

clearly two-branched MA and the CuA2–CuP area somewhat less narrowed than in the holotype (Fig. 89b); specimen PIN, no. 3840/1227, forewing fragment, similar to the previous one, but with the anterior branch of MA connected to RS near the base of this MA branch (Fig. 89c); specimen PIN, no. 3840/1229, fragment of a rather small forewing, similar in size to the holotype, but with insufficiently distinct venation. The provisional attribution of these impressions to the new species is based on the assumptions that the larger wings probably belong to females and, in the smaller males, the first branch of MA was probably more strongly reduced (in female, only early stages of this process are possible, but in male, this branch can turn into a sinuate veinlet that has practically lost its connection with M and looks like an additional intercalary vein).

Isadyphasma suchonae Gorochov, sp. nov.

E t y m o l o g y. From the Sukhona River.

H o l o t y p e. PIN, no. 3840/1228, positive impression of slightly distorted forewing without proximal part; Isady locality, Vologda Region; Severodvinian Stage.

D e s c r i p t i o n (Figs. 89d, 90g). The wing is similar to that of *I. bashkuevi*, but its apical portion is somewhat wider because of the development of two short additional branches in the distal part of the second branch of MA; an additional longitudinal veinlet is present in the area between the first and second branches of MA; such a vein is absent in the area between MA and MP + CuA1; the distance between the base of MA and the apex of 2A is subequal to the distance between the apex of 2A and wing apex. Coloration is not preserved.

M e a s u r e m e n t s, mm. Length of impression, 15.5; estimated wing length, 17–18.

C o m p a r i s o n. The differences between the new species and *I. bashkuevi* are listed above (in the description of *I. suchonae*).

M a t e r i a l. Holotype.

Isadyphasma deminutum Gorochov, sp. nov.

E t y m o l o g y. Neutral form of the Latin *deminutus* (diminished).

H o l o t y p e. PIN, no. 3840/1231, part and counterpart of almost complete forewing; Isady locality, Vologda Region; Severodvinian Stage.

D e s c r i p t i o n (Figs. 89e, 90h). The wing is similar to that of *I. bashkuevi*, but distinctly smaller and somewhat shorter (almost oval in shape); RS bifurcates markedly distal to the middle of the interradiar area; MA has two branches; all areas between RA and MP + CuA1 lack visible additional longitudinal veinlets; the CuA2–CuP area is not distinctly narrowed in the region of the base of MA; the distance between the base of MA and the apex of 2A is subequal to the dis-

tance between the apex of 2A and wing apex. Coloration is partially preserved; the entire wing was probably uniformly darkened.

M e a s u r e m e n t s, mm. Wing length, 9.5.

C o m p a r i s o n. The new species differs from *I. suchonae* in the following characters: the forewing is markedly smaller and shorter; the point of bifurcation of RS is distinctly closer to the wing apex; the second branch of MA is single; additional longitudinal veinlets in the interradiar area and between branches of MA are undeveloped. The differences of the new species from *I. bashkuevi* are listed in the description. Since all longitudinal veins of the wing of the new species are well pronounced (approximately to the same extent as in congeners), the wing was apparently not nymphal, i.e., *I. deminutum* was probably just a short-winged species (like many modern phasmids).

M a t e r i a l. Holotype.

3. RESULTS AND DISCUSSION

3.1. Insects of the Permian and Early Triassic (Urzhumian–Olenekian Ages) and the Problem of the Permian–Triassic Biodiversity Crisis

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The extensive material of fossil insects from Biarmian and Tatarian localities of European Russia, collected mostly by expeditions of the Arthropoda Laboratory, PIN, during the last decade and described in the previous chapters of this volume, once again raise the question of the character of changes in the composition of the largest group of living organisms at the most dramatic boundary in the Phanerozoic history of life: at the Permian–Triassic boundary and around it. This question is the subject of this chapter.

3.1.1. Materials

The data on the Urzhumian–Induan fossil insect localities of European Russia are given above (Chapter 1). Brief data on other materials from localities of this age outside European Russia are added below.

Surieikova 1. Russia, Kemerovo Region, Kuznetskii District, left bank of the Tom River upstream from the mouth of the Surieikova River; Middle Permian, Urzhumian Stage, Kol'chugino Group, Il'inskoe Subgroup, Kazankova–Markina Formation (Shcherbakov, 2008);

judging from the insect assemblage, Severodvinian Stage (see below). A total of 670 insect specimens have been collected; they are stored in PIN (Rohdendorf et al., 1961).

Order Tripida. Family Lophioneuridae (Vishniakova, 1981).

Order Hemiptera. Families Archescitinidae (D.E. Shcherbakov, pers. comm.), Prosbolidae, Protopsyllidiidae, Scytinopteridae, Serpentinidae, and Suriokocixiidae (Shcherbakov, 2000).

Order Paleomanteida. Family Paleomanteidae (Rohdendorf et al., 1961),

Order Coleoptera. Families Permocupedidae, Rhombocoleidae, Schizocoleidae, and Taldycupedidae (Ponomarenko, 2004)

Order Jurinida. Family Jurinidae (see Chapter 2.1).

Order Panorpida. Families Kaltanidae (Rohdendorf et al., 1961); Permochoristidae, and Permotipulidae (Novokshonov, 1997).

Order Grylloblattida. Families Liomopteridae and Megakhosaridae (Aristov, 2009b),

Sokolova 2. Russia, Kemerovo Region, Prokop'evskii District, left bank of the Bol'shaya Tykhta River, somewhat upstream from the village of Sokolova; Upper Permian, Severodvinian Stage, Kol'chugino Series, Erunakovo Subseries, Gramoteino Formation (Shcherbakov, 2008). Judging from the insect assemblage, Vyatkian Stage (see below). A total of 569 insect fossils have been collected; stored in PIN (Rohdendorf et al., 1961).

Order Hemiptera. Families Prosbolidae, Scytinopteridae, Dysmorphoptilidae, and Paraknightiidae (Shcherbakov, 2000).

Order Paleomanteida. Family Permosialidae (Rohdendorf et al., 1961).

Order Coleoptera. Families Permocupedidae, Rhombocoleidae, Schizocoleidae, Permosynidae, and Taldycupedidae (Ponomarenko, 2004).

Order Neuroptera. Family Permithonidae (A.G. Ponomarenko, pers. comm.)

Order Jurinida. Family Glosselytridae (see Chapter 2.1)

Order Panorpida. Family Permochoristidae (Novokshonov, 1997).

Karaungir. Kazakhstan, East Kazakhstan Province, Zaisanskii District, Saur Mountain Range, right bank of the Karaungir River 500 m downstream of the mouth of the Maichat Creek (coll. nos. 2494 and 2495); right bank of the Kenderlyk River (coll. no. 2781); Saikan Mountain Range, right bank of the Karaungir River, Kyuryul'tyu gully (coll. no. 3060); Upper Permian, Vyatkian Stage (Shcherbakov, 2008), Maichat and Akkolka Formations. Judging from the insect assemblage, Urzhumian Stage (see below). A total of about 550 specimens have been collected, stored in PIN (*Katalog kollektsii ...*, 2010).

Order Odonata. Family Meganeuridae (identified by D.V. Vassilenko).

Order Tripida. Family Lophioneuridae (Vishniakova, 1981).

Order Hemiptera. Families Archescitinidae, Ingridae, Pereboriidae, Prosbolidae, Protopsyllidiidae, Dysmorphoptilidae, Scytinopteridae, Serpentinidae, ?Dunstaniidae, and ?Prosbolopseidae (Shcherbakov, 2000).

Order Paleomanteida. Family Permosialidae (see Chapter 2.1).

Order Coleoptera. Families Permocupedidae, Rhombocoleidae, Schizocoleidae, and Taldycupedidae (Ponomarenko, 2004).

Order Jurinida. Families Jurinidae and Glosselytridae (see Chapter 2.1).

Order Panorpida. Families Kaltanidae and Permochoristidae (Novokshonov, 1997).

Order Trichoptera. Families Protomeropidae (Novokshonov, 1997), Microptysmatidae (see Chapter 2.5).

Order Grylloblattida. Families Liomopteridae, Tshekardominidae, Ideliidae, Megakhosaridae, Blatogryllidae, and Permothemopsidae (Aristov, 2009b)

Order Perlida. Families Palaeonemouridae and Paleoperlidae (Sinitshenkova, 1987).

Bor-Tologoi. Mongolia, South Gobi Province, 16 km southeast of Tsogtsetsii Sum, Bor-Tologoi locality 20 km east-southeast of Tabun-Tologoi quarry; Upper Permian, Severodvinian Stage, Tsankhin Formation. The formation can be correlated with the Leninsk Formation of the Kuznetsk Basin (Shcherbakov, 2008). Based on the insect assemblage, Urzhumian Stage (see below). A total of about 860 specimens have been collected, stored in PIN (*Katalog kollektsii ...*, 2010).

Order Odonata. Family Ditaxineuridae (identified by D.V. Vassilenko).

Order Caloneurida. Family Caloneuridae (Rasnitsyn in Rasnitsyn and Quicke, 2002, p. 108, as Apsidoneuridae).

Order Dictyoneuridae. Family Mongolodictyidae (Sinitshenkova, 1992).

Order Hemiptera. Families Archescitinidae, Boreoscytidae, Prosbolopseidae, Ingridae, Pereboriidae, Prosbolidae, Scytinopteridae, Dunstaniidae, Stenoviciidae (Shcherbakov, 2000), and Coleoscytidae (*Katalog kollektsii ...*, 2010).

Order Paleomanteida. Families Paleomanteidae (*Katalog kollektsii ...*, 2010) and Permosialidae (Aristov, 2004b).

Order Coleoptera. Families Permocupedidae, Rhombocoleidae, Schizocoleidae, Taldycupedidae, and Asiocoleidae (Ponomarenko, 2004).

Order Corydalida. Family Parasialidae (Ponomarenko, 2000a).

Order Jurinida. Family Glosselytridae (Ponomarenko, 2000a).

Order Neuroptera. Family Permithonidae (*Katalog kollektsii ...*, 2010).

Order Panorpida. Families Kaltanidae (Novokshonov, 1994) and Permochoristidae (Novokshonov, 1997).

Order Trichoptera. Family Microptysmatidae (see Chapter 2.5).

Order Grylloblattida. Families Tsherkardominidae, Ideliidae, and Liomopteridae (Aristov, 2009b).

Order Perlida. Family Palaeonemouridae (Dijk and Geertsema, 2004).

Order Forficulida. Family Dermelytridae (*Katalog kollektsii ...*, 2010).

Order Phasmatida. Family Permophasmatidae (Gorochoy, 1992)

Normandien. South African Republic, KwaZulu-Natal Province, group of localities in the Karoo and Lebombo river basins near the Drakensberg Mountains (Bulver, KwaYaya, Clouston Farm, Lidgetton, Mount West, Mooi River, Far End, Emakwezini, etc.); Upper Permian, Changhsingian or Wuchiapingian Stage, Karoo Supergroup, Beaufort Group, Adelaide Subgroup, Normandien Formation, equivalent of Emakwezini Formation (Aristov et al., 2009a; Prevec et al., 2009). Judging from the insect assemblage (see below), the deposits belong to the Severodvinian Stage. A total of about 250 specimens have been collected, stored in the Natal Museum and in the Bernard Price Institute (M.B. Mostovski, pers. comm.).

Order Odonata. Families Ditaxineuridae and Permolestidae (L.N. Pritykina, pers. comm.).

Order Diaphanoptera. Family Scytohymenidae (Chapter 2.2).

Order Hemiptera. Families Prosbolidae, Protosyllidiidae, Dunstaniidae, Ignotalidae (Shcherbakov, 2000), Dysmorphoptilidae (Shcherbakov, 1984), and Scytinopteridae (D.E. Shcherbakov, pers. comm., for *Afrostenovicia* Dijk et Geertsema, 1999).

Order Paleomanteida. Families Paleomanteidae (Dijk and Geertsema, 1999) and Permosialidae (Rasnitsyn and Dijk, 2011).

Order Coleoptera. Families Rhombocoleidae, Schizocoleidae, Permosynidae, and Taldycupedidae (Ponomarenko and Mostovski, 2005).

Order Neuroptera. Families Permithonidae and Archeosmylidae (Dijk and Geertsema, 1999).

Order Panorpida. Family Permochoristidae (Novokshonov, 1997).

Order Trichoptera. Families Protomeropidae (Sukacheva et al., 2007) and Cladochoristidae (Chapter 2.5).

Order Grylloblattida. Families Chaulioditidae, Liomopteridae, Megakhosaridae (Aristov et al., 2009a), and Skaliciidae (D.S. Aristov, unpublished data).

Order Perlida. Families Palaeonemouridae (Dijk and Geertsema, 2004) and Euxenoperlidae (Riek, 1976).

Order Forficulida. Family Permofulgoridae (Rasnitsyn and Quicke, 2002).

Order Orthoptera. Families Pruvostitidae (Gorochoy, 1995) and Xenopteridae (Dijk and Gorochoy, 2011).

Belmont. Australia, New South Wales, Group of liomopterid localities in the area of Belmont and Warner's Bay north of Sydney (Brown's Outcrop, Burton Road, Croudace Quarry, 205, 206, St. Andrews Park, etc.); Upper Permian, lower layers of the Changhsingian Stage (Shi et al., 2010), Sydney Basin, Upper Newcastle Coal Measures, upper part of the Croudace Bay Formation, Belmont Conglomerate Member. Judging from the insect assemblage (see below), these deposits belong to the Vyatkian Stage. A total of at least 2000 insect specimens have been collected, stored in the Australian Museum, Sydney, Australia, and in the Natural History Museum, London, United Kingdom (Beattie, 2007).

Order Odonata. Family Permaeshnidae (Jell, 2004).

Order Hypoperlida. Family Ischnoneuridae (Rasnitsyn and Aristov, 2012; Chapter 2.1).

Order Psocida. Family Psocidiidae (Jell, 2004).

Order Tripida. Family Lophioneuridae (Jell, 2004).

Order Hemiptera. Families Archescytinidae, Prosbolidae, Protosyllidiidae, Dysmorphoptilidae, Dunstaniidae, Stenoviciidae, Paraknightiidae, Progonomimicidae, Pincombeidae (Shcherbakov, 2000), and Simulaphididae (Shcherbakov, 2007).

Order Palaeomanteida. Family Permosialidae (Riek, 1968).

Order Coleoptera. Families Rhombocoleidae, Permosynidae (Ponomarenko, 2004), and Asiocoleidae (A.G. Ponomarenko pers. comm.).

Order Neuroptera. Families Permithonidae and Archeosmylidae (Ponomarenko and Shcherbakov, 2004).

Order Jurinida. Family Jurinidae (Jell, 2004).

Order Panorpida. Families Permochoristidae, Belmontiidae, Robinjohniidae, Permotipulidae, Permotanyderidae, Parachoristidae (Novokshonov, 1997), and Mesopsychidae (Bashkuev, 2011b).

Order Trichoptera. Family Protomeropidae (Novokshonov, 1997), Cladochoristidae (Chapter 2.5).

Order Grylloblattida. Families Liomopteridae and Sylvaphlebiidae (Aristov, 2009b).

Order Perlida. Family Eustheniidae (Chapter 2.7).

Order Forficulidae. Family Dermelytridae and Permofulgoridae (Rasnitsyn and Quicke, 2002).

Intertrappean Deposits of the Tunguska Basin

Intertrappean deposits of the Tunguska Basin (Central Siberian Plateau, Krasnoyarsk Region, Evenkiiskii District) belong to four horizons: Tutonchanian (the earliest), Lebedevskian, Khungtukunian

(Korvunchana Group), and Putoranian (Putorana Group) (Sadovnikov and Orlova, 1995). Insects have been found in the last three horizons. The correlation of these horizons with other regions and with the General Stratigraphic Chart is controversial. Some authors attribute the intertrappean deposits to the Upper Permian (Meyen, 1992; Sadovnikov and Orlova, 1994). Sadovnikov and Orlova (1994) attribute the Tutonchana and Lebedevskian horizons to the Vyatkian Stage and the Khungtukunian and Putoranian horizons to the "Taimyrian" Stage, the terminal stage of the Permian. At the same time, a part of the Putoranian Horizon corresponds to the lower portion of the Vokhma Formation (Nedubrovo and Astashikha members) of European Russia (Sadovnikov, 2009). According to all officially approved stratigraphic scales, these deposits belong to the Triassic. In the opinion of Mogucheva and Kruglovkykh (2009), the lower layers of the Dvurogian (=Lebedevskian) Horizon correspond to the upper layers of the Induan and the lower layers of the Olenekian; the upper layers of the Dvurogian (=Khungtukunian) Horizon and the lower layers of the Putoranian Horizon correspond to the Olenekian Stage; and the upper layers of the Putoranian Horizon correspond to the Anisian Stage. In the above-mentioned study, the lower layers of the Dvurogian (=Lebedevskian) Horizon are correlated with the Kedrovi beds of the Mal'tsevo Formation of the Kuznetsk Basin (Babii Kamen' locality).

At the same time, the most reliable currently available absolute dates point not only to a relatively short period of the outflow of the Siberian traps (less than two million years), but also to the termination of their main phase about 250.3 ± 1.1 Ma, i.e., before the officially accepted Permian–Triassic boundary (249.25 ± 0.14 million years; Reichow et al., 2009). This circumstance suggests that intertrappean assemblages were approximately contemporaneous and, thus, they are analyzed jointly, primarily because assemblages from different horizons are rather similar and, what is more important, they are too poor and nonrepresentative separately, but taken together provide rather definite information. Therefore, at the present level of knowledge of these deposits, such a generalized analysis is justified.

The Lebedevskian Horizon is represented by the localities of **Anakit** (three localities on the Lower Tunguska River near the mouth of the Anakit River; Chichikan Formation) and **Bugarkita-1** (=Nizhnyaya Bugarikhta; Bugarikhta River (left tributary of the Tutonchana River 30 km upstream from its mouth), 1 km from the mouth; Bugarikhta Formation). The Lebedevskian or Khungtukunian Horizon is represented by the intertrappean locality of **Malaya Kheta** (=Arktika, =Ust'-Port; Taimyrskii District, left bank of the Yenisei River near the mouth of the Malaya Kheta River, 120 km northwest of Dudinka). The Khungtukunian Horizon is represented by **Khungtukun-2** and **Khungtukun-4** (right bank of the Lower

Tunguska River, 4.9 km and 3.1 km, respectively, east of the mouth of the Khungtukun River; Pirda Formation) and, probably, by **Nizhnyaya Lyulyuikta-1** (left bank of the Lower Tunguska River, 3.2 km west-southwest of the mouth of the Nizhnyaya Lyulyuikta River; upper layers of the Lebedevskian Horizon or lower layers of the Khungtukunian Horizon). The Putoranian Horizon is represented by **Severnoe** (southern shore of Lake Severnoe opposite the mouth of the Epekli-Sen River; Nidym Formation), **Untuun-2** (Lower Tunguska River Basin, left bank of the Untuun River, left bank of the Kochechumo River, 15 km from the mouth, or 10 km by a straight line, opposite the mouth of the Khoktokon River; Kochechumo Formation), **Nikungdakan-1** (=Tura; Lower Tunguska River Basin 33 km east-southeast of the village of Tura, left bank of the Nirungdakan River, 10 km from its mouth; Agitnak Formation), and **Ukshunukan-2** (=Ilimpeya; right bank of the middle reaches of the Ilimpeya River, 3.3 km downstream from the Ukshunukan River; Limgtekon Formation).

