica* (Gitmez & Sarjeant 1972) Lentin & Williams 1976. Upper  
 2622 Tithonian (Craspedites subditus Zone) of Kashpir. Sample K8, SEM stub 9, grid square  
 2623 3/III. Dorsal focus.
- 2624 5. *Phoberocysta tabulata* Raynaud 1978. Valanginian (unzoned) of Kashpir. Sample  
 2625 K24, SEM stub 8, grid square 3/IV. Ventral view.
- 2626 6. *Scrinodinium pharo* (Duxbury 1977) Davey 1982. Valanginian (unzoned) of Kashpir.  
 2627 Sample K17, SEM stub 3, grid square 2/II. Ventral view, note the large sulcal  
 2628 claustrum.
- 2629 7. *Amphorula expirata* (Davey 1982) Courtinat 1989. Upper Tithonian (Craspedites  
 2630 subditus Zone) of Kashpir. Sample K8, SEM stub 9, grid square 3/IV. Oblique lateral  
 2631 view.
- 2632 8. *Hystriodinium pulchrum* Deflandre 1935 (variety 1). Valanginian (unzoned) of  
 2633 Kashpir. Sample K21, SEM stub 11, grid square 2/II. Ventral view.
- 2634 9. *Cribroperidinium* cf. *C. volkovae* Iosifova 1996. Valanginian (unzoned) of Kashpir.  
 2635 Sample K17, SEM stub 4, grid square 1/III. Dorsal view, note intratabular tuberculae.
- 2636 10. *Pseudoceratium brevicornutum* Herngreen et al. 2000. Valanginian (unzoned) of  
 2637 Kashpir. Sample K17, SEM stub 4, grid square 3/I. Ventral view.
- 2638 11. *Tehamadinium daveyi* Jan du Chêne et al. 1986. Upper Tithonian (Craspedites  
 2639 subditus Zone) of Kashpir. Sample K8, SEM stub 9, grid square 3/III. Dorsal view.  
 2640  
 2641
- 2642 Appendix 1.
- 2643 An alphabetical listing of all validly described dinoflagellate cyst species recorded in  
 2644 this study with full author citations. References to the dinoflagellate cyst author  
 2645 citations can be found in Fensome and Williams (2004).  
 2646
- 2647 *Achomosphaera neptuni* (Eisenack 1958) Davey & Williams 1966

- 2648 *Ambonosphaera? staffinensis* (Gitmez 1970) Poulsen & Riding 1992
- 2649 *Amphorula expirata* (Davey 1982) Courtinat 1989
- 2650 *Aprobolocysta galeata* Backhouse 1987
- 2651 *Aprobolocysta trycheria* Pourtoy 1988
- 2652 *Apteodinium spinosum* Jain & Millepied 1975
- 2653 *Apteodinium spongiosum* McIntyre & Brideaux 1980
- 2654 *Athigmatocysta glabra* Duxbury 1977
- 2655 *Avellodinium falsificum* Duxbury 1977
- 2656 *Batioladinium? gochtii* (Alberti 1961) Lentin & Williams 1977
- 2657 *Batioladinium jaegeri* (Alberti 1961) Brideaux 1975
- 2658 *Batioladinium radiculatum* Davey 1982
- 2659 *Cassiculosphaeridia magna* Davey 1974
- 2660 *Cassiculosphaeridia pygmaeus* Stevens 1987
- 2661 *Cassiculosphaeridia reticulata* Davey 1969
- 2662 *Chlamydothorella nyei* Cookson & Eisenack 1958
- 2663 *Chytroeisphaeridia cerastes* Davey 1979
- 2664 *Chytroeisphaeridia chytroeides* (Sarjeant 1962) Downie & Sarjeant 1965
- 2665 *Circulodinium compta* (Davey 1982) Helby 1987
- 2666 *Circulodinium copei* Bailey et al. 1997
- 2667 *Circulodinium distinctum* (Deflandre & Cookson 1955) Jansonius 1986
- 2668 *Cometodinium habibii* Monteil 1991
- 2669 *Cometodinium whitei* (Deflandre & Courteville 1939) Stover & Evitt 1978
- 2670 *Cribroperidinium erymnoseptatum* Bailey 1993
- 2671 *Cribroperidinium magnificum* Smith & Harding 2004
- 2672 *Cribroperidinium nuciforme* (Deflandre 1939 ex Sarjeant 1962) Courtinat 1989
- 2673 *Cribroperidinium undoryensis* Smith & Harding 2004
- 2674 *Cribroperidinium venustum* (Klement 1960) Poulsen 1996
- 2675 *Cribroperidinium* cf. *C. volkovae* Iosifova 1996
- 2676 *Cymososphaeridium validum* Davey 1982
- 2677 *Dapsilidinium multispinosum* (Davey 1974) Bujak et al. 1980
- 2678 *Dichadogonyaulax? chondra* (Drugg 1978) Courtinat 1989
- 2679 *Dingodinium cerviculum* Cookson & Eisenack 1958
- 2680 *Dingodinium jurassicum* Cookson & Eisenack 1958
- 2681 *Dingodinium tuberosum* (Gitmez 1970) Fisher & Riley 1980
- 2682 *?Downiesphaeridium? aciculare* (Davey 1969) Islam 1993
- 2683 *Egmontodinium toryna* (Cookson & Eisenack 1960) Davey 1979