A total of 600 insect specimens, stored in PIN, have been collected in these localities. A combined list of the families identified from these localities is given below.

Order Ephemeroptera. Families Sharephemeridae (Khungtukun-2) and Vogesonymphidae (Khungtukun-2, Khungtukun-4) (Sinitshenkova, 2013).

Order Hemiptera. Families Archescytinidae (Niznyaya Bugarikhta), Stenoviidae (Khungtukun-2), Surijokocixiidae (Ust'-Port), and Ignotalidae (Ukshunukan, Severnoe, Khungtukun-2) (Shcherbakov, 2000; D.E. Shcherbakov, pers. comm.).

Order Coleoptera. Families Taldycupedidae (Ukshunukan), Schizocoleidae (Anakit, Ukshunukan), Permosynidae (Anakit, Lyulyuikta, Khungtukun, Anakit), Asiocoleidae (Anakit), Triaplidae (Anakit), and Trachypachidae (Anakit) (A.G. Ponomarenko, pers. comm.).

Order Neuroptera. Family Permitionidae (Ukshunukan; Ponomarenko and Shcherbakov, 2004).

Order Panorpida. Families Mesopsychidae (Khungtukun-2), Nedubroviidae (Lyulyuikta), and Permotanyderidae (Niznyaya Bugarikhta, Lyulyuikta) (Bashkuev, 2013).

Order Blattella. Family Phylloblattidae (Vršanský, 2010b).

Order Grylloblattidae. Families Chaulioditidae (Anakit, Khungtukun), Geinitziidae (Malaya Lyulyuikta), Megakhosaridae (Anakit), Blattogryllidae (Anakit) (Aristov, 2011).

Order Orthoptera. Family Locustavidae (Niznyaya Bugarikhta; Sharov, 1968).

Babii Kamen'. Russia, Kemerovo Region, Novokuznetskii District, right bank of the Tom River, 10 km downstream from the city of Ust'-Naryk; Aba Group, Mal'tsevo Formation, Kedrovi beds. A total

of 138 specimens have been collected, stored in PIN. The age of the insect-bearing beds corresponds to the Induan Stage (Shcherbakov et al., 2002). According to an opposite point of view (Mogucheva and Kruglovskiy, 2009), the Kedrovi beds are correlated with the lower layers of the Dvurogian (=Lebedevskian) Horizon, which correspond to the upper layers of the Induan and the lower layers of the Olenekian. According to the latest, most reliable data of the Ar-Ar isotope method, the Permian–Triassic boundary lies at 249.25 ± 0.14 Ma (Reichow et al., 2009), and runs in the Kuznetsk Basin in the upper part of the Mal'tsevo Formation, upward in the section from the position of the Karaganskii sill (250.3 ± 0.7 – 250.7 ± 0.6) and Syrkashevskii sill (252.2 ± 0.5 – 252.3 ± 0.6 : Buslov et al., 2010). According to Shcherbakov et al. (2002), the insect-bearing beds lie lower in the section. Thus, the age of insects of Babii Kamen' and that of intertrappean Siberian assemblages is technically estimated as approximately the same, terminal Permian. Biogeographically, Babii Kamen' was situated at that time at a higher paleolatitude than Tunguska, in the cold–temperate climatic zone rather than in the temperate semiarid zone, to which Tunguska belonged (Shcherbakov, 2009).

The following insects have been collected in Babii Kamen':

Order Ephemera. Family Mithodotidae (Shcherbakov et al., 2002).

Order Hemiptera. Families Prosbolidae, Scytinopleridae, and Hylcellidae (Shcherbakov et al., 2002).

Order Coleoptera. Families Schizocoleidae, Ademosynidae (as Permosynidae in Table 1, text-fig. 1, and calculations), Triaplidae, Trachypachidae, Hydrophilidae, and Byrrhidae (Ponomarenko, 2004).

Order Neuroptera. Family Archeosmylidae (Ponomarenko and Shcherbakov, 2004).

Order Panorpida. Family Mesopsychidae (Bashkuev, 2011b).

Order Blattida. Families Subioblattidae and Blattulidae (P. Vršanský, pers. comm.).

Order Grylloblattida. Families Chaulioditidae (Aristov, 2003), Geinitziidae (Aristov, 2004).

Order Orthoptera. Family Mesoedischidae (Gorochov, 2005a).

Structure and Dynamics of Insect Diversity in the Period Studied

To date, a total of 25 orders and 115 families of insects have been found in deposits of the terminal Permian (Urzhumian to Vyatkian) and Lower Triassic. Particular finds of families and their general distribution, along with similar data on other, better studied regions of the planet, are given in Table 2 and Figs. 91 and 92. Calculations based on these data are shown in Tables 3–14 and Figs. 93–95. The results allow discussing some aspects of the insect diversity dynamics

during this period. However, first we have to substantiate the methodological approaches we used.

3.1.2. Methods

The analysis of distribution and taxonomic dynamics is performed here based on the data on insect families and their distribution over particular localities or, in some cases, groups of presumably contemporaneous localities of limited geographic distribution. The taxonomic level of families is generally accepted as optimal for such purposes and scarcely requires additional substantiation. The analysis of particular localities rather than successive stratigraphic units is connected with continuing heated debates on the correctness of various methods for analyzing such data (cf. Rasnitsyn, 2005, and Dmitriev and Ponomarenko, 2009). The use of particular local assemblages does not imply such problems, but it is not free from other difficulties. The most important of them is the necessity to arrange the analyzed assemblages in a linear sequence, even if there is not enough stratigraphic grounds for such an ordination. This problem can be solved to some extent by comparison of several alternative sequences (see below).

The initial stratigraphic sequence of assemblages used here (Table 3) mostly follows Shcherbakov (2008). The Permian–Triassic insect assemblages from the intertrappean deposits of Tunguska, which were not discussed there, are taken for a single combined assemblage, because the presumably short duration of the trappean outflows in Siberia suggests that these assemblages are close in age (see above), their composition at the family level is rather uniform, and the amount of material from each formation is insufficient for calculations. The position immediately before Vyazniki of the Aristov assemblage, which is also not included in the Shcherbakov's sequence, directly follows from the results given in Chapter 1.

Tables 3–8, 10–12, 14, show the data on particular assemblages, including the total number of specimens, the number of first and last appearances of families in the fossil record, and the number of families in some other categories. These categories include (1) *transitional* families (those that emerged before the Urzhumian and survived until at least the Middle Triassic); (2) families that emerged **before the Urzhumian** and did not survive through the Lower Triassic, hereinafter called *conditionally considered Paleozoic* or simply *ancient* (strictly in this context); (3) families that emerged **not earlier than the Urzhumian** and survived through the Lower Triassic, hereinafter called *conditionally considered post-Paleozoic* or *young*; and (4) families *conditionally considered endemic* to the period in question (those that emerged not earlier than the Urzhumian and became extinct not later than the Early Triassic).

To provide at least a rough estimate of the direction and rate of the faunal renewal, we included in the

Table 2. Insect families found in the Urzhumian-Induan and their complete distribution. References: [1] Engel (2009); [2] Bashkuev et al (2012); [3] Sinitshenkova and Vassilenko (2011); [4] Rasnitsyn and Quicke (2002); [5] Brauckmann (1991); [6] Tillyard (1926); [7] Pritykina (1981); [8] Tillyard (1926); [9] Rasnitsyn et al. (2004); [10] Carpenter (1992); [11] Kukalová-Peck (1972); [12] Vishniakova (1981); [13] Shcherbakov (2000); [14] Shcherbakov (2008); [15] Shcherbakov (pers. comm.); [16] Shcherbakov (1988); [17] Shcherbakov (2007); [18] Katalog kolektsii ... (2010); [19] Aristov and Rasnitsyn (2009); [20] Ponomarenko (2000b); [21] Ponomarenko (1969); [22] Tan et al. (2009); [23] Ponomarenko (pers. comm.); [24] Ponomarenko (1977); [25] Ponomarenko and Shcherbakov (2004); [26] Rohdendorf et al. (1961); [27] Novokshonov (1997); [28] Novokshonov and Sukacheva (2001); [29] Aristov (2009b); [30] Vishniakova (1998); [31] Martins-Neto et al. (2005); [32]; Vršanský (pers. comm.); [33] Vršanský (2008); [34] Schneider (1983); [35] Papier and Grauvogel-Stamm (1995); [36] Vršanský (2003); [37] Storozhenko (1997); [38] Béthoux and Beckemeyer (2007); [39] Aristov et al. (2009); [40] Aristov et al. (2009); [41] Aristov (2005); [42] Storozhenko (1998); [43] Aristov (2011a); [44] Aristov (2004d); [45] Aristov (2012); [46] Sinitshenkova (1987); [47] Gorochoy (2005a); [48] Gorochoy (1995); [49] Gorochoy (2005b); [50] Gorochoy (pers. comm.); [51] Dijk and Gorochoy (2011); [51] Dijk and Gorochoy (2011); [52] Sinitshenkova (2012). No reference is given to the records considered above in this publication

Family	First appearance	Occurrence in localities analyzed	Last appearance
Dasyleptidae	C ₃ st [1]	Isady	T ₂ ani [2]
Protereismatidae	P ₁ sk [3]	Isady	Isady
Misthodotidae	P ₁ ar [4]	Isady, Babii Kamen'	T ₂ [3]
Sharephemeridae	Khungtukun [52]	Khungtukun-2 [52]	J ₃ [52]
Vogesonymphidae	Khungtukun [52]	Khungtukun-2, -4 [52]	T ₂ [52]
Meganeuridae	C ₂ b [5]	Kargala, Karaungir, Novo-Aleksandrovka	Novo-Aleksandrovka
Kennedyidae	P ₁ ar [6]	Isady	T ₃ [7]
Ditaxineuridae	P ₁ ar [8]	Bor-Tologoi, Normandien	Normandien
Permolestidae	P ₁ kg [4]	Kargala, Isady, Normandien	Normandien
Caloneuridae	C ₂ [4]	Kargala, Bor-Tologoi, Isady	Isady
Ischnoneuridae	C ₂ [4]	Chepanikha, Isady, Belmont	Belmont
Toccladidae	P ₁ ar	Kargala	Kargala
Hypoperlidae	P ₁ kg [4]	Isady	Isady
Mongolodictyidae	Bor-Tologoi	Bor-Tologoi	Bor-Tologoi
Calvertiellidae	C-P [9]	Isady	Isady
Scytohymenidae	P ₁ kg [10]	Normandien	Normandien
Moravohymenidae	P ₁ sk [11]	Isady	Isady
Psocidiidae	P ₁ sk [4]	Isady, Belmont, Nedubrovo	Nedubrovo
Lophioneuridae	P ₁ ar [12]	Suriekovo, Karaungir Isady, Belmont, Sokovka, Balymotikha	K ₂ st [10]
Archescitinidae	P ₁ sk [13]	Suriekovo, Bor-Tologoi, Karaungir, Belmont, Nedubrovo, Nizhnyaya Bugarikhta	Nizhnyaya Bugarikhta
Boreoscytidae	P ₁ kg [13]	Bor-Tologoi	Bor-Tologoi
Coleoscytidae	P ₁ kg [13]	Bor-Tologoi	Bor-Tologoi
Prosbolopseidae	P ₁ kg [13]	Bor-Tologoi, Novo-Aleksandrovka, Karaungir	Karaungir
Prosbolidae	P ₂ kz ¹ [13]	Chepanikha, Suriekovo, Sokolova, Bor-Tologoi, Novo-Aleksandrovka, Karaungir, Isady, Normandien, Belmont, Balymotikha, Babii Kamen'	Babii Kamen'
Ingruidae	P ₁ kg [13]	Chepanikha, Novo-Aleksandrovka, Bor-Tologoi, Karaungir Isady	Belmont
Scytinopteridae	P ₂ kz ¹ [13]	Chepanikha, Suriekovo, Sokolova, Bor-Tologoi, Novo-Aleksandrovka, Karaungir Isady, Normandien, Balymotikha, Nedubrovo, Babii Kamen', Khungtukun-2	K ₁ [13]
Stenoviciidae	P ₃ sv [13]	Bor-Tologoi, Novo-Aleksandrovka, Isady, Aristovo, Balymotikha, Belmont, Khungtukun-2	T ₂₋₃ [13]
Pereboriidae	P ₂ kz ¹ [13]	Chepanikha, Kargala, Bor-Tologoi, Novo-Aleksandrovka, Isady, Balymotikha, Karaungir	Karaungir
Surijokocixiidae	Chepanikha	Chepanikha, Suriekovo, Kargala, Novo-Aleksandrovka, Balymotikha, Nedubrovo, Ust'-Port, Khungtukun-2	T ₃ [13]
Serpentivenidae	Chepanikha	?Chepanikha, Suriekovo, Karaungir	T ₂₋₃ [13]
Dunstaniidae	Bor-Tologoi	Bor-Tologoi, Karaungir, Isady, Normandien, Belmont, Aristovo, Balymotikha	J ₁ [13]
Ignotalidae	P ₂ sd ² [14]	Normandien, Ukshunukan, Severnoe	T _{2/3} [15]
Dysmorphoptilidae	P ₂ kz ¹ [13]	?Chepanikha, Novo-Aleksandrovka, Karaungir, Isady, Sokolova, Normandien, Belmont, Balymotikha	J ₁ [13]
Paraknightiidae	Sokolova	Sokolova, Belmont, Balymotikha	T ₂₋₃ [13]
Hylcellidae	Babii Kamen'	Babii Kamen'	K ₁ [16]
Progonocimicidae	Isady	Isady, Belmont, Balymotikha, Nedubrovo	K ₁ [4]

Table 2. (Contd.)

Family	First appearance	Occurrence in localities analyzed	Last appearance
Pincombeidae	Belmont	Belmont	T ₃ [13]
Protopsyllidiidae	P ₂ kz ¹ [4]	Suriekovo, Karaungir, Normandien, Belmont, Novo-Aleksandrova, Isady, Balymotikha	K ₂ [13]
Simulaphididae	Belmont	Belmont	?T ₃ [17]
Paleomanteidae	C ₂ [9]	Chepanikha, Suriekovo, Bor-Tologoi, Isady, Normandien, Nedubrovo	Isady
Permosialidae	P ₁ sk	Chepanikha, Kostovaty, Sokolova Bor-Tologoi, Isady, Normandien, Karaungir, Belmont, Balymotikha, Nedubrovo	Karatau [18]
Permembiiidae	P ₁ ar [19]	Isady	Isady
Permocupedidae	P ₂ kz ¹ [20]	Chepanikha, Suriekovo, Kargala, Karaungir, Novo-Aleksandrova, Sokolova, Bor-Tologoi, Isady	T ₂ Franconia [23]
Rhombocoleidae	P ₂ kz ² [4]	Chepanikha, Kostovaty, Suriekova, Kargala, Novo-Aleksandrova, Sokolova, Bor-Tologoi, Isady, Normandien, Karaungir, Belmont, Balymotikha	Belmont
Schizocoleidae	P ₂ kz ² [4]	Chepanikha (as Schizophoridae), Suriekovo, Novo-Aleksandrova, Sokolova, Bor-Tologoi, Isady, Normandien, Aristovo, Karaungir, Balymotikha, Nedubrovo, Entala, Babii Kamen', Anakit, Ukshunukan	J ₂ [21]
Permosynidae	Kul'chumovo	Sokolova, Normandien, Aristovo, Belmont, Sokovka, Balymotikha, Babii Kamen', Anakit, Lyulyuikta, Khungtukun	K ₁ [21]
Taldycupedidae	Kargala	Kargala, Suriekovo, Sokolova, Bor-Tologoi, Isady, Normandien, Karaungir, Nedubrovo, Ukshunukan, Anakit, Khungtukun	T ₃ [21]
Asiocolidae	P ₂ kz ² [4]	Kostovaty, Novo-Aleksandrova, Bor-Tologoi, Isady, Aristovo, Belmont, Balymotikha, Anakit	J ₂ [22 as Tricoleidae]
Triaplidae	Babii Kamen'	Babii Kamen', Anakit	T ₃ [23]
Trachypachidae	Babii Kamen'	Babii Kamen', Anakit	Recent
Hydrophilidae	Babii Kamen'	Babii Kamen'	Recent
Byrrhidae	Babii Kamen'	Babii Kamen'	Recent
Parasialidae	Soyana [24]	Bor-Tologoi, Isady	Isady
Permithonidae	P ₁ sk [4]	Kargala, Bor-Tologoi, Sokolova, Isady, Normandien, Belmont, Balymotikha, Ukshunukan	Ukshunukan
Archeosmylidae	Belmont	Normandien, Belmont, Babii Kamen'	T ₃ [25]
Jurinidae	P ₂ kz ¹	Chepanikha, Suriekovo, Isady, Karaungir, Belmont	J ₁
Glosselytridae	P ₁ kg	Karaungir, Bor-Tologoi, Isady, Sokolova,	T ₃
Kaltanidae	P ₂ kz ² [26]	Chepanikha, Suriekovo, Bor-Tologoi, Karaungir	Karaungir
Permochoristidae	P ₁ ar [8]	Chepanikha, Kostovaty, Kargala, Suriekovo, Bor-Tologoi, Novo-Aleksandrova, Sokolova, Isady, Normandien, Aristovo, Karaungir, Belmont, Balymotikha, Nedubrovo	J [27]
Mesopsychidae	Isady	Isady, Belmont, Sokovka, Balymotikha, Nedubrovo, Babii Kamen', Khungtukun-2	K ₁ [28]
Nedubroviidae	Isady	Isady, Sokovka, Balymotikha, Nedubrovo, Lyulyuikta	Lyulyuikta
Belmontiidae	Belmont	Belmont	Belmont
Robinjohniidae	P ₁ ? [27]	Isady, Belmont	Belmont
Permotipulidae	Suriekovo	Suriekovo, Belmont	Belmont
Permotanyderidae	Isady	Isady, Aristovo, Belmont, Nedubrovo Nizhnyaya Bugarikhta, Lyulyuikta	Nizhnyaya Bugarikhta
Parachoristidae	Belmont	Belmont	T ₃ [27]
Protomeropidae	P ₁ sk	Normandien, Karaungir, Belmont	Belmont
Microptysmatidae	P ₁ sk	Chepanikha, Kostovaty, Bor-Tologoi, Karaungir, Balymotikha	Balymotikha
Cladochoristidae	Isady	Isady, Normandien, Belmont, Balymotikha	T ₃ [27]
Prorhyacophilidae	Balymotikha	Balymotikha	T ₃ [27]
Idelinellidae	P ₁ kg [29]	Isady	Isady
Soyanopteridae	P ₁ kg	Isady	Isady
Mylacrididae	C ₂ [4]	Chepanikha, Normandien, Balymotikha	Balymotikha
Spiloblattinidae	C ₂ [4]	Kargala	T _{2/3} [30]

Table 2. (Contd.)

Family	First appearance	Occurrence in localities analyzed	Last appearance
Argentinoblattidae	Novo-Aleksandrovka	Novo-Aleksandrovka, Isady, Sokovka, Balymotikha, Nedubrovo	T ₃ [31]
Mutoviidae	Isady	Isady, Aristovo, Balymotikha	Balymotikha
Caloblattinidae	Kul'chumovo	Isady	K ₁ [32]
Phyloblattidae	C ₂ [4]	Chepanikha, Kargala, Novo-Aleksandrovka, Isady, Aristovo, Balymotikha, Entala, Nizhnyaya Bugarikhta	K ₁ apt [33]
Subioblattidae	P ₁ sk [34]	Novo-Aleksandrovka, Isady, Babii Kamen'	T ₂ lad [35]
Blattulidae	Babii Kamen'	'Babii Kamen'	K ₁ [36]
Cacurgidae	C ₂ [45]	Isady	Isady
Permuliidae	P ₁ [37]	Chepanikha, Isady	Isady
Tshekardominidae	P ₁ ar [38]	Chepanikha, Bor-Tologoi, Karaungir, Novo-Aleksandrovka	Novo-Aleksandrovka
Chaulioditidae	P ₂ kz ² [39]	Chepanikha, Kargala, Novo-Aleksandrovka, Isady, Normandien, Aristovo, Sokovka, Balymotikha, Entala, Nedubrovo, Babii Kamen', Tikhvinskoe, Anakit, Khungtukun	T ₂ [2]
Geinitziidae	P ₂ kz ² [39]	Novo-Aleksandrovka, Isady, Babii Kamen', Malaya Lyuluyikta	J ₃ [40]
Lemmatophoridae	C-P [9]	Kostovaty	Kostovaty
Liomopteridae	C-P [9]	Chepanikha, Kostovaty, Kargala, Suriekovo, Bor-Tologoi, Novo-Aleksandrovka, Isady Normandien, Aristovo, Belmont	Belmont
Ideliidae	P ₁ kg [29]	Kargala, Bor-Tologoi, Karaungir	T ₃ [41]
Skaliciidae	P ₁ sk [52]	Kargala, Normandien	Normandien
Megakhosaridae	P ₁ kg [29]	Chepanikha, Kargala, Suriekovo, Isady, Normandien, Aristovo, Karaungir, Balymotikha, Anakit	T _{2/3} [42]
Blattogryllidae	P ₂ kz ² [43]	Karaungir, Isady, Nedubrovo, Anakit	K ₁ [42]
Kortchakoliidae	P ₁ kg [29]	Isady	Isady
Tunguskapteridae	P ₃ sd [29]	Isady	T _{2/3} [42]
Kargalopteridae	Kargala	Kargala	Kargala
Sylvaphlebiidae	P ₁ sk [44]	Belmont	Belmont
Permothemopsidae	P ₁ kg [29]	Isady, Karaungir	Karaungir
Mesorthopteridae	Isady	Isady	T ₃ [10]
Tshekardoperlidae	P ₁ kg [46]	Isady	Isady
Palaeonemouridae	P ₂ kz ² [46]	Chepanikha, Kargala, Bor-Tologoi, Novo-Aleksandrovka, Isady, Normandien, Karaungir, Aristovo	Karaungir
Palaeoperlidae	P ₂ kz ² [46]	Kargala, Novo-Aleksandrovka, Isady, Karaungir	Isady
Euxenoperlidae	Isady	Isady, Normandien	T ₃ [46]
Eustheniidae	Isady	Isady, Belmont	Recent
Dermelytridae	Bor-Tologoi	Bor-Tologoi, Isady, Belmont	Belmont
Permofulgoridae	P ₂ kz ¹ [4]	Normandien, Belmont	Belmont
Mesoedischiidae	Babii Kamen'	Babii Kamen'	T ₂₋₃ [47]
Pruvostitidae	P ₁ kg [48]	Kargala, Isady, Normandien	Normandien
Oedischiidae	C ₃ [NB]	Chepanikha	Chepanikha
Permecanidae	P ₁ ar [48]	Chepanikha, Novo-Aleksandrovka, Isady, Nedubrovo	T _{2/3} [48]
Locustavidae	Belmont	Belmont, Nizhnyaya Bugarikhta	T ₂₋₃ [49]
Proparagryllacrididae	Isady	Isady	T ₂₋₃ [49]
Xenopteridae	Soyana [50]	Normandien	T ₃ [51]
Permophasmatidae	Bor-Tologoi	Bor-Tologoi, Isady	Isady
Deinotitanidae	Novo-Aleksandrovka	Novo-Aleksandrovka, Isady, Balymotikha	Balymotikha
Homoeodictyidae	Kargala	Kargala	Kargala
Alexarasniidae	Isady	Isady	Isady

Table 3. Initial sequence of assemblages (sum of gaps 661). Families conditionally considered Paleozoic are those the first appearance of which is earlier than the Urzhumian and the last appearance of which is not later than the Induan; families conditionally considered post-Paleozoic are those the first appearance of which is not earlier than the Urzhumian and the last appearance of which is later than the Induan; families provisionally considered endemic of the Urzhumian-Induan are those the first and last appearances of which fall in this period; $\ln_{total}$ is natural logarithm of the total number of insect specimens in the assemblage; Pz/pPz is the ratio of the number of families provisionally considered Paleozoic and post-Paleozoic; turnover (measure of faunal renewal) is the sum of first and last appearances normalized by the logarithm of the number of specimens

Assemblage	Kargala	Chepanikha + Kostovaty	Sutikova	Novo-Aleksandrovka	Isady	Sokolova	Bor-Tolgoi	Karamgir	Belmont	Normandien	Aristovo	Vyznitski	Babii Kamen'	Tunguska	Nedubrovo
Total number of specimens	300	400	670	300	3500	570	900	550	2000	250	250	350	140	600	200
$\ln_{total}$	5.7	6.0	6.5	5.7	8.2	6.3	6.8	6.3	7.6	5.5	5.5	5.9	4.9	6.4	5.3
Total number of families	23	29	18	26	69	13	32	31	37	30	13	30	18	22	18
Families/ $\ln_{total}$	4.0	4.7	2.8	4.6	8.6	2.1	4.4	4.9	4.9	5.5	2.5	5.2	3.7	3.1	3.6
Number of first appearances	4	1	1	3	16	2	1	0	6	1	0	1	7	2	0
First/ $\ln_{total}$	0.7	0.3	0.1	0.5	1.6	0.3	0.7	0	0.8	0.2	0	0.2	1.6	0.3	0
Number of last appearances	3	2	0	0	12	0	6	7	6	7	2	6	1	1	4
Last/ $\ln_{total}$	0.5	0.3	0	0	1.7	0	0.9	1.1	1.2	0.3	0.2	1.2	0.2	0.2	0.7
Number of transitional	7	12	8	12	22	7	8	13	9	9	6	11	7	7	9
Number of transitional/ $\ln_{total}$	1.2	2.0	1.2	2.1	2.7	1.1	1.2	2.1	1.2	1.6	1.1	1.9	1.4	1.1	1.7
Number of Paleozoic	12	14	6	10	26	3	18	15	11	14	2	6	1	2	2
Number of Paleozoic/ $\ln_{total}$	2.1	2.3	0.9	1.7	3.2	0.5	2.6	2.4	1.4	2.3	0.4	1.0	0.2	0.3	0.4
Number of post-Paleozoic	2	2	3	3	13	3	3	3	13	7	3	10	10	11	5
Post-Paleozoic/ $\ln_{total}$	0.3	0.3	0.5	0.5	1.6	0.5	0.4	0.5	1.7	1.3	0.5	1.7	2.0	1.7	0.9
Number of endemics	2	0	1	1	7	0	3	0	4	0	2	3	0	2	2
Endemics/ $\ln_{total}$	0.3	0	0.1	0.2	0.8	0	0.4	0	0.5	0	0.4	0.5	0	0.3	0.4
First/last	1.3	0.5	/0	/0	1.3	/0	0.2	0	1.0	0.1	0	0.2	7.0	2.0	0
Pz/pPz	6.0	7.0	2.0	3.3	2.0	1.0	6.0	5.0	0.8	2.0	0.7	0.6	0.1	0.2	0.4
Turnover	1.2	0.5	0.1	0.5	3.4	0.3	1.0	1.1	1.6	1.5	0.4	1.2	1.6	0.5	0.7

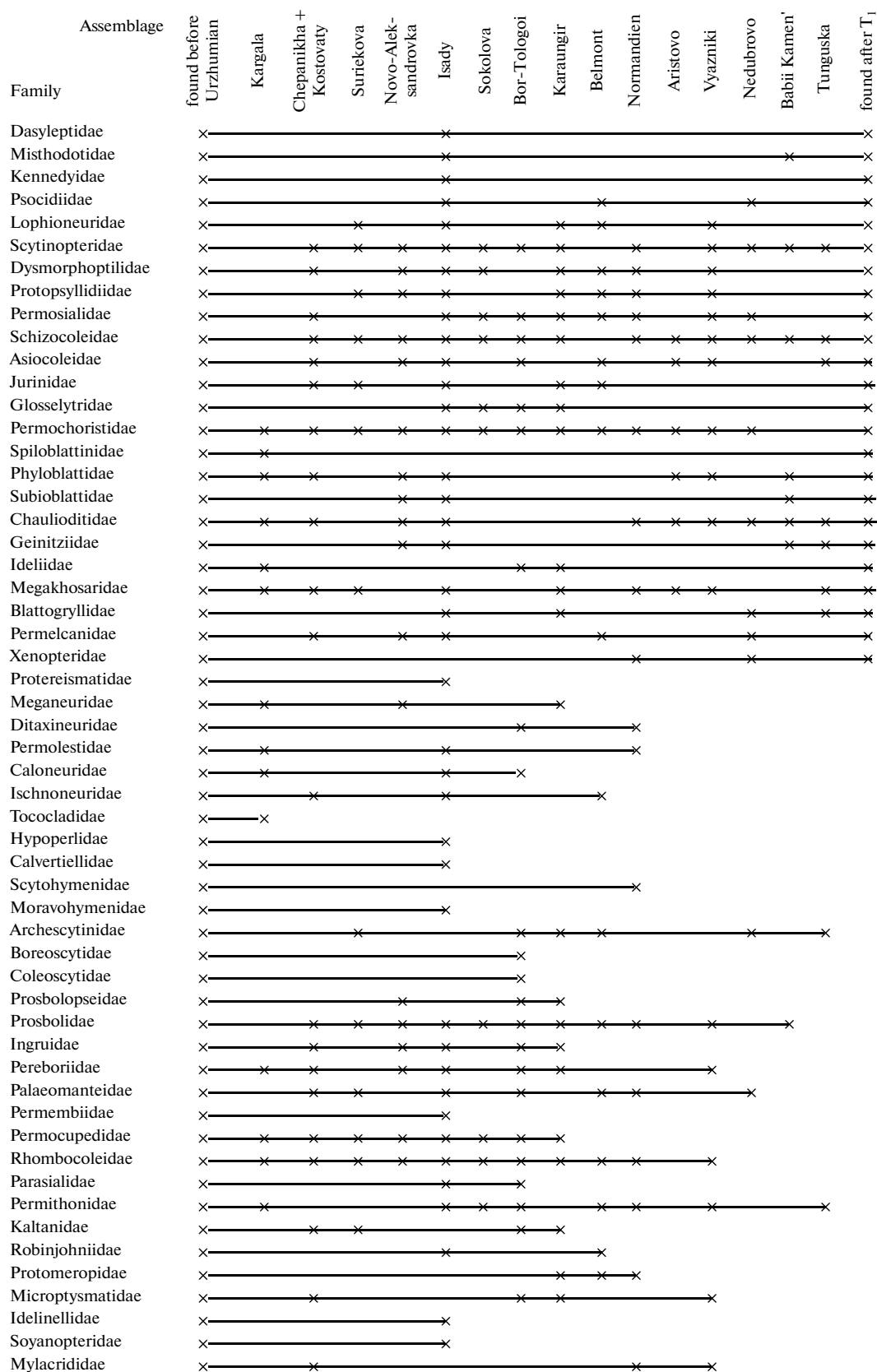


Fig. 91. Distribution of insect families over the stratigraphic range under study (initial sequence of assemblages as in Table 3; for explanations, see the text). For sources on each record, see Table 2.

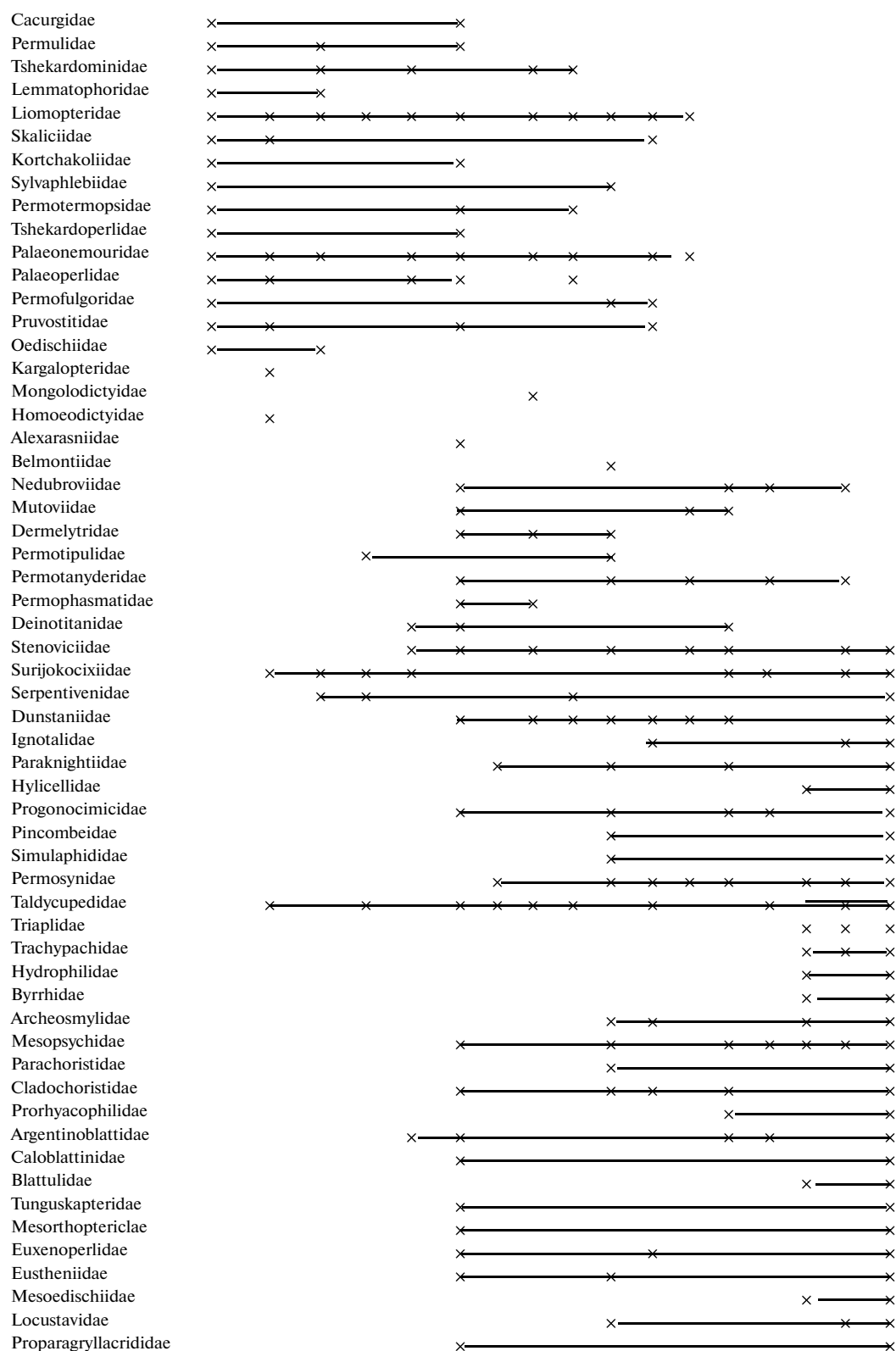


Fig. 91. (Contd.)

Table 4. Sequence of assemblages optimized by Pz/pPz (sum of gaps 612). For designations, see Table 3

Assemblage	Chepanikha + Kostovaty	Kargala	Bor-Tolgoi	Karaungir	Novo-Aleksandrovka	Surieikova	Isady	Normandien	Sokolova	Belmont	Aristovo	Vyazniki	Nedubrovo	Tunguska	Babii Kamen'
Total number of specimens	400	300	900	550	300	670	3500	250	570	2000	250	350	200	600	140
$\ln_{\text{total}}$	6.0	5.7	6.8	6.3	5.7	6.5	8.2	5.5	6.3	7.6	5.5	5.9	5.3	6.4	4.9
Total number of families	29	23	32	31	26	18	69	30	13	37	13	30	18	22	18
Families/ $\ln_{\text{total}}$	4.7	4.0	4.4	4.9	4.6	2.8	8.6	5.5	2.1	4.9	2.5	5.2	3.6	3.1	3.7
Number of first appearances	2	3	5	0	2	1	13	3	1	5	0	1	0	4	5
First/ $\ln_{\text{total}}$	0.3	0.5	0.7	0	0.3	0.1	1.6	0.5	0.2	0.7	0	0.2	0	0.6	1.0
Number of last appearances	2	3	3	0	3	1	18	5	0	8	2	6	1	4	1
Last/ $\ln_{\text{total}}$	0.3	0.5	0.4	0	0.5	0.1	2.2	0.9	0	1.0	0.4	1.0	0.2	0.6	0.2
Number of transitional	12	7	8	13	12	8	22	9	7	9	6	11	9	7	7
Number of transitional/ $\ln_{\text{total}}$	2.0	1.2	1.2	2.1	2.1	1.2	2.7	1.6	1.1	1.2	1.1	1.9	1.7	1.1	1.4
Number of Paleozoic	14	12	18	15	10	6	26	14	3	11	2	6	2	2	1
Number of Paleozoic/ $\ln_{\text{total}}$	2.3	2.1	2.6	2.4	1.7	0.9	3.2	2.5	0.5	1.4	0.4	1.0	0.4	0.3	0.2
Number of post-Paleozoic	2	2	3	3	3	3	13	7	3	13	3	10	5	11	10
Post-Paleozoic/ $\ln_{\text{total}}$	0.3	0.3	0.4	0.5	0.5	0.5	1.6	1.3	0.5	1.7	0.5	1.7	0.9	1.7	2.0
Number of endemics	0	2	3	0	1	1	7	0	0	4	2	3	2	2	0
Endemics/ $\ln_{\text{total}}$	0	0.3	0.4	0	0.2	0.1	0.8	0	0	0.5	0.4	0.5	0.4	0.3	0
First/last	1	1	1.7	/0	0.7	1	0.7	0.6	/0	0.6	0	0.2	0	1	5.0
Pz/pPz	7.0	6.0	6.0	5.0	3.3	2.0	2.0	2.0	1.0	0.8	0.7	0.6	0.4	0.2	0.1
Turnover	0.7	1.0	1.2	0	0.9	0.3	3.8	1.5	0.2	1.7	0.4	1.2	0.2	1.2	1.2

tables lines with the same data normalized by the logarithm of the number of fossil specimens collected in each particular locality (i.e., the same values divided by the natural logarithm of the total number of specimens collected in the assemblage). This normalization is based on the fact that the species diversity index, according to which the number of taxa in samples of modern organisms is considered proportional to the logarithm of the sample size ($(S - 1)/\ln N$, where S is the number of taxa in a sample of N specimens), although far from perfect, still “the best of ... the empirical indices” (Pesenko, 1982, p. 60).