- 2684 *Egmontodinium polyplacophorum* Gitmez & Sarjeant 1972
- 2685 *Ellipsoidictyum cinctum* Klement 1960
- 2686 *Endoscrinium granulatum* (Raynaud 1978) Lentin & Williams 1981
- 2687 *Exochosphaeridium phragmites* Davey et al. 1966
- 2688 *Exiguisphaera phragma* Duxbury 1977
- 2689 *Glossodinium dimorphum* Ioannides et al. 1977
- 2690 *Gochteodinia mutabilis* (Riley in Fisher & Riley 1980) Fisher & Riley 1982
- 2691 *Gochteodinia tuberculata* Below 1990
- 2692 *Gochteodinia villosa* (Vozzhennikova 1967) Norris 1978
- 2693 *Gonyaulacysta* cf. *G. centriconnata* Riding 1983
- 2694 *Gonyaulacysta dentata* (Raynaud 1978) Lentin & Vozzhennikova 1990
- 2695 *Gonyaulacysta eisenackii* (Deflandre 1938) Górká 1965
- 2696 *Gonyaulacysta pectinigera* (Gocht 1970) Fensome 1979
- 2697 *Gonyaulacysta speciosa* Harding 1990
- 2698 *Hystrichodinium pulchrum* Deflandre 1935
- 2699 *Hystrichodinium voigtii* (Alberti 1961) Davey 1974
- 2700 *Hystrichosphaeridium petilum* Gitmez 1970
- 2701 *Impletosphaeridium lumectum* (Sarjeant 1960) Islam 1993
- 2702 *Isthmocystis distincta* Duxbury 1979
- 2703 *Kalyptea diceras* Cookson & Eisenack 1960
- 2704 *Kleithriasphaeridium corrugatum* Davey 1974
- 2705 *Kleithriasphaeridium eoinodes* (Eisenack 1958) Davey 1974
- 2706 *Kleithriasphaeridium fasciatum* (Davey & Williams 1966) Davey 1974
- 2707 *Kleithriasphaeridium porosispinum* Davey 1982
- 2708 *Kleithriasphaeridium telaspinosum* (Fisher & Riley 1980) Lentin & Williams 1981
- 2709 *Lagenorhytis delicatula* (Duxbury 1977) Duxbury 1979
- 2710 *Leptodinium subtile* Klement 1960
- 2711 *Lithodinia arcanitabulata* Brenner 1988
- 2712 *Meiourogonyaulax bulloidea* (Cookson & Eisenack 1960) Sarjeant 1969
- 2713 *Meiourogonyaulax distincta* Smith & Harding 2004
- 2714 *Mendicodinium reticulatum* Morgenroth 1970
- 2715 *Muderongia endovata* Riding et al. 2001
- 2716 *Nelchinopsis kostromiensis* (Vozzhennikova 1967) Wiggins 1972
- 2717 *Oligosphaeridium complex* (White 1842) Davey & Williams 1966
- 2718 *Oligosphaeridium pulcherrimum* (Deflandre & Cookson 1955) Davey & Williams 1966
- 2719 *Pareodinia ceratophora* Deflandre 1947