The above-mentioned analysis of alternative stratigraphic sequences is aimed at constructing a sequence of assemblages optimal according to certain criteria. The main problems of this task are the choice of optimizing criteria and the ways for exhausting the alternative sequences. We suggest two independent optimality criteria, which should provide a more objective and reliable stratigraphic ordination (ordering) of assemblages. The first criterion, representing the dynamics of the faunal pattern of an assemblage as the ratio of its families conditionally considered Paleozoic (ancient) and post-Paleozoic (young) (Pz/pPz), is a modification of the well-known Lyell's percentage, i.e., the proportion of modern species in the composi-

tion of ancient faunas (see Zherikhin, 1978; Rasnitsyn, 1988). This method was some time extremely popular, but the development of other methods for dating and correlating deposits pushed it aside. However, if a sufficient number of orthostratigraphic taxa is absent and applicability of other, more reliable methods is limited (which is generally typical of nonmarine deposits), the use of alternative approaches is justified, as shown below. The ratio Pz/pPz is used for the ordination of insect assemblages characterized in Tables 4, 8, and 12.

The second criterion for ordination is based on the concept of the ghost range, which is useful for similar purposes in different cases (see Rasnitsyn, 2000, 2010). Figures 91 and 92 show that the families studied are not necessarily observed in every assemblage within their stratigraphic range. Each of such gaps is regarded as a single ghost range, during which the taxon in question existed, but has not been found. However, a gap may result not only from the incompleteness of materials, but also from an incorrectly constructed sequence of assemblages, where an earlier or later assemblage in which this taxon is naturally absent (having not yet emerged or already become extinct) is erroneously placed between assemblages where the taxon is present. Rearranging the assem-

Table 5. Complete set of assemblages: initial sequence and ten best sequences of assemblages (sequence of assemblages set in bold type is fixed). First column is the sum of ghost ranges. Designations: (Karg) Kargala, (Ch + Ko) Chepanikha + Kostovaty, (Suri) Surieikova, (N-Alek) Novo-Aleksandrovka, (Isad) Isady, (Soko) Sokolova, (B-Tol) Bor-Tologoi, (Karau) Karaungir, (Belm) Belmont, (Norm) Normandien, (Aris) Aristovo, (Vyaz) Vyazniki, (B-Kam) Babii Kamen', (Tung) intertrappean deposits of the Tunguska, (Nedu) Nedubrovo. First line is the initial sequence, followed by ten sequences ordered by the minimum sum of ghost ranges

661	Karg	Ch+Ko	Suri	N-Alek	Isad	Soko	B-Tol	Karau	Belm	Norm	Aris	Vyaz	B-Kam	Tung	Nedu
590	Ch + Ko	Karg	Karau	B-Tol	Isad	N-Alek	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	Tung	B-Kam
592	Ch + Ko	Karau	Karg	B-Tol	Isad	N-Alek	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	Tung	B-Kam
594	Ch + Ko	Karau	B-Tol	Karg	Isad	N-Alek	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	Tung	B-Kam
595	Karau	Ch + Ko	Karg	B-Tol	Isad	N-Alek	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	Tung	B-Kam
597	Karau	Ch + Ko	B-Tol	Karg	Isad	N-Alek	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	Tung	B-Kam
598	Karau	Ch + Ko	B-Tol	N-Alek	Karg	Isad	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	Tung	B-Kam
599	Karau	B-Tol	Ch + Ko	Karg	Isad	N-Alek	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	Tung	B-Kam
600	Karau	B-Tol	Ch + Ko	N-Alek	Karg	Isad	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	Tung	B-Kam
602	Karau	B-Tol	Ch + Ko	N-Alek	Karg	Isad	Vyaz	Norm	Aris	Belm	Suri	Nedu	Soko	Tung	B-Kam
603	Karau	B-Tol	N-Alek	Ch + Ko	Karg	Isad	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	Tung	B-Kam

blages (changing their sequence), we can try to minimize the number of such cases (i.e., minimize the sum of gaps in the geological history of families) and, thus, approach the true stratigraphic sequence of assemblages. The mutual control of these two criteria of optimal ordination of assemblages is used here to provide more reliable results.

It is impossible to exhaust manually all sequences (if their number is not very small) and this operation requires the development of an appropriate computer program and a computer of sufficient calculating power. Such a program was developed by D.A. Rasnitsyn, who also performed calculations. The program can be briefly described as follows (it is planned to describe it in detail in a separate publication).

The program reads initial data, including the limits (boundary conditions and sequences) from an MS Excel file and, then, generates all possible rearrangements complying with the boundary conditions and, if necessary, with the conditions of the sequence. The last restriction, introduced as an option, means fixation of the sequence of some assemblages in accordance with available geological data in the cases where it is known with certainty that, e.g., Isady is later than Kargala, but earlier than Aristovo. The number of gaps (ghost ranges) in the rearrangements generated is calculated dynamically, parallel to the generation of each sequence. The given number of sequences with the minimum number of gaps is accumulated in a dynamically sorted list, which, as the calculations are completed, is saved in an MS Excel file.

The above-mentioned condition of succession (fixation of the sequence of the most reliably dated assemblages) turned out to be necessary because available calculating power of the computer appeared insufficient for processing more than a trillion rearrangements needed for our 15 assemblages (the factorial

$15! = 1\,307\,674\,368\,000$). To overcome this difficulty, several ways of reducing the number of rearrangements to an acceptable level have been tested. The more radical among them was fixation of the sequence of several most reliably dated assemblages, in this case, Kargala → Isady → Vyazniki → Nedubrovo (Tables 5, 6). Another way was reducing the number of assemblages analyzed to 13, which decreases the number of required rearrangements to six billion ($13! = 6\,227\,020\,800$). The reduction was performed by either excluding relatively poor assemblages of Surieikova and Sokolova (Tables 7–10) or combining two pairs of assemblages (Bor-Tologoi with Karaungir and Babii Kamen' with Tunguska; Tables 11–14).

The latter way allows reducing the amount of calculations to an acceptable level without sacrificing any materials, but it requires additional substantiation. Combining the assemblages of Tunguska and Babii Kamen' is justified by the fact that both assemblages are intertrappean and, consequently, approximately contemporaneous, although they are divided by a considerable distance (see above). The possibility to combine the even more remote assemblages of Karaungir and Bor-Tologoi was only revealed in the course of this study; in all variants of optimizing the sequence, the two assemblages were positioned almost invariably next to each other (Tables 5, 9) and, in Karaungir, the first or last appearances of families almost have not been recorded (Tables 4, 6, 8, 10). In other words, the proximity of these assemblages is obvious.

Another important parameter, the *renewal measure* (ratio of the numbers of the first or last appearances of families in each assemblage), which shows the direction of changes in assemblages, its enrichment or depletion, certainly depends on the position occupied by particular assemblage in the general sequence (cf. Tables 3, 4, and 6; 7, 8, and 10; 11, 12, and 14). It cannot be used for ordination of assemblages, but,

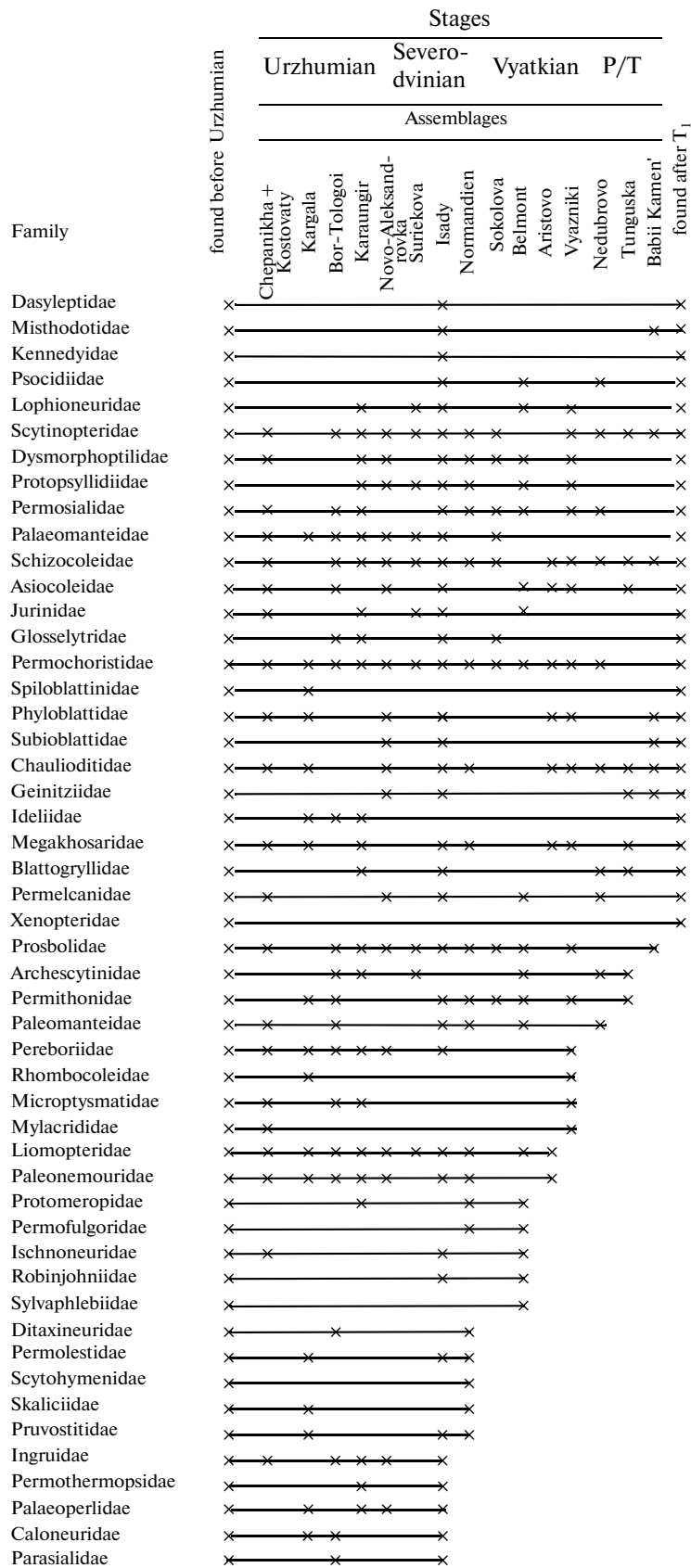


Fig. 92. Distribution of insect families over the stratigraphic range under study (preferred sequence of assemblages, as in Table 4). For sources on each record, see Table 2.

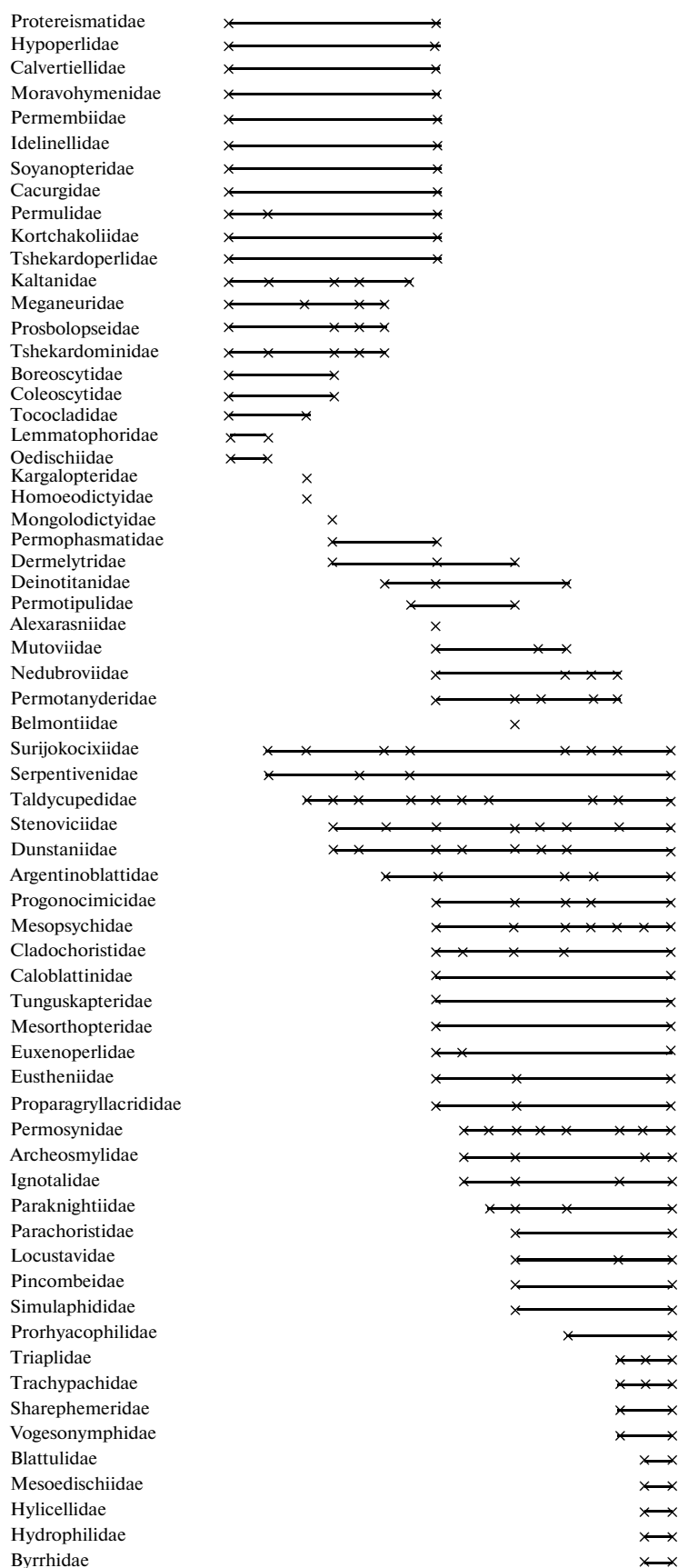


Fig. 92. (Contd.)

Table 6. Complete set of assemblages with four fixed sequences with the minimum number of ghost ranges (590: Table 8, line 2). For designations, see Table 5

Assemblage	Chepanikha + Kostovaty	Kargala	Karauingir	Bor-Tologoi	Isady	Novo-Aleksandrovska	Normandien	Vyazniki	Aristovo	Belmont	Surikova	Nedubrovo	Sokolova	Tunguska	Babii Kamen'
Total number of specimens	400	300	550	900	3500	300	250	350	250	2000	670	200	570	600	140
$\ln_{\text{total}}$	6.0	5.7	6.3	6.8	8.2	5.7	5.5	5.9	5.5	7.6	6.5	5.3	6.3	6.4	4.9
Total number of families	29	23	31	32	69	26	30	30	13	37	18	18	13	22	18
Families/ $\ln_{\text{total}}$	4.7	4.0	4.9	4.4	8.6	4.6	5.5	5.2	2.5	4.9	2.8	3.6	2.1	3.1	3.7
Number of first appearances	2	3	0	3	14	0	3	2	0	6	0	0	0	4	5
First/ $\ln_{\text{total}}$	0.3	0.5	0	0.4	1.7	0	0.5	0.3	0	0.8	0	0	0	0.6	1.0
Number of last appearances	2	3	0	3	19	6	5	4	2	7	3	1	1	4	1
Last/ $\ln_{\text{total}}$	0.3	0.5	0	0.4	2.3	1.0	0.9	0.7	0.4	0.9	0.5	0.2	0.2	0.6	0.2
Number of transitional	12	7	13	8	22	12	9	11	6	9	8	9	7	7	7
Number of transitional/ $\ln_{\text{total}}$	2.0	1.2	2.1	1.2	2.7	2.1	1.6	1.9	1.1	1.2	1.2	1.7	1.1	1.1	1.4
Number of Paleozoic	14	12	15	18	26	10	14	6	2	11	6	2	3	2	1
Number of Paleozoic/ $\ln_{\text{total}}$	2.3	2.1	2.4	2.6	3.2	1.7	2.5	1.0	0.4	1.4	0.9	0.4	0.5	0.3	0.2
Number of post-Paleozoic	2	2	3	3	13	3	7	10	3	13	3	5	3	11	10
Post-Paleozoic/ $\ln_{\text{total}}$	0.3	0.3	0.5	0.4	1.6	0.5	1.3	1.7	0.5	1.7	0.5	0.9	0.5	1.7	2.0
Number of endemics	0	2	0	3	7	1	0	3	2	4	1	2	0	2	0
Endemics/ $\ln_{\text{total}}$	0	0.3	0	0.4	0.8	0.2	0	0.5	0.4	0.5	0.1	0.4	0	0.3	0
First/last	1	1	/0	1	0.7	0	0.6	0.5	0	0.9	0	0	0	1	5.0
Pz/pPz	7.0	6.0	5.0	6.0	2.0	3.3	2.0	0.6	0.7	0.8	2.0	0.4	1.0	0.2	0.1
Turnover	0.7	1.0	0	0.9	4.0	1.0	1.5	1.0	0.4	1.7	0.5	0.2	0.2	1.2	1.2

Table 7. First reduced initial sequence (without Surieikova and Sokolova; sum of gaps 533). For designations, see Table 3

Assemblage	Kargala	Chepanikha + Kostovaty	Novo-Aleksandrovka	Isady	Bor-Tologoi	Karaungir	Belmont	Normandien	Aristovo	Vyazniki	Babii Kamen	Tunguska	Nedubrovo
Total number of specimens	300	400	300	3500	900	550	2000	250	250	350	140	600	200
$\ln_{\text{total}}$	5.7	6.0	5.7	8.2	6.8	6.3	7.6	5.5	5.5	5.9	4.9	6.4	5.3
Total number of families	23	29	26	69	32	31	37	30	13	30	18	22	18
Families/ $\ln_{\text{total}}$	4.0	4.7	4.6	8.6	4.4	4.9	4.9	5.5	2.5	5.2	3.7	3.1	3.6
Number of first appearances	4	1	3	16	1	0	9	1	0	1	7	2	0
first/ $\ln_{\text{total}}$	0.7	0.2	0.5	1.9	0.1	0	1.2	0.2	0	0.2	1.4	0.3	0
Number of last appearances	3	2	0	12	6	7	6	7	3	6	1	1	4
last/ $\ln_{\text{total}}$	0.5	0.3	0	1.5	0.9	1.1	0.8	1.3	0.5	1.0	0.2	0.2	0.7
Number of transitional	7	12	12	22	8	13	9	9	6	11	7	7	9
Number of transitional/ $\ln_{\text{total}}$	1.2	2.0	2.1	2.7	1.2	2.1	1.2	1.6	1.1	1.9	1.4	1.1	1.7
Number of Paleozoic	12	14	10	26	18	15	11	14	2	6	1	2	2
Number of Paleozoic/ $\ln_{\text{total}}$	2.1	2.3	1.7	3.2	2.6	2.4	1.4	2.5	0.4	1.0	0.2	0.3	0.4
Number of post-Paleozoic	2	2	3	13	3	3	13	7	3	10	10	11	5
Post-Paleozoic/ $\ln_{\text{total}}$	0.3	0.3	0.5	1.6	0.4	0.5	1.7	1.3	0.5	1.7	2.0	1.7	0.9
Number of endemics	2	0	1	7	3	0	4	0	2	3	0	2	2
Endemics/ $\ln_{\text{total}}$	0.3	0	0.2	0.8	0.4	0	0.5	0	0.4	0.5	0	0.3	0.4
First/last	1.3	0.5	/0	1.3	0.2	0	1.3	0.1	0	0.2	7.0	2.0	0
Pz/pPz	6.0	7.0	3.3	2.0	6.0	5.0	0.8	2.0	0.7	0.6	0.1	0.2	0.4
Turnover	1.2	0.5	0.5	3.4	1.0	1.1	2.0	1.5	0.5	1.2	1.6	0.5	0.7

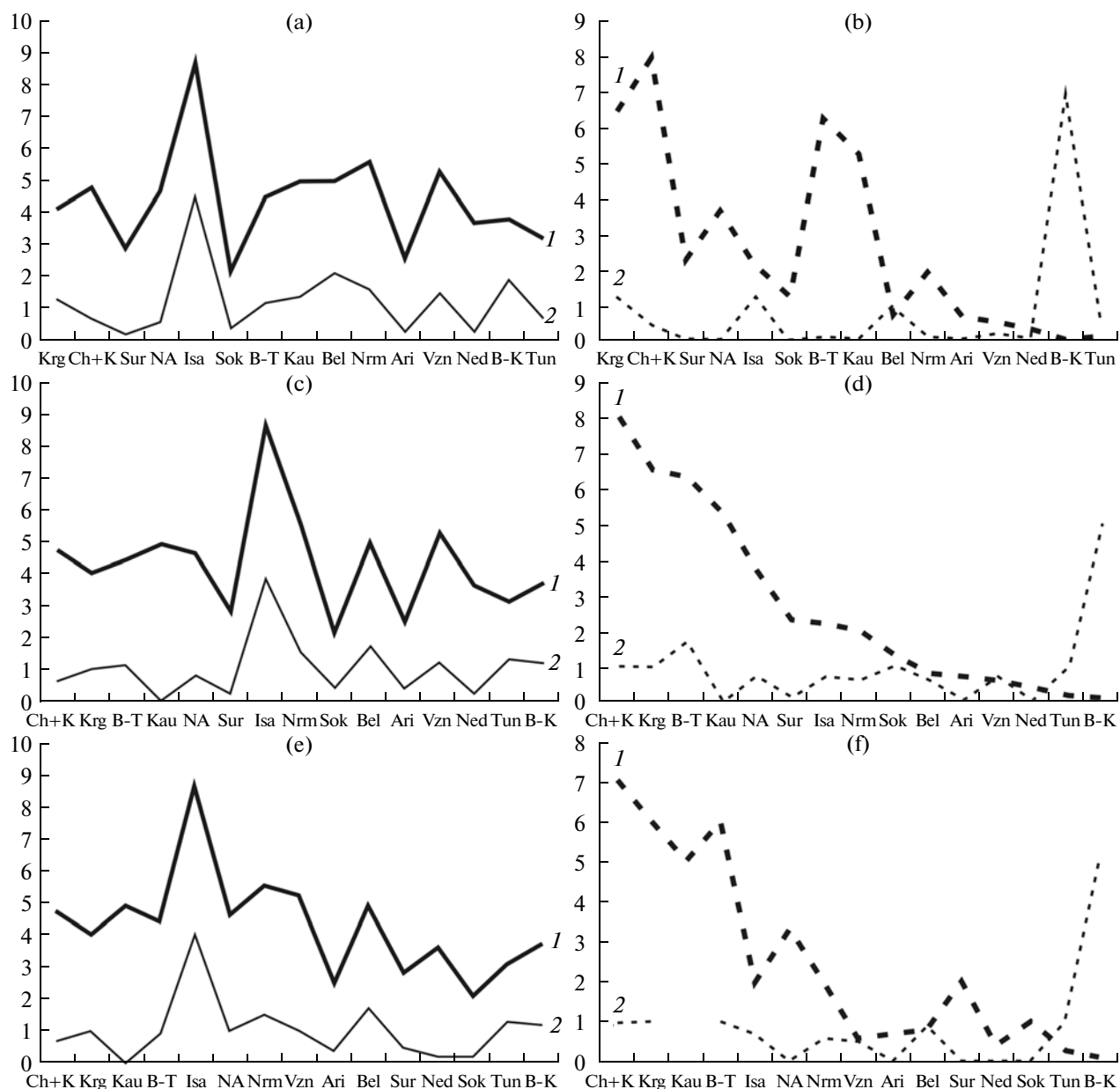


Fig. 93. Dynamics of insect families over the stratigraphic range under study, complete set of assemblages: (a, b) initial sequence (Table 3): (a) normalized number of families (*I*) and turnover measure (2); (b) faunal pattern index Pz/pPz (*I*) and renewal measure (ratio of first to last appearances) (2); (c, d) sequence optimized by the faunal pattern (Pz/pPz) (Table 4): (c) normalized number of families (*I*) and turnover measure (2); (d) faunal pattern index Pz/pPz (*I*) and renewal measure (2); (e, f) sequence of assemblages optimized by minimum number of gaps, the sequence Kargala–Isady–Vyazniki–Nedubrovo is fixed (Table 6): (e) normalized number of families (*I*) and turnover measure (2); (f) faunal pattern index Pz/pPz (*I*) and renewal measure (2). Designation of assemblages: (Ari) Aristovo, Vologda Region; (B-K) Babii Kamen'; (B-T) Bor-Tologoi, Mongolia; (Bel) Belmont, Australia; (Ch + K) Chepanikha + Kostovaty (Udmurtia); (Isa) Isady, Vologda Region; (Kau) Karaungir, western Kazakhstan; (Krg) Kargala (Orenburg Region); (N-A) Novo-Aleksandrova, Orenburg Region; (Ned) Nedubrovo; (Nrm) Normandie, South Africa; (Sok) Sokolova II, Kemerovo Region; (Sur) Surievko, Kemerovo Region; (Tun) intertrappean deposits of the Tunguska Basin; (Vzn) Vyazniki (Balymotikha and Sokovka, Vladimir Region) (for more detail, see the text).

when the ordination is established, this measure becomes an important analytical tool.

The above-said is also true of the last tool used. The *faunal turnover measure* is calculated as the sum of the normalized numbers of first and last appearances and shows the intensity of changes regardless of their

direction. All above methods and approaches are questioned by Labandeira (2005), who refers to the Signor–Lipps effect (Signor and Lipps, 1982), which is responsible for “that the last occurrences of variably preserved or moderately sampled fossil taxa at a major extinction will be recorded in a stepwise fashion back

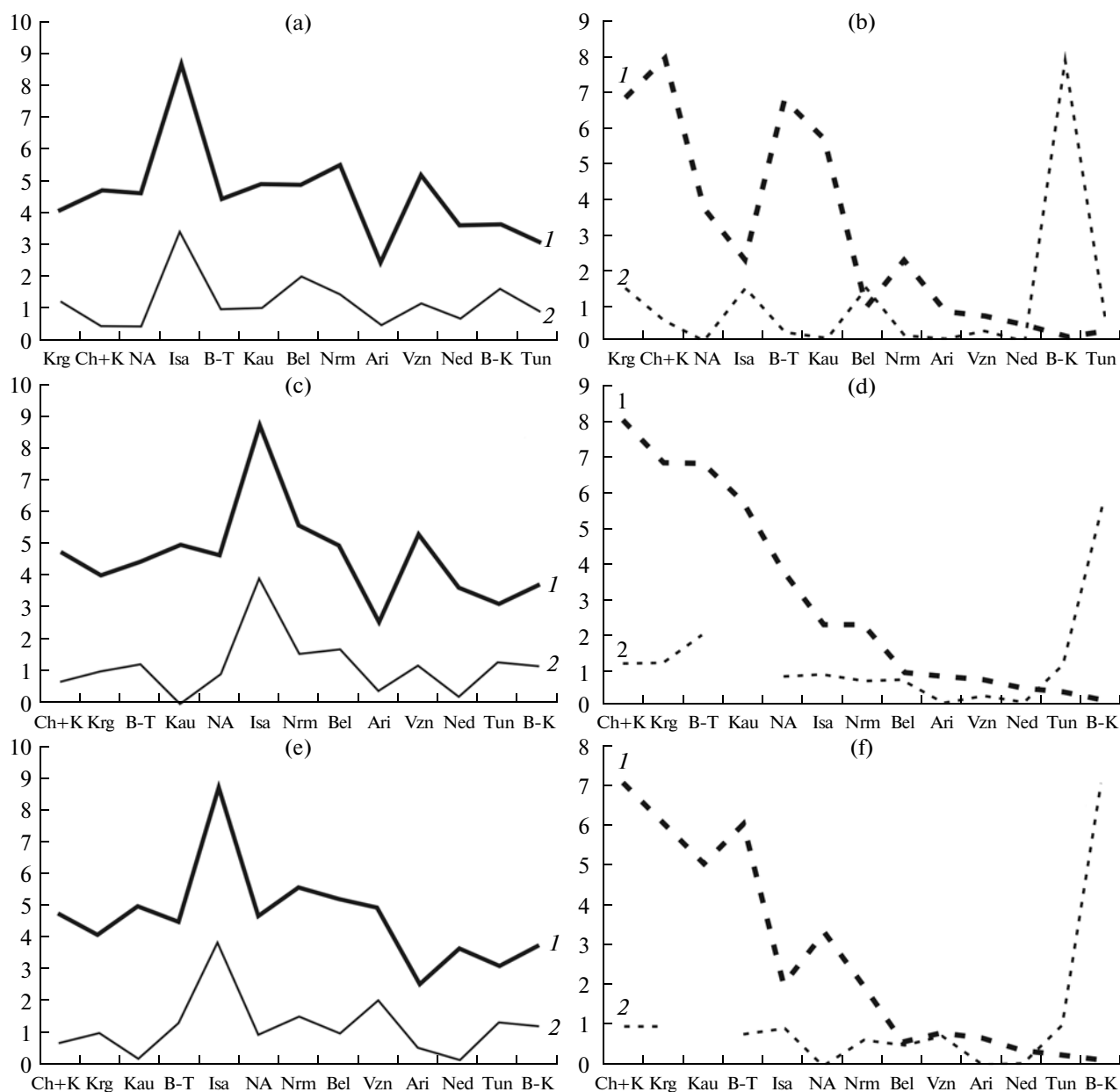


Fig. 94. Dynamics of insect families, first reduced sequence (Suričkova and Sokolova are excluded): (a, b) initial sequence (Table 7): (a) normalized number of families (I) and turnover measure (2); (b) faunal pattern index Pz/pPz (I) and renewal measure (ratio of first to last appearances) (2); (c, d) sequence normalized by faunal pattern Pz/pPz (Table 8): (c) normalized number of families (I) and turnover measure (2); (d) Pz/pPz (I) and renewal measure (2); (e, f) sequence of assemblages optimized by minimum number of gaps (Table 10): (e) normalized number of families (I) and turnover measure (2); (f) Pz/pPz (I) and renewal measure (2). For designations, see Fig. 93.

onto immediately earlier time units from the actual event. Thus, there is a stair-stepped pattern to last fossil occurrences that segregates taxa with a poorer fossil record from those with a better record. This pattern gives an impression that there are a series of earlier extinction events when in fact, they are an effect of a single, more massive extinction" (Labandeira 2005, p. 20). In other words, long stepwise (or gradual) decrease of diversity cannot falsify hypothesis of a sin-

gle mass extinction event. This proposal cannot be accepted for several reasons.

First, when paleontologist speaks about extinction, the word is used highly metaphorically, for we have no tool to identify the real extinction time, as *Latimeria* Smith, 1939, *Grylloblatta* Walker, 1914, *Syntexis* Rohwer, 1915, and other living fossils witness irrefutably. We can only identify time when a taxon leaves the fossil record, that is, when the taxon went beyond a margin of the

Table 8. First reduced set of assemblages (without Surieikova and Sokolova), arranged according to Pz/pPz (number of gaps 503). For designations, see Table 3

Assemblage	Chapanikha + Kostovaty	Kargala	Bor-Tologoi	Karabungir	Novo-Aleksandrovka	Isady	Normandien	Belmont	Aristovo	Vyazniki	Nedubrovo	Tunguska	Babii Kamen'
Total number of specimens	400	300	900	550	300	3500	250	2000	250	350	200	600	140
$\ln_{\text{total}}$	6.0	5.7	6.8	6.3	5.7	8.2	5.5	7.6	5.5	5.9	5.3	6.4	4.9
Total number of families	29	23	32	31	26	69	30	37	13	30	18	22	18
Families/ $\ln_{\text{total}}$	4.7	4.0	4.4	4.9	4.6	8.6	5.5	4.9	2.5	5.2	3.6	3.1	3.7
Number of first appearances	2	3	5	0	2	13	3	5	0	1	0	4	5
First/ $\ln_{\text{total}}$	0.3	0.5	0.7	0	0.3	1.6	0.5	0.7	0	0.2	0	0.6	1.0
Number of last appearances	2	3	3	0	3	18	5	8	2	6	1	4	1
Last/ $\ln_{\text{total}}$	0.3	0.5	0.4	0	0.5	2.2	0.9	1.0	0.4	1.0	0.2	0.6	0.2
Number of transitional	12	7	8	13	12	22	9	9	6	11	9	7	7
Number of transitional/ $\ln_{\text{total}}$	2.0	1.2	1.2	2.1	2.1	2.7	1.6	1.2	1.1	1.9	1.7	1.1	1.4
Number of Paleozoic	14	12	18	15	10	26	14	11	2	6	2	2	1
Number of Paleozoic/ $\ln_{\text{total}}$	2.3	2.1	2.6	2.4	1.7	3.2	2.5	1.4	0.4	1.0	0.4	0.3	0.2
number of post-Paleozoic	2	2	3	3	3	13	7	13	3	10	5	11	10
Post-Paleozoic/ $\ln_{\text{total}}$	0.3	0.3	0.4	0.5	0.5	1.6	1.3	1.7	0.5	1.7	0.9	1.7	2.0
Number of endemics	0	2	3	0	1	7	0	4	2	3	2	2	0
Endemics/ $\ln_{\text{total}}$	0	0.3	0.4	0	0.2	0.8	0	0.5	0.4	0.5	0.4	0.3	0
First/last	1	1	1.7	/0	0.7	0.7	0.6	0.6	0	0.2	0	1.0	5.0
Pz/pPz	7.0	6.0	6.0	5.0	3.3	2.0	2.0	0.8	0.7	0.6	0.4	0.2	0.1
Turnover	0.7	1.0	1.2	0	0.9	3.8	1.5	1.7	0.4	1.2	0.2	1.2	1.2

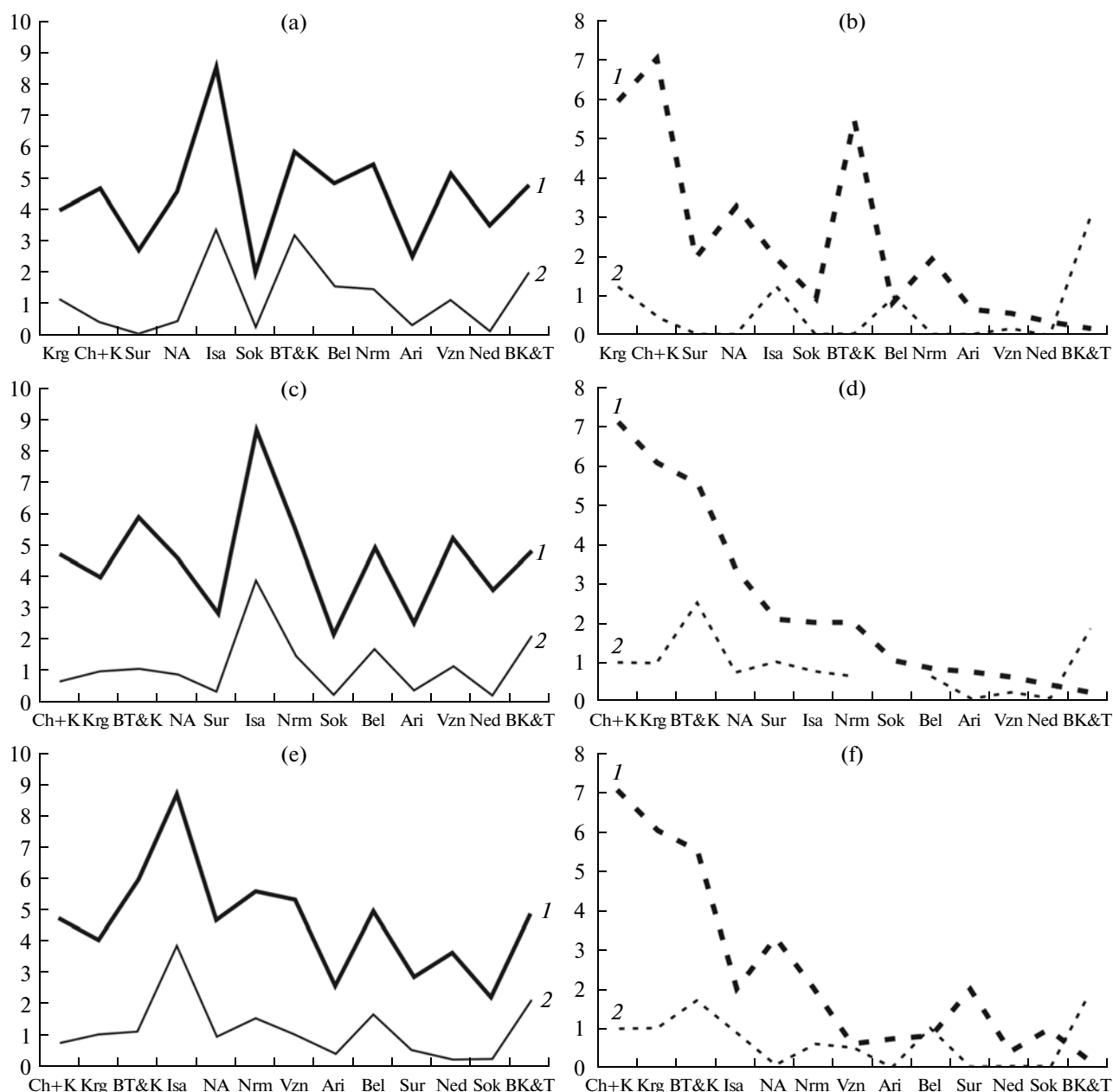


Fig. 95. Dynamics of insect families, second reduced sequence of assemblages (Bor-Tologoi is combined with Karaungir; Babii Kamen' is combined with Tunguska): (a, b) initial sequence (Table 11): (a) normalized number of families (*I*) and turnover measure (2); (b) faunal pattern index Pz/pPz (*I*) and renewal measure (ratio of first to last appearances) (2); (c, d) sequence normalized by faunal pattern Pz/pPz (Table 12): (c) normalized number of families (*I*) and turnover measure (2); (d) Pz/pPz (*I*) and renewal measure (2); (e, f) sequence of assemblages optimized by minimum number of gaps (Table 14): (e) normalized number of families (*I*) and turnover measure (2); (f) Pz/pPz (*I*) and renewal measure (2). Designations: (BT&K) combined assemblage of Bor-Tologoi and Karaungir; (BK&T) combined assemblage of Babii Kamen' and Tunguska; for other designations, see Fig. 93.

taphonomic window. In other words, when its taphonomic (recovery) potential went too much down due to loss of its abundance and/or taphonomic diversity. This implies that the gradually (in wide sense, including stepwise) decreasing diversity is not an observational artifact (Signor–Lipps effect). Instead, it indicates a real process of decreasing taphonomic potential, which is traditionally (and correctly) interpreted as decreasing biodiversity.