- 2720 *Perisseiasphaeridium ingegerdiae* Nøhr-Hansen 1986
- 2721 *Phoberocysta neocomica* (Gocht 1957) Millioud 1969
- 2722 *Phoberocysta tabulata* Raynaud 1978
- 2723 *Prolixosphaeridium parvispinum* (Deflandre 1937) Davey et al. 1969
- 2724 *Pseudoceratium brevicornutum* Herngreen et al. 2000
- 2725 *Pseudoceratium pelliferum* Gocht 1957
- 2726 *Rhynchodiniopsis martonense* Bailey et al. 1997
- 2727 *Scriniodinium campanula* Gocht 1959
- 2728 *Scriniodinium inritibile* Riley in Fisher & Riley 1980
- 2729 *Scriniodinium pharo* (Duxbury 1977) Davey 1982
- 2730 *Senoniasphaera jurassica* (Gitmez & Sarjeant 1972) Lentin & Williams 1976
- 2731 *Sentusidinium* aff. *S. ?fibrillosum* Backhouse 1988
- 2732 *Sentusidinium rioultii* (Sarjeant 1968) Sarjeant & Stover 1978
- 2733 *Sirmiodinium grossii* Alberti 1961
- 2734 *Spiniferites primaevus* (Duxbury 1977) Monteil 1991
- 2735 *Spiniferites ramosus* (Ehrenberg 1838) Mantell 1858
- 2736 *Stanfordella exsanguia* (Duxbury 1977) Helenes & Lucas-Clark 1997
- 2737 *Stanfordella fastigiata* (Duxbury 1977) Helenes & Lucas Clarke 1997
- 2738 *Stephanelytron membranoideum* (Vozzhennikova 1967) Courtinat 1999
- 2739 *Stiphrosphaeridium anthophorum* (Cookson & Eisenack 1958) Lentin & Williams 1985
- 2740 *Stiphrosphaeridium dictyophorum* (Cookson & Eisenack 1958) Lentin & Williams 1985
- 2741 *Systematophora areolata* Klement 1960
- 2742 *Systematophora daveyi* Riding & Thomas 1988
- 2743 *Systematophora palmula* Davey 1982
- 2744 *Tanyosphaeridium isocalamum* (Deflandre & Cookson 1955) Davey & Williams 1969
- 2745 *Tanyosphaeridium magneticum* Davies 1983
- 2746 *Tehamadinium daveyi* Jan du Chêne et al. 1986
- 2747 *Tehamadinium evittii* (Dodekova 1969) Jan du Chêne et al. 1986
- 2748 *Tehamadinium sousense* (Below 1981) Jan du Chêne et al. 1986
- 2749 *Tenua hystrix* Eisenack 1958
- 2750 *Thalassiphora? robusta* Smith & Harding 2004
- 2751 *Trichodinium ciliatum* (Gocht 1970) Eisenack & Klement 1964
- 2752 *Tubotuberella apatela* (Cookson & Eisenack 1960) Ioannides et al. 1977
- 2753 *Valensiella ovulum* (Deflandre 1947) Eisenack 1963
- 2754 *Wallodinium anglicum* (Cookson & Hughes 1964) Lentin & Williams 1973
- 2755 *Wallodinium cylindricum* (Habib 1970) Duxbury 1983

- 2756 *Wallothinium krutzschii* (Alberti 1961) Habib 1972  
 2757 *Wallothinium luna* (Cookson & Eisenack 1960) Lentin & Williams 1973  
 2758 *Warrenia? brevispinosa* (Iosifova 1992) Iosifova 1996  
 2759 *Wrevittia* cf. *W. helicoidea* (Eisenack & Cookson 1960) Helenes & Lucas-Clark 1997

2760

2761

2762 Appendix 2.

2763 Sample details – a listing of the 70 samples collected from the sections at Gorodishche

2764 (sample numbers prefixed “U”) and Kashpir (sample numbers prefixed “K”), giving the

2765 bed number, Stage/Substage and the ammonite zone where appropriate.

2766

2767 **I Gorodishche:**

2768 **Sample No. Bed No. Stage/Substage Ammonite Zone/Subzone**

2769

2770	U40	20	Valanginian	unzoned
2771	U39	20	Valanginian	unzoned
2772	U38	20	Valanginian	unzoned
2773	U37	20	Valanginian	unzoned
2774	U36	20	Valanginian	unzoned
2775	U35	20	Valanginian	unzoned
2776	U34	20	Valanginian	unzoned
2777	U33	19	Upper Tith./Lower Berr.	Craspedites nodiger
2778	U32	18	Upper Tith./Lower Berr.	Craspedites nodiger
2779	U31	18	Upper Tith./Lower Berr.	Craspedites nodiger
2780	U30	18	Upper Tithonian	Craspedites subditus
2781	U29	18	Upper Tithonian	Craspedites subditus
2782	U28	18	Upper Tithonian	Kachpurites fulgens
2783	U27	18	Upper Tithonian	Kachpurites fulgens
2784	U26	17	Upper Tithonian	Epivirgatites nikitini
2785	U25	17	Upper Tithonian	Epivirgatites nikitini
2786	U24	16	Middle/Upper Tithonian	Virgatites virgatus
2787	U23	15	Middle/Upper Tithonian	Virgatites virgatus
2788	U22	14	Middle/Upper Tithonian	Virgatites virgatus
2789	U21	14	Middle/Upper Tithonian	Virgatites virgatus
2790	U20	13	Middle Tithonian	D. panderi-Z. zarajskensis
2791	U19	12	Middle Tithonian	D. panderi-Z. zarajskensis

2792	U18	10	Middle Tithonian	D. panderi-Z. zarajskensis
2793	U17	10	Middle Tithonian	D. panderi-Z. zarajskensis
2794	U16	9	Middle Tithonian	D. panderi-Z. zarajskensis
2795	U15	9	Middle Tithonian	D. panderi-Z. zarajskensis
2796	U14	8	Middle Tithonian	D. panderi-Z. zarajskensis
2797	U13	7	Middle Tithonian	D. panderi-Z. zarajskensis
2798	U12	7	Middle Tithonian	D. panderi-Z. zarajskensis
2799	U11	6	Middle Tithonian	D. panderi-Z. zarajskensis
2800	U10	6	Middle Tithonian	D. panderi-Z. zarajskensis
2801	U9	6	Middle Tithonian	D. panderi-Z. zarajskensis
2802	U8	5	Middle Tithonian	D. panderi-Z. zarajskensis
2803	U7	5	Middle Tithonian	D. panderi-Z. zarajskensis
2804	U6	4	Middle Tithonian	D. panderi-Z. zarajskensis
2805	U5	4	Middle Tithonian	D. panderi-Z. zarajskensis
2806	U4	3	Middle Tithonian	D. panderi-Z. zarajskensis
2807	U3	2	Middle Tithonian	D. panderi-Z. zarajskensis
2808	U2	2	Middle Tithonian	D. panderi-Z. zarajskensis
2809	U1	1	Middle Tithonian	D. panderi-Z. zarajskensis

2810

2811 **II Kashpir:**

2812	<b>Sample No.</b>	<b>Bed No.</b>	<b>Stage/Substage</b>	<b>Ammonite Zone</b>
2813				
2814	K30	30	Valanginian	unzoned
2815	K29	30	Valanginian	unzoned
2816	K28	30	Valanginian	unzoned
2817	K27	29	Valanginian	unzoned
2818	K26	29	Valanginian	unzoned
2819	K25	29	Valanginian	unzoned
2820	K24	29	Valanginian	unzoned
2821	K23	28	Valanginian	unzoned
2822	K22	27	Valanginian	unzoned
2823	K21	27	Valanginian	unzoned
2824	K20	27	Valanginian	unzoned
2825	K19	27	Valanginian	unzoned
2826	K18	26	Valanginian	unzoned
2827	K17	24	Valanginian	unzoned

2828	K16	23	Upper Berriasian	<i>Surites tzikwinianus</i>
2829	K15	23	Upper Berriasian	<i>Surites spasskensis</i>
2830	K14	23	Upper Berriasian	<i>Surites spasskensis</i>
2831	K13	21	Middle/Upper Berriasian	unzoned
2832	K12	19	Middle/Upper Berriasian	unzoned
2833	K11	19	Middle/Upper Berriasian	unzoned
2834	K10	18	Middle/Upper Berriasian	unzoned
2835	K9	17	Upper Tith./Lower Berr.	<i>Craspedites nodiger</i>
2836	K8	14	Upper Tithonian	<i>Craspedites subditus</i>
2837	K7	14	Upper Tithonian	<i>Craspedites subditus</i>
2838	K6	13	Upper Tithonian	<i>Craspedites subditus</i>
2839	K5	13	Upper Tithonian	<i>Craspedites subditus</i>
2840	K4	11	Upper Tithonian	<i>Kachpurites fulgens</i>
2841	K3	11	Upper Tithonian	<i>Kachpurites fulgens</i>
2842	K2	3	Middle Tithonian	<i>Dorsoplanites panderi</i>
2843	K1	2	Middle Tithonian	<i>Dorsoplanites panderi</i>