The second reason to reject the Signor–Lipps effect as an explanation why slow and prolonged decrease in diversity could agree with the hypothesis of a single and geologically short mass extinction is in our results themselves. When studied at a more detailed stratigraphic scale than before, the insect diversity demonstrates neither gradual nor stepwise decrease toward the P/T boundary. Instead, after the end-Severodvian peak, it varies cha-

Table 9. First reduced set of assemblages (without Surieikova and Sokolova): initial sequence and ten best sequences. For designations, see Table 5

533	Krga	Ch+Ko	N-Alek	Isad	B-T	Karau	Belm	Norm	Aris	Vyaz	Babiy	Tung	Ned
499	Ch+ K	Krga	Karau	B-T	Isad	N-Al	Norm	Vyaz	Belm	Aris	Ned	Tung	Babiy
500	Ch + K	Krga	Karau	B-T	Isad	N-Al	Norm	Vyaz	Aris	Belm	Ned	Tung	Babiy
501	Ch + K	Karau	Karg	B-T	Isad	N-Al	Norm	Vyaz	Belm	Aris	Ned	Tung	Babiy
502	Ch + K	Karau	B-To	Isad	N-Al	Krga	Norm	Vyaz	Belm	Aris	Ned	Tung	Babiy
503	Ch + K	Karau	B-To	Isad	N-Al	Krga	Norm	Vyaz	Aris	Belm	Ned	Tung	Babiy
504	Karau	Ch + K	Karg	B-To	Isad	N-Al	Norm	Vyaz	Belm	Aris	Ned	Tung	Babiy
505	Karau	Ch + K	B-T	Isad	N-Al	Krga	Norm	Vyaz	Belm	Aris	Ned	Tung	Babiy
506	Karau	Ch + K	B-T	Isad	N-Al	Krga	Norm	Vyaz	Aris	Belm	Ned	Tung	Babiy
507	Karau	B-T	Ch + K	Isad	N-Al	Krga	Norm	Vyaz	Belm	Aris	Ned	Tung	Babiy
508	Karau	B-T	Ch + K	Isad	Krga	N-Al	Norm	Vyaz	Belm	Aris	Ned	Tung	Babiy

otically within a rather narrow corridor, to give a new peak in the intertrappean time, that is, at the very moment of suggested biotic catastrophe (see Figs. 95c, 95d and text below).

3.1.3. Results

As follows from Table 3, the initial sequence is far from optimal by both criteria (Figs. 91, 93a, 93b). Optimizing it by the first criterion (Pz/pPz; Tables 4, Figs. 92, 93d, 93e) gives the sequence Chepanikha + Kostovaty—Kargala—Bor-Tologoi—Karaungir—Novo-Aleksandrovka—Surieikova—Isady—Normandien—Sokolova—Belmont—Aristovo—Vyazniki—Nedubrovo—intertrappean Tunguska—Babii Kamen' (cf. also Tables 8, 12, Figs. 94d, 94e, 95d, 95e). The differences from the initial sequence (Tables 3) are considerable, but they do not affect the sequence of well-dated assemblages (Kargala—Isady—Aristovo—Vyazniki—Nedubrovo). This gives evidence of the adequacy of the ordination method used. However, it should be taken into account that the faunal pattern criterion (Pz/pPz), at least in this case, has an obvious weak point: some values used are ratios of two small numbers (4/3 for Sokolova; 2/3 for Aristovo; 3/5 for Nedubrovo), so that the criterion is very vulnerable statistically. Interpretation of such data requires reasonable caution.

Optimization of the sequence of assemblages by the minimum sum of ghost ranges (Tables 6, 10, 14; Figs. 93e, 93f, 94e, 94f, 95e, 95f) gives rise to certain other problems. The differences between the best sequences by this criterion are minimum; the reliability of such differences is, therefore, low and, hence, the choice of a single best sequence is a nontrivial task. The solution we use for this problem is based on informal analysis of several (in this case, ten) best sequences and scrutiny of the trends revealed. It is shown that, among the complete set of assemblages (with four of them fixed; Table 5), the sequence Normandien—Vyazniki—Aristovo—Belmont—Surieikova—Nedubrovo—Sokolova—intertrappean Tunguska—

Babii Kamen' is stably reproduced. In the first reduced set (Table 9), in all ten sequences, the segment including Normandien—Vyazniki—(Belmont—Aristovo)—Nedubrovo—Tunguska—Babii Kamen' remains stable (with the order of Belmont and Aristovo randomly alternating). The second reduced set (Table 13) yields almost the same stable unit, Aristovo—Belmont—Surieikova—Nedubrovo—Sokolova—intertrappean, which is preceded by randomly alternating Normandien and Vyazniki.

In the first half of the sequence, in all three variants, only the position of the Chepanikha—Kostovaty assemblage at the very beginning of the list is more or less stably reproduced. Subsequently, a certain order is not observed, although based on three or four upper lines, the complete set with four assemblages fixed (Table 5) is characterized by random alternation of Kargala, Karaungir, and Bor-Tologoi, stably followed by Isady and, then, by Novo-Aleksandrovka. A similar pattern is found in the first reduced set (Table 9), while the second reduced set (Table 13) includes a more definitive sequence of Chepanikha + Kostovaty—Kargala—(Bor-Tologoi + Karaungir)—Isady—Novo-Aleksandrovka. Comparison of these data with the sequence optimized by the faunal pattern criterion (Chepanikha + Kostovaty—Kargala—Bor-Tologoi—Karaungir—Novo-Aleksandrovka—Surieikova—Isady—Normandien—Sokolova—Belmont—Aristovo—Vyazniki—Nedubrovo—intertrappean Tunguska—Babii Kamen') shows a certain, but incomplete similarity. The position of Isady before or after Novo-Aleksandrovka apparently indicates the small difference in age between these localities, beyond the sensitivity of the method, if applied to insufficiently large material (as is the case of Novo-Aleksandrovka). A much stronger difference is found in the position of the Surieikova, Sokolova, and Vyazniki assemblages: ordination by minimum number of gaps results in the first two shifted far to the right (suggesting a younger age) and Vyazniki shifted to the left (older age) compared to the ordering by the faunal pattern (Pz/pPz). Vyazniki

Table 10. First reduced set of assemblages (without Suriekova and Sokolova) arranged based on the minimum number of gaps (Table 5, line 2: total number of gaps 499). For designations, see Table 3

Assemblage	Chapanikha + Kostovaty	Kargala	Karungir	Bor-Tologoi	Isady	Novo-Aleksandrovka	Normandien	Vyazniki	Belmont	Aristovo	Nedubrovo	Tunguska	Babii Kamen'
Total number of specimens	400	300	550	900	3500	300	250	350	2000	250	200	600	140
ln_{total}	6.0	5.7	6.3	6.8	8.2	5.7	5.5	5.9	7.6	5.5	5.3	6.4	4.9
Total number of families	29	23	31	32	69	26	30	30	37	13	18	22	18
Families/ ln_{total}	4.7	4.0	4.9	4.4	8.6	4.6	5.5	5.2	4.9	2.5	3.6	3.1	3.7
Number of first appearances	2	3	1	4	15	0	3	2	6	0	0	4	5
First/ ln_{total}	0.3	0.5	0.2	0.6	1.8	0	0.5	0.3	0.8	0	0	0.6	1.0
Number of last appearances	2	3	0	5	16	5	5	4	9	3	1	4	1
Last/ ln_{total}	0.3	0.5	0	0.7	1.9	0.9	0.9	0.7	1.2	0.5	0.2	0.6	0.2
Number of transitional	12	7	13	8	22	12	9	11	9	6	9	7	7
Number of transitional/ ln_{total}	2.0	1.2	2.1	1.2	2.7	2.1	1.6	1.9	1.2	1.1	1.7	1.1	1.4
Number of Paleozoic	14	12	15	18	26	10	14	6	11	2	2	2	1
Number of Paleozoic/ ln_{total}	2.3	2.1	2.4	2.6	3.2	1.7	2.5	1.0	1.4	0.4	0.4	0.3	0.2
Number of post-Paleozoic	2	2	3	3	13	3	7	10	13	3	5	11	10
Post-Paleozoic/ ln_{total}	0.3	0.3	0.5	0.4	1.6	0.5	1.3	1.7	1.7	0.5	0.9	1.7	2.0
Number of endemics	0	2	0	3	7	1	0	3	4	2	2	2	0
Endemics/ ln_{total}	0	0.3	0	0.4	0.8	0.2	0	0.5	0.5	0.4	0.4	0.3	0
First/last	1	1	/0	0.8	0.9	0	0.6	0.5	0.7	0	0	1	7.0
Pz/pPz	7.0	6.0	5.0	6.0	2.0	3.3	2.0	0.6	0.8	0.7	0.4	0.2	0.1
Turnover	0.7	1.0	0.2	1.3	3.8	0.9	1.5	1.0	2.0	0.5	0.2	0.2	1.2

Table 11. Second reduced set of assemblages (pairs Bor-Tologoi and Karaungir, Tunguska and Babii Kamen' are combined; total number of gaps 553). Intertrappean: Tunguska and Babii Kamen'; for designations, see Table 3

Assemblage	Kargala	Chepanikha + Kostovaty	Surtekov	Novo-Aleksandrovka	Isady	Sokolova	Bor-Tologoi + Karaungir	Belmont	Normandien	Aristovo	Vyazniki	Intertrappean	Nedubrovo
Total number of specimens	300	400	670	300	3500	570	1450	2000	250	250	350	740	200
$\ln_{\text{total}}$	5.7	6.0	6.5	5.7	8.2	6.3	7.3	7.6	5.5	5.5	5.9	6.6	5.3
Total number of families	23	29	18	26	69	13	43	37	30	13	30	32	18
Families/ $\ln_{\text{total}}$	4.0	4.7	2.8	4.6	8.6	2.1	5.9	4.9	5.5	2.5	5.2	4.8	3.6
Number of first appearances	4	1	1	3	16	2	1	6	1	0	1	9	0
First/ $\ln_{\text{total}}$	0.7	0.3	0.1	0.5	1.6	0.3	0.1	0.8	0.2	0	0.2	1.4	0
Number of last appearances	3	2	0	0	12	0	23	14	7	2	8	3	4
Last/ $\ln_{\text{total}}$	0.5	0.3	0	0	1.7	0	3.1	1.2	1.3	0.2	1.2	0.4	0.7
Number of transitional	7	12	8	12	22	7	14	9	9	6	11	10	9
Number of transitional/ $\ln_{\text{total}}$	1.2	2.0	1.2	2.1	2.7	1.1	1.9	1.2	1.6	1.1	1.9	1.5	1.7
Number of Paleozoic	12	14	6	10	26	3	22	11	14	2	6	3	2
Number of Paleozoic/ $\ln_{\text{total}}$	2.1	2.3	0.9	1.7	3.2	0.5	3.0	1.4	2.5	0.4	1.0	0.4	0.4
Number of post-Paleozoic	2	2	3	3	13	3	4	13	7	3	10	17	5
Post-Paleozoic/ $\ln_{\text{total}}$	0.3	0.3	0.5	0.5	1.6	0.5	0.5	1.7	1.3	0.5	1.7	1.1	0.9
Number of endemics	2	0	1	1	7	0	3	4	0	2	3	2	2
Endemics/ $\ln_{\text{total}}$	0.3	0	0.1	0.2	0.8	0	0.4	0.5	0	0.4	0.5	0.3	0.4
First/last	1.3	0.5	/0	/0	1.3	/0	~0	1.0	0.1	0	0.2	3.0	0
Pz/pPz	6.0	7.0	2.0	3.3	2.0	1.0	5.5	0.8	2.0	0.7	0.6	0.2	0.4
Turnover	1.2	0.5	0.1	0.5	3.4	0.3	3.3	1.6	1.5	0.4	1.2	1.8	0.7

Table 12. Second reduced set of assemblages optimized based on Pz/pPz (number of gaps 514). For designations, see Tables 3 and 11

Assemblage	Chapanikha + Kostovaty	Kargala	Bor-Toloi + Karanigir	Novo-Aleksandrovska	Surikovo	Isady	Normandien	Sokolova	Belmont	Aristovo	Vyazniki	Nedubrovo	Intertappean
Total number of specimens	400	300	1450	300	670	3500	250	570	2000	250	350	200	740
$\ln_{\text{total}}$	6.0	5.7	7.3	5.7	6.5	8.2	5.5	6.3	7.6	5.5	5.9	5.3	6.6
Total number of families	29	23	43	26	18	69	30	13	37	13	30	18	32
Families/ $\ln_{\text{total}}$	4.7	4.0	5.9	4.6	2.8	8.6	5.5	2.1	4.9	2.5	5.2	3.6	4.8
Number of first appearances	2	3	5	2	1	13	3	1	5	0	1	0	9
First/ $\ln_{\text{total}}$	0.3	0.5	0.7	0.3	0.1	1.6	0.5	0.2	0.7	0	0.2	0	1.4
Number of last appearances	2	3	3	3	1	18	5	0	8	2	6	1	5
Last/ $\ln_{\text{total}}$	0.3	0.5	0.4	0.5	0.1	2.2	0.9	0	1.0	0.4	1.0	0.2	0.8
Number of transitional	12	7	14	12	8	22	9	7	9	6	11	9	10
Number of transitional/ $\ln_{\text{total}}$	2.0	1.2	1.9	2.1	1.2	2.7	1.6	1.1	1.2	1.1	1.9	1.7	1.5
Number of Paleozoic	14	12	22	10	6	26	14	3	11	2	6	2	3
Number of Paleozoic/ $\ln_{\text{total}}$	2.3	2.1	3.0	1.7	0.9	3.2	2.5	0.5	1.4	0.4	1.0	0.4	0.4
Number of post-Paleozoic	2	2	4	3	3	13	7	3	13	3	10	5	17
Post-Paleozoic/ $\ln_{\text{total}}$	0.3	0.3	0.5	0.5	0.5	1.6	1.3	0.5	1.7	0.5	1.7	0.9	1.1
Number of endemics	0	2	3	1	1	7	0	0	4	2	3	2	2
Endemics/ $\ln_{\text{total}}$	0	0.3	0.4	0.2	0.1	0.8	0	0	0.5	0.4	0.5	0.4	0.3
First/last	1	1	2.5	0.7	1	0.7	0.6	/0	0.6	0	0.2	0	1.8
Pz/pPz	7.0	6.0	5.5	3.3	2.0	2.0	2.0	1.0	0.8	0.7	0.6	0.4	0.2
Turnover	0.7	1.0	1.1	0.9	0.3	3.8	1.5	0.23	1.7	0.4	1.2	0.2	2.1

Table 13. Second reduced set of assemblages: initial sequence and ten best sequences according to the number of gaps. Designations: (B-T&K) combined assemblage of Bor-Tologoi and Karaungir; (intertrap) intertrappean assemblages of Tunguska and Babii Kamen'; For other designations, see Table 5

553	Krga	Ch + K	Suri	N-Alek	Isad	Soko	B-T&K	Belm	Norm	Aris	Vyaz	intertrap	Nedu
493	Ch + K	Krga	B-T&K	Isad	N-Alek	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	intertrap
494	Ch + K	Krga	B-T&K	Isad	N-Alek	Norm	Aris	Vyaz	Belm	Suri	Nedu	Soko	intertrap
495	Ch + K	Krga	B-T&K	Isad	N-Alek	Vyaz	Norm	Aris	Belm	Suri	Nedu	Soko	intertrap
496	Ch + K	B-T&K	Isad	N-Alek	Krga	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	intertrap
498	Ch + K	B-T&K	Isad	N-Alek	Krga	Vyaz	Norm	Aris	Belm	Suri	Nedu	Soko	intertrap
500	B-T&K	Ch + K	Isad	N-Alek	Krga	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	intertrap
502	B-T&K	Isad	Ch + K	N-Alek	Krga	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	intertrap
504	B-T&K	Isad	N-Alek	Ch + K	Krga	Norm	Vyaz	Aris	Belm	Suri	Nedu	Soko	intertrap
506	B-T&K	Isad	N-Alek	Ch + K	Krga	Vyaz	Norm	Aris	Belm	Suri	Nedu	Soko	intertrap
508	B-T&K	Isad	N-Alek	Ch + K	Krga	Aris	Norm	Vyaz	Belm	Suri	Nedu	Soko	intertrap

appears older than Belmont, Surieikova is younger than Belmont, and Sokolova is younger than Nedubrovo. This result is in conflict with available geological data (see above in this section and Chapter 1.3 for Vyazniki); therefore, it should not be taken for a plausible model. Possible causes of this contradiction are discussed below, but, in any case, the data on the dynamics of the faunal pattern (Pz/pPz) should be preferred here.

Among other results, we should primarily pay attention to the parallel (to a first approximation) trend of changes in local diversity (normalized number of families per assemblage) and faunal turnover measure (Figs. 93a, 94a, 95a). This predictable result is evidence of the absence or scarcity of anomalous processes, in which a poor assemblage shows a relatively higher number of the first and/or last appearances of families and vice versa. It is not improbable that, in this case, anomalous assemblages come from Karaungir and, less certainly, Kargala; these assemblages stably (i.e., in different versions of calculations) demonstrate rates of renewal lower and higher than expected, respectively. The analysis of causes of these possible anomalies should be postponed until a greater amount of similar data is accumulated.

3.1.4. Discussion

Turning to the discussion of results, we should primarily mark the difficulties of correlation of the assemblages studied. More or less reliable stratigraphic data (see Chapter 1 and this section above) only give evidence that the Chepanikha, Kostovaty, and Kargala localities were formed not later than the Urzhumian, Middle Permian; Isady is near the upper boundary of the Severodvinian; Vyazniki is near the upper boundary of the Upper Vyatkian; Aristovo is more or less immediately followed by Vyazniki; and the Nedubrovo and intertrappean assemblages are not earlier than the nearest neighborhood of the Permian–Triassic boundary. Therefore, it is not always possible to correlate events

revealed in the history of insects during the Urzhumian–Lower Triassic period with the stratigraphic units of the General and International scales. Nevertheless, our data allow specifying this correlation.

As shown above, the optimizing methods used in the present study reveal two alternative sequences:

(1) Chepanikha + Kostovaty–Kargala–Bor-Tologoi–Karaungir–Novo-Aleksandrovka–Surieikova–Isady–Normandien–Sokolova–Belmont–Aristovo–Vyazniki–Nedubrovo–intertrappean Tunguska–Babii Kamen' (by the ratio of families considered Paleozoic and post-Paleozoic);

(2) (Chepanikha + Kostovaty)–Kargala–(Karaungir + Bor-Tologoi)–Isady–Novo-Aleksandrovka–Normandien–Vyazniki–(Belmont + Aristovo)–Surieikova–Nedubrovo–Sokolova–Tunguska–Babii Kamen' (by minimum ghost ranges).

Sequence (1), on the whole, complies well with stratigraphic data and looks optimal. Its only somewhat unexpected component is the position of the Nedubrovo assemblage below the intertrappean assemblages of Tunguska and Babii Kamen'; however, the stratigraphic argumentation in favor of the opposite order is not very strong (see above in the section *Materials*). Since both of our criteria, the faunal pattern (Pz/pPz) and minimum of ghost ranges, unanimously suggest a lower position for Nedubrovo, we are compelled to rest on this conclusion. Sequence (2), as noted in the section *Results*, is more contradictory. The positions of Vyazniki below and Surieikova above Belmont and Aristovo and Sokolova above Nedubrovo contradict well-founded stratigraphic data (see above in this chapter and Chapter 3.1) and cannot be accepted. However, the causes of these contradictions deserve attention and analysis, since they are important for understanding the specifics of the methods and can contribute to the recognition of the trends not revealed by other parameters. The younger age (shift towards the end of the sequence) for small assemblages of Sokolova and Surieikova, the number of families in

Table 14. Second reduced set of assemblages optimized based on the total number of gaps (Table 12, second line; total number of gaps 493). For designations, see Tables 3 and 11

Assemblage	Chapanikha + Kostovaty	Kargala	Bor-Tolugoi + Karanungir	Isady	Novo-Aleksandrovka	Normandien	Vyzniki	Aristovo	Belmont	Surikova	Nedubrovo	Sokolova	Intertappean
Total number of specimens	400	300	1450	3500	300	250	350	250	2000	670	200	570	740
$\ln_{\text{total}}$	6.0	5.7	7.3	8.2	5.7	5.5	5.9	5.5	7.6	6.5	5.3	6.3	6.6
Total number of families	29	23	43	69	26	30	30	13	37	18	18	13	32
Families/ $\ln_{\text{total}}$	4.7	4.0	5.9	8.6	4.6	5.5	5.2	2.5	4.9	2.8	3.6	2.1	4.8
Number of first appearances	2	3	5	15	0	3	2	0	6	0	0	0	9
First/ $\ln_{\text{total}}$	0.3	0.5	0.7	1.8	0	0.5	0.3	0	0.8	0	0	0	1.4
Number of last appearances	2	3	3	16	5	5	4	2	6	3	1	1	5
Last/ $\ln_{\text{total}}$	0.3	0.5	0.3	1.9	0.9	0.9	0.7	0.4	0.8	0.5	0.2	0.2	0.8
Number of transitional	12	7	14	22	12	9	11	6	9	8	9	7	10
Number of transitional/ $\ln_{\text{total}}$	2.0	1.2	1.9	2.7	2.1	1.6	1.9	1.1	1.2	1.2	1.7	1.1	1.5
Number of Paleozoic	14	12	22	26	10	14	6	2	11	6	2	3	3
Number of Paleozoic/ $\ln_{\text{total}}$	2.3	2.1	3.0	3.2	1.7	2.5	1.0	0.4	1.4	0.9	0.4	0.5	0.4
Number of post-Paleozoic	2	2	4	13	3	7	10	3	13	3	5	3	17
Post-Paleozoic/ $\ln_{\text{total}}$	0.3	0.3	0.5	1.6	0.5	1.3	1.7	0.5	1.7	0.5	0.9	0.5	1.1
Number of endemics	0	2	3	7	1	0	3	2	4	1	2	0	2
Endemics/ $\ln_{\text{total}}$	0	0.3	0.4	0.8	0.2	0	0.5	0.4	0.5	0.1	0.4	0	0.3
First/last	1	1	1.7	0.9	0	0.6	0.5	0	1	0	0	0	1.8
Pz/pPz	7.0	6.0	5.5	2.0	3.3	2.0	0.6	0.7	0.8	2.0	0.4	1.0	0.2
Turnover	0.7	1.0	1.1	3.8	0.9	1.5	1.0	0.4	1.6	0.5	0.2	0.2	2.1

which is 13 and 18, respectively, may be a mathematical artifact. Certainly, the entomofauna of the terminal Permian is depleted (see below), so that the number of gaps in the right wing of our distribution (Figs. 91, 92) is much greater than in its other parts. Small assemblages by definition display many gaps, and our method of minimizing ghost ranges (internal gaps within the temporal distribution of families) can automatically shift such assemblages to that end of the distribution where the number of such gaps is great. Consequently, the ordination of small assemblages by the method of ghost ranges can be especially unreliable. This is, of course, an entirely preliminary supposition, which requires testing. The case of the Vyazniki assemblage is different, but it is more convenient to discuss this paradox later.

For the time being, we accept sequence (1) in a generalized form as the final, combining assemblages most similar in available parameters: (3) (Chepanikha + Kostovaty)—Kargala—(Bor-Tologoi + Karaungir)—Novo-Aleksandrovka—(Surieikova—Isady—Normandien)—Sokolova—Belmont—Aristovo—Vyazniki—Nedubrovo—(intertrappean Tunguska + Babii Kamen').

The reasons for combining Chapanykha with Kostovaty, Bor-Tologoi with Karaungir, and Tunguska with Babii Kamen' are given above; Surieikova, Isady, and Normandien are combined based on their identical values of the faunal pattern index.

The results of our study allow making the following conclusions:

1. The change in the composition of insect families during the period studied was extremely uneven, with noncoincident moments of sharp changes in different parameters.

2. The faunal pattern of successive assemblages (Pz/pPz; Figs. 93d, 94d, 95d) changes smoothly; however, several stages of these changes are recognized. In early assemblages (Chepanikha—Novo-Aleksandrovka), ancient families (conditionally considered Paleozoic) strongly dominate. In Surieikovo, Isady, and Normandien, their dominance is distinct, but less pronounced. Starting with Sokolova, the proportion of ancient families smoothly decreases from parity to 1 : 5.

3. The direction of changes (the ratio of the number of the first and last appearances of families; Figs. 93d, 94d, 95d) changes more chaotically, but, on the whole, we can trace a very slow change from parity at the beginning to the disappearance of the first appearances to Nedubrovo (with a local peak in Bor-Tologoi) and a new peak of diversification in the intertrappean deposits of Siberia.

4. The intensity of changes, reflected in the turnover measure (Figs. 93c, 94c, 95c) seems chaotic, but, as mentioned above, it is mostly determined by the summarized diversity of respective assemblages. The chaotic changes in the last parameter are probably caused by the diversity of living conditions. Although

the highest value of diversity (Isady) coincides with the largest size of collection and one of the lowest values (Aristovo) coincides with one of the smaller collections; in other cases, a distinct correlation between diversity and the size of collections is not observed. The four minimums observed (Surieikova, Sokolova, Aristovo, Nedubrovo) represent collections of different size (200 to 670 specimens), and medium values of diversity are found in collections ranging from 300 to 2000 specimens (other assemblages, except Isady). Therefore, it is hardly probable that the correlation between the rate of renewal and diversity of assemblages is caused by the direct influence of the extent of knowledge (number of specimens collected) and, hence, the insufficiency of diversity normalization by the logarithm of collection size (see the section *Materials*). The hypothesis of the influence of local environmental factors seems more feasible in many aspects, although other factors should also be looked for to gain a better understanding of the almost twofold growth of the renewal rate found in Isady. These factors may include, for instance, the unevenness of temporal distribution of assemblages: if the time between Isady and the nearest preceding and succeeding assemblages is very long, all other things being equal, proportionally greater numbers of the first and last appearances could have accumulated over a longer time. However, the Isady assemblage does not differ from the others, for instance, from Surieikova and Normandien, in other parameters, which are also time-dependent, e.g., in the faunal pattern (Pz/pPz). Thus, at present, there is no reason to appeal to the time gap hypothesis.

5. The following boundaries proved to be most important: (1) before Isady: the end of a rapid fall of the proportion of ancient families and transition to unbalanced changes, with the prevalence of the last appearances of families; (2) beginning from Belmont (or the insufficiently known Sokolova): transition to a very gradual decrease in the proportion of ancient families, retaining a strongly negative balance of changes; (3) intertrappean time: return to strongly positive dynamics in the composition of assemblages. The recognition of Isady as a special stage based on the sharp intensification of faunal renewal is questionable. It is not improbable that, in this case, we deal with results of certain specific local or regional conditions, or uniquely favorable fossilization conditions, i.e., that this phenomenon is geographic or taphonomic rather than evolutionary.

It is noteworthy that combining in one sequence large amounts of data on Angaraland (including Subangaraland) and considerably more limited data on Gondwana (one assemblage from Australia and one from South Africa) did not result in difficulties in interpretation. The data on the Belmont and Normandien assemblages are neatly integrated into the sequence of the Angaraland assemblages, without distorting this sequence. It proved even easier to combine

in one sequence assemblages of European Russia, southern and central Siberia, eastern Kazakhstan, and Mongolia. This result suggests a largely global character of changes in the entomofauna around the Permian–Triassic boundary and, thus, the acceptability of the approach used here.

Taking these reservations into account, we can formulate the following preliminary conclusions. At the beginning of the period studied, the dynamics of the insect fauna at the taxonomic level of families had a balanced character. The first and last appearances approximately counterbalanced each other (with the exception of a short-term peak at the level of Bor-Tolgoi); ancient (conditionally considered Paleozoic) families dominated over young ones (conditionally considered post-Paleozoic), but the extent of their dominance rapidly decreased. Beginning from Novo-Aleksandrovka and Isady, the negative component of changes stably prevailed and the Paleozoic faunal pattern (dominance of ancient families) gradually leveled out. The intensity of changes, which sharply increased in the Isady time, subsequently decreased, but the evolutionary rather than geographic or taphonomic nature of the Isady peak requires confirmation. The negative character of faunal turnover sharply intensified at least at the level of Vyazniki, if not Aristovo. At the transitional Permian–Triassic phase (Tunguska, Babii Kamen'), the taxonomic dynamics, approximately retaining its former intensity, changed to sharply positive and the faunal pattern became definitely post-Paleozoic.

According to these results and taking into account available stratigraphic data, we can tentatively propose a distribution pattern of the insect assemblages under study over the stratigraphic units of the Middle (its upper part) and Upper Permian. Chepanikha, Kostovaty, Kargala, Bor-Tolgoi, and Karaungir, which are characterized by the faunal pattern index from 5 to 7, can be preliminarily correlated with the Urzhumian Stage of the Middle Permian. Novo-Aleksandrovka, Suriekova, Isady, and Normandien (Pz/pPz = 2–3,3) are assigned to the Severodvinian Stage of the Upper Permian; Sokolova, Belmont, Aristovo, and Vyazniki are dated as the Vyatkian Stage (Pz/pPz = 0.6–1). The position of intertrappean assemblages (Tunguska and Babii Kamen', Pz/pPz = 0.1–0.2) in the transitional P/T range is generally accepted. The position of Nedubrovo remains uncertain; it probably belongs to the Vyatkian Stage, the more so as the dominance of the last appearances over first ones makes it similar to presumably Vyatkian assemblages. However, a number of features of the Nedubrovo fauna and flora were previously interpreted as supporting its correlation with the post-trappean or late trappean level (see above). Therefore, the solution of this question should be postponed.

Doubtlessly Early Triassic (post-trappean) insect faunas are known very poorly. They are undoubtedly impoverished, but it is not at all easy to interpret this

fact. Indeed, in the transitional P/T range (beginning from Nedubrovo) and doubtless Lower Triassic, 40 insect families have been recorded, while in the preceding range (Sokolova–Vyazniki, presumably Vyatkian, Late Permian), 47 families have been recorded, and in the range before that (Novo-Aleksandrovka–Normandien, presumably Severodvinian, Late Permian), there are 87 families; in the presumably Urzhumian time (Chepanikha–Karaungir), 59 families have been recorded. However, if we take into account not only the directly recorded families, but also those that have been recorded before and after each particular range and, thus, also existed in this range, but have not been found, the ratio will be different: 64 families in the Early Triassic, 67 in the Vyatkian, 96 in the Severodvinian, and 80 in the Urzhumian. Thus, the known Early Triassic insect fauna is not disastrously depleted; almost the same level of impoverishment is found in the preceding Vyatkian fauna. A more profound impoverishment (almost by one-third) is only observed in comparison with the rich Severodvinian fauna. However, if we normalize the diversity of insects over the stages (see the section *Methods*), the differences will change. Normalized insect diversity, taking into account transitional families, is 10.4 in the Urzhumian, 11.3 in the Severodvinian, 8.3 in the Vyatkian, and 9.4 in the Early Triassic (including transitional assemblages). Thus, it is the Vyatkian fauna, rather than the Early Triassic one, that is the most depleted, but even this fauna is depleted only by one-third compared with the richest Severodvinian fauna.

Thus, in the history of insects, the Permian–Triassic crisis (the meaning of this term in the context of this study is discussed below) begins with the dominance of negative events over positive ones and is possibly accompanied by a sharp short-term peak of dynamics (Isady). Extinction of families continues to dominate until the end of the Vyatkian and, only at the Permian–Triassic boundary, the emergence of new families begins to prevail. The crisis manifests itself in an inhibition of taxonomic diversification rather than intensification of extinction, because a mass extinction of insects did not occur at this boundary. This is why the change in the faunal pattern lags behind and the fauna becomes clearly post-Paleozoic only in the Vyazniki time, immediately before the transitional P/T range.

We can try to compare the results of this study with the previously performed analyses of the Cretaceous biocoenotic crisis (Zherikhin, 1978; Dmitriev and Zherikhin, 1988; Rasnitsyn, 1988, 1989; Bugdaeva et al., 2006). The scope of those studies included a considerably wider range, covering the terminal Jurassic and entire Cretaceous, and revealed a characteristic stepwise development of the process. For instance, successive phases of the crisis were formulated: preparatory, paradoxical, drastic, and calming (Rasnitsyn, 1989). It was pointed out that the preparatory phase is

characterized by a rapid decrease in the proportion of extinct families (in our case, these are ancient families conditionally considered Paleozoic); the paradoxical phase is characterized by the deceleration of diversification and archaization of the fauna (temporary increase in the proportion of extinct families). The drastic phase is distinguished by a rapid renewal of the fauna; and the calming phase is distinguished by a decrease in the rate of faunal renewal, reaching the background level, primarily through deceleration of extinction. It was noted that, during the calming phase, "extinction quickly ceases, and emergence continues, sometimes even intensifying. Obviously, the crisis resulted in the appearance of communities with much greater capacities than before" (Rasnitsyn, 1989, p. 39).

A comparison of the results of the present study with the conclusions drawn in studies of the Cretaceous crisis reveals certain, although incomplete, similarity. The preparatory phase of the crisis in the case in question probably corresponds to the Urzhumian, when the proportion of ancient families sharply decreased, but the balance of changes remained positive or neutral (Figs. 93–95). During the Severodvinskian and Vyatkian time, the proportion of ancient families continued to decrease rapidly, but not so much because of the emergence of young families as because of the continuing extinction of ancient ones, since diversification was suppressed and the balance of changes remained negative; the fauna became depleted. This stage probably represents a strongly protracted paradoxical phase of the crisis. At the same time, archaization of the fauna, described for this phase in the Cretaceous crisis, is not explicitly pronounced here (as a temporary increase in the proportion of ancient families). However, the above-noted paradoxical behavior of the Vyazniki assemblage in the case of ordination by the minimum number of stratigraphic gaps, where this assemblage precedes earlier assemblages from Belmont and Aristovo, may be simply a different manifestation of the same archaization phenomenon; this supposition requires special testing. It will be recalled that the Vyazniki assemblage shows a distinct archaic character, in particular, in traces of interactions between insects and plants (Chapter 1.4).

The beginning of the drastic phase is probably represented by transitional Permian–Triassic assemblages, especially intertrappean, characterized by a strong dominance of positive processes over negative ones and, possibly, by a general activation of faunal renewal. However, testing of this hypothesis is a matter for future studies. The drastic phase of the crisis is represented in the material of the present study at best by its very beginning, and the calming phase is not represented at all, so that little can be said about it. In any event, it is apparent that an almost complete cessation of extinction of families, as in the Paleogene, did not take place in the Mesozoic. However, a rapid growth of insect diversity, described for the Late Cretaceous and

post-Cretaceous situation, is also clearly pronounced after the Permian crisis. According to Dmitriev (Dmitriev and Ponomarenko, 2002), the curve of insect families shows a slow growth in the Paleozoic, terminating in a small decrease in the latter half of the Permian and at the beginning of the Triassic and, then, from the Middle Triassic to Recent, stable rapid growth with a barely discernible decrease in its rate from the terminal Jurassic to terminal Cretaceous (Dmitriev and Ponomarenko, 2002, text-fig. 478b).

Thus, the events around the Permian–Triassic boundary, reflected in the composition of successive assemblages of insect families, had a rather complex pattern, resembling to some extent that of the polyphase Cretaceous biocoenotic crisis. By analogy, the Permian–Triassic biocoenotic crisis can also be recognized; however, the crisis character of the phenomenon is manifested in this case to an even greater extent than in the Cretaceous in the transformation of the community structure rather than negative processes, such as mass extinction. The new biocoenotic structure which emerged after the transformation proved to have such a high capacity that it gave rise to a rapid and almost uninterrupted growth of taxonomic diversity of insects during the entire Meso–Cenozoic, only with a Cretaceous decrease barely noticeable on this scale. Since the above-described pattern of the taxonomic dynamics of insects at the family level closely matches that of marine organisms within the range from the Carboniferous to Recent (with the major difference that extinctions in marine ecosystems around the Permian–Triassic and Cretaceous–Paleogene boundaries were rather strong: Alekseev et al., 2001, text-fig. 6), it is proposed that the reorganization of communities was an important, or even the most important, aspect and result of these and many other crises in the development of the biosphere.

Another conclusion, not so large-scale, but also deserving attention, is that a few more or less thoroughly examined insect assemblages outside Angaraland (from the African and Australian parts of Gondwana) are naturally integrated into the processes revealed in Angaraland, suggesting a considerable level of unity in the entomofauna of that time and a global character of the processes and events described. However, since the processes reconstructed based on fossil insects and marine animals prove to be similar (see above), there is no surprise that the processes in entomofaunas of Angaraland and Gondwana are also similar.

3.1.5. Conclusions

The results obtained by the group of paleoentomologists of PIN and their collaborators and generalized here display a relatively diverse insect fauna from localities of the terminal Permian and basal Triassic (Urzhumian to Olenekian). A total of 25 orders and 115 families of insects have been recorded; one family, 27 genera, and 117 species are newly described. Three

orders (Caloneurida, Dictyoneurida, and Mischopterida) and nine families are recorded for the first time in the Late Permian. Fifteen more or less representative successive insect assemblages have been revealed (13 from Angaraland and two from Gondwana). Comparison of the composition of families in these assemblages has confirmed the absence of catastrophic extinction of insects at the boundary between the Late Permian and Triassic; a depletion took place during the Vyatkian, but it was not catastrophic during this age nor at the end of it. The Vyatkian decrease in diversity was caused mostly by deceleration of diversification rather than by actual extinction. The depletion of Vyatkian and Early Triassic assemblages was neither catastrophic nor global. In the Early Triassic, including the transitional period, only 46% of families recorded in the preceding Severodvinian Time have been found; in the Vyatkian Time, there were 54% of such families. However, taking into account transitional families not recorded in particular periods, Vyatkian and Early Triassic assemblages contain 70 and 67% of Severodvinian families, respectively. In the Vyatkian and Early Triassic, the probability for insects to fall in the burial probably in general decreased due to a decrease in ranges (survival in refugia), unfavorable changes in fossilization conditions, or some other presently uncertain reasons.

The pattern of changes revealed in the present study displays certain, although incomplete, similarity to the stages (phases) of the Cretaceous biocoenotic crisis; the difference of the Permian–Triassic crisis is the even smaller, compared to the Cretaceous, contribution of negative processes (extinction). The reorganization of the biocoenotic structure towards unlimited growth of its capacity becomes a factor of primary importance, as in the Cretaceous.

Some other aspects and features of insect evolution near the P/T boundary are discussed in other publications based on the present study (Rasnitsyn, 2012; Rasnitsyn et al., 2013).

The methods developed in the course of this study for ordination of fossil assemblages of insufficiently clear stratigraphic position proved quite efficient and deserve further testing with the use of other groups and stratigraphic levels and, probably (in the case of ordination by the sum of ghost ranges), even in fields beyond paleontology. Using these methods with paleontological materials is quite promising for fine correlation of deposits on both the regional and global scale.

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REFERENCES

- Alekseev, A.S., Dmitriev, V.Yu., and Ponomarenko, A.G., *Evolutsiya taksonomicheskogo raznoobraziya*, (Evolution of Taxonomic Diversity), Moscow: Geos, 2001.
- Amalitzky, V.P., *Geologicheskaya ekskursiya na sever Rossii*, in *Tr. Imper. St. Peterb. O—va Estestvoispyt.*, 1897, vol. 28, no. 1, part 1, pp. 77–82.
- Ansorge, J., Revision der liassischen “Permochoristidae” (Stammgruppenvertreter der Antliophora = Mecoptera + Diptera), *Stud. Dipterol.*, 1995, vol. 2, no. 1, pp. 21–26.
- Arefiev, M.P., The Study of the Tikhvinskoe Locality in the Svyato-Alekseevskaya Hermitage, in *Verkhnei paleozoi Rossii: stratigrafiya i paleogeografiya. Materialy Vserossiiskoi konferentsii, posvyashchennoi pamyati professora Vyacheslava Georgievicha Khalymbadzhii* (All-Russia Conference on the Upper Paleozoic of Russia: Stratigraphy and Paleogeography, Devoted to the Memory of the Professor Vyacheslav Georgievich Khalymbadzhii), Kazan, 2007, pp. 9–12.
- Arefiev, M.P., On Relationships of Sedimentological Conditions and Biodiversity of the Aquatic Biota in Permian–Triassic Deposits of the Moscow Syncline, in *Permskaya sistema: stratigrafiya, paleontologiya, paleogeografiya, geodinamika i mineral'nye resursy. Materialy Mezhdunar. nauch. konf., posvyashchennoi 170-letiyu so dnya otkrytiya permskoi sistemy* (International Scientific Conference on the Permian System: Stratigraphy, Paleontology, Paleogeography, Geodynamics and Mineral Resources, Devoted to 170th Anniversary of the Discovery of Permian System), Perm: Perm. Gos. Univ., 2011, pp. 21–26.
- Arefiev, M.P. and Naugolnykh, S.V., Isolated Roots from the Tatarian Stage of the Sukhona and Malaya Northern Dvina River Basin, *Paleontol. Zh.*, 1998, no. 1, pp. 86–99.
- Arefiev, M.P., Shkurskii, B.B., and Grigor'eva, A.V., The Influence of the Baltic and Ural Feeding Provinces on Sedimentation at the Permian–Triassic Boundary in the Northeast Part of the Moscow Syncline, in *Kontseptual'nye problemy litologicheskikh issledovaniy v Rossii: Materialy 6-go Vserossiiskogo litologicheskogo soveshchaniya* (6th All-Russia Lithologic Conference on the Conceptual Problems of Lithologic Studies in Russia), Kazan: Kazan. Gos. Univ., 2011, vol. 1, pp. 63–67.
- Aristov, D.S., Revision of the Family Tomiidae (Insecta: Grylloblattida), *Paleontol. Zh.*, 2003, no. 1, pp. 32–39.

- Aristov, D.S., Features of Grylloblattid Insects at the Transition from the Permian to Triassic, in *Ekosistemnye perestroiki i evolyutsiya biosfery* (Ecosystem Reorganization and Evolution of the Biosphere), Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2004a, vol. 6, pp. 137–140.
- Aristov, D.S., The Fauna of Grylloblattid Insects (Grylloblattida) from the End of the Late Permian to the First Half of the Triassic, *Paleontol. Zh.*, 2004b, no. 5, pp. 45–52.
- Aristov, D.S., Grylloblattids of the Family Chaulioditidae (=Tomiidae syn. nov.) (Insecta: Grylloblattida) from the Upper Permian of the Orenburg Region, *Paleontol. J.*, 2004c, vol. 38, suppl. no. 2, pp. 146–149.
- Aristov, D.S., The Fauna of Grylloblattid Insects (Grylloblattida) of the Lower Permian Locality of Tshekarda, *Paleontol. J.*, 2004d, vol. 38, suppl. no. 2, pp. 80–145.
- Aristov, D.S., Grylloblattids of the Family Liomopteridae (Insecta: Grylloblattida) of the Upper Half of the Upper Permian, *Paleontol. J.*, 2004e, vol. 38, suppl. no. 2, pp. 150–157.
- Aristov, D.S., New Grylloblattids (Insecta: Grylloblattida) from the Triassic of Eastern Europe, Eastern Kazakhstan, and Mongolia, *Paleontol. Zh.*, 2005, no. 2, pp. 64–67.
- Aristov, D.S., New Tatarian Representatives of the Subfamily Chaulioditinae (Insecta: Grylloblattida: Chaulioditidae) from European Russia, *Paleontol. Zh.*, 2008a, no. 1, pp. 33–36.
- Aristov, D.S., New Grylloblattids of the Family Megakhorisidae (Insecta: Grylloblattida) from the Permian of Russia, *Paleontol. Zh.*, 2008b, no. 3, pp. 45–49.
- Aristov, D.S., A New Grylloblattida (Insecta) from the Middle and Upper Permian of the Russia, *Far East. Entomol.*, 2008c, no. 188, pp. 1–7.
- Aristov, D.S., Late Permian Faunas of Grylloblattid Insects (Insecta: Grylloblattida), in *Sovremennaya paleontologiya: klassicheskie i noveishie metody* (Modern Paleontology: Classical and Modern Methods), Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2009a, pp. 17–22.
- Aristov, D.S., Review of the Stratigraphical Distribution of Permian Grylloblattida (Insecta) with Descriptions of New Taxa, *Paleontol. Zh.*, 2009b, no. 6, pp. 37–45.
- Aristov, D.S., New Grylloblattids (Insecta: Grylloblattida) from the Isady Locality (Severodvinian Stage of the Vologda Region), *Russ. Entomol. J.*, 2009c, vol. 18, no. 1, pp. 17–22.
- Aristov, D.S., New Grylloblattida (Insecta) from Kargala Locality (Russia; Middle Permian), *Far East. Entomol.*, 2009d, no. 192, pp. 1–8.
- Aristov, D.S., Review of Grylloblattid Insects (Insecta: Grylloblattida) from the Solikamsk Deposits of the Perm Region, *Paleontol. Zh.*, 2010, no. 5, pp. 28–36.
- Aristov, D.S., New and Little Known Blattogryllidae (Insecta: Grylloblattida) from the Permian and Triassic of Russia, Kazakhstan, and Kyrgyzstan, *Paleontol. Zh.*, 2011a, no. 1, pp. 59–65.
- Aristov, D.S., New and Little Known Grylloblattida (Insecta) from Intertrappean Deposits of the Tunguska Basin of Siberia, *Paleontol. Zh.*, 2011b, no. 5, pp. 61–68.
- Aristov, D.S., Composition and Distribution of the Family Cacurgidae (Insecta: Grylloblattida), *Paleontol. Zh.*, 2012, no. 3, pp. 29–36.
- Aristov, D.S., New Grylloblattida (Insecta) from the Upper Permian and Lower Triassic of European Russia and the Upper Permian of Kazakhstan, *Paleontol. Zh.*, 2013a, no. 1, pp. 48–56.
- Aristov, D.S., New and Little-known Eoblattida (Insecta) from the Paleozoic of Russia, *Paleontol. Zh.*, 2013b, no. 3, pp. 64–73.
- Aristov, D.S. and Bashkuev, A.S., New Insects (Insecta: Mecoptera, Grylloblattida) from the Middle Permian Chepanikha Locality, Udmurtia), *Paleontol. Zh.*, 2008, no. 2, pp. 54–59.
- Aristov, D.S., Novokshonov, V.G., and Pan'kov, N.N., Taxonomy of the Fossil Grylloblattid Nymphs (Insecta: Grylloblattida), *Paleontol. Zh.*, 2006, no. 1, pp. 75–85.
- Aristov, D.S., Ponomarenko, A.G., Shcherbakov, D.E., Insecta, in *Geosites of the Yaroslavl Area: Stratigraphy, Paleontology, Paleogeography*, Moscow: Izd. Dom "Yustitsinform", 2012, pp. 83–84.
- Aristov, D.S., Prevec, R., and Mostovski, M.B., New and Poorly Known Grylloblattids (Insecta: Grylloblattida) from the Lopingian of the Lebombo Basin, South Africa, *Afr. Invertebr.*, 2009a, vol. 50, no. 2, pp. 279–286.
- Aristov, D.S. and Rasnitsyn, A.P., Position and Taxonomy of the Permian Fossil Insect Family Permibiidae (Insecta: Palaeomanteida = Miomoptera), *Russ. Entomol. J.*, 2008, vol. 17, no. 4, pp. 327–334.
- Aristov, D.S. and Rasnitsyn, A.P., The Family Tillyardembiidae Zalesky, 1938 and the System of the Plecopteroid Insects, *Russ. Entomol. J.*, 2009, vol. 18, no. 3, pp. 257–264.
- Aristov, D.S. and Rasnitsyn, A.P., A New Eoblattids (Insecta: Eoblattida) from the Permian of Russia, *Far East. Entomol.*, 2011, no. 230, pp. 1–12.
- Aristov, D.S. and Rasnitsyn, A.P., Revision of the Family Idelinellidae, with a Review of Permian Eoblattida (Insecta), *Paleontol. Zh.*, 2012, no. 1, pp. 48–59.
- Aristov, D.S. and Storozhenko, S.Yu., Review of the Permian Family Permuliidae nomen novum pro Aliculidae Storozhenko, 1997 (Grylloblattida), in *ZooKeys*, 2011, no. 130 (Advances in the Systematics of Fossil and Modern Insects: Honouring Alexandr Rasnitsyn, Shcherbakov, D.E., Engel, M.S., and Sharkey M.J., Eds.), pp. 111–130.
- Aristov, D.S., Wappler, T., and Rasnitsyn, A.P., New and Little-Known Grylloblattids of the Family Geinitziidae (Insecta: Grylloblattida) from the Triassic and Jurassic of Europe, Asia, and South Africa, *Paleontol. Zh.*, 2009b, no. 4, pp. 59–65.
- Barbot-de-Marni, N.P., Geognostic Journey to Northern Provinces of European Russia, *Zap. Imper. St. Peterb. Mineral. O-va*, 1868, Ser. 2, part 3, pp. 204–283.
- Bashkuev, A.S., The First Record of Kaltanidae (Insecta: Mecoptera: Kaltanidae) in the Permian of European Russia, *Paleontol. Zh.*, 2008, vol. 42, no. 4, pp. 401–405.
- Bashkuev, A.S., Nedubroviidae, a New Family of Mecoptera: The First Paleozoic Long-proboscid Scorpionflies, *Zootaxa*, 2011a, no. 2895, pp. 47–57.
- Bashkuev, A.S., The Earliest Mesopsychidae and Revision of the Family Mesopanorpididae (Mecoptera), *ZooKeys*, 2011b, no. 130 (Advances in the Systematics of Fossil and Modern Insects: Honouring Alexandr Rasnitsyn, Shcherbakov, D.E., Engel, M.S., and Sharkey, M.J., Eds.), pp. 263–279.
- Bashkuev, A.S., New Mecoptera from the End-Permian Intertrappean Deposits of the Tunguska Basin, *Russ. Entomol. J.*, 2013, no. 1, pp. 00–00.
- Bashkuev, A., Sell, J., Aristov, D., Ponomarenko, A., Sinitshenkova, N., and Mahler, H., Insects from the Buntsand-

- stein of Lower Franconia and Thuringia, *Paläontol. Z.*, 2012, vol. 85, no. 3, pp. 175–185.
- Beattie, R.G., A Palaeoenvironmental and Palaeoecological Reconstruction of the Upper Permian Insect Beds at Belmont, New South Wales, Australia, in *3rd International Congress on Palaeoentomology, Pretoria, South Africa, February 7–11, 2005: Programme and Abstracts*, Pretoria, 2005, p. 13.
- Beattie, R., The Geological Setting and Palaeoenvironmental and Palaeoecological Reconstructions of the Upper Permian Insect Beds at Belmont, New South Wales, Australia, *Afr. Invertebr.*, 2007, vol. 48, no. 1, pp. 41–57.
- Beck, A.L., Labandeira, C.C., and Mamay, S.H., Early Permian Insect Folivory on a Gigantopterid-Dominated Riparian Flora from North–Central Texas, *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 1998, vol. 142, pp. 139–173.
- Beckemeyer, R.J., *Ligogramma wichita*, a New Species of Caloneuroidea (Polyneoptera: Orthoptera) from the Lower Permian Wellington Formation of Noble County, Oklahoma, *J. Kansas Entomol. Soc.*, 2009, vol. 82, no. 4, pp. 300–304.
- Béthoux, O., Cnemidolestodea (Insecta): An Ancient Order Reinstated, *J. Syst. Palaeontol.*, 2005, vol. 3, no. 4, pp. 403–408.
- Béthoux, O., The Earliest Beetle Identified, *J. Palaeontol.*, 2009, vol. 83, pp. 931–937.
- Béthoux, O. and Beckemeyer, R.J., New and Rare Insect Species from the Wellington Formation (Orthoptera, Grylloblattodea; Lower Permian, USA), *Alavesia*, 2007, vol. 1, pp. 49–61.
- Béthoux, O. and Nel, A., Some Palaeozoic ‘Protorthoptera’ Are ‘Ancestral’ Orthopteroids: Major Wing Braces As Clues to a New Split among the ‘Protorthoptera’ (Insecta), *J. Syst. Palaeontol.*, 2005, vol. 2, no. 4, pp. 285–309.
- Béthoux, O., Nel, A., and Lapeyrie, J., The Extinct Order Caloneuroidea (Insecta: Pterygota: Panorthoptera): Wing Venation, Systematics and Phylogenetic Relationships, *Ann. Zool.*, 2004, vol. 54, no. 2, pp. 289–318.
- Béthoux, O. and Wieland, F., Evidence for Carboniferous Origin of the Order Mantodea (Insecta: Dictyoptera) Gained from Forewing Morphology, *Zool. J. Linn. Soc.*, 2009, vol. 156, pp. 79–113.
- Brauckmann, C., Arachniden und Insekten aus dem Namurium von Hagen-Vorhalle (Ober-Karbon, West-Deutschland), *Veröff. Fuhr.-Mus.*, 1991, vol. 1, pp. 1–275.
- Brongniart, C., Les Insectes fossils des terrains primaires, in *Bulletin de la Société des Amis des Science naturelles de Rouen*, 1885, pp. 50–68.
- Bugdaeva, E.V., Volynets, E.B., Golozubov, V.V., et al., *Flora i geologicheskie sobytiya serediny melovogo perioda (Alchanskii bassein, Primor’e)* (Flora and Geological Events of the Middle of the Cretaceous: Alchanskii Basin, Primorie Region), Vladivostok: Dal’nauka, 2006.
- Buslov, M.M., Safonova, I.Yu., Fedoseev, G.S., et al., Permo–Triassic Plume Magmatism of the Kuznetsk Basin (Central Asia): Geology, Geochronology, Geochemistry, and Geodynamic Consequences, *Geol. Geofiz.*, 2010, vol. 51, no. 9, pp. 1310–1328.
- Carpenter, F.M., The Lower Permian Insects of Kansas: Part 1. Introduction and the Order Mecoptera, *Bull. Mus. Compar. Zool. Harvard Coll.*, 1930, vol. 52, pp. 69–101.
- Carpenter, F.M., The Lower Permian Insects of Kansas: Part 12. Protorthoptera (Continued), Neuroptera, Additional Palaeodictyoptera, and Families of Uncertain Position, *Psyche*, 1976, vol. 83, no. 1, pp. 336–376.
- Carpenter, F.M., Superclass Hexapoda, in *Treatise on Invertebrate Paleontology: Part 4: Arthropoda*, Moore, R.C. et al., Eds., Boulder (Colorado)–Lawrence (Kansas), Geol. Soc. Am. Univ. Kansas, 1992.
- Chernova, O.A., The Order Ephemeroptera (Mayflies), in *Osnovy paleontologii. Chlenistonogie, trakheinye i khelitse-rovye* (Fundamentals of Paleontology: Arthropods, Tracheates, and Chelicerates), Moscow: Akad. Nauk SSSR, 1962, pp. 55–64.
- Commission for the Permian System: Resolution on the Modernization of the Upper Series of the System, Session on July 14–15, 2004 (Kazan, Kazan State University), *Postanovl. Mezhvedomstv. Stratigr. Komit. Post. Komis.*, 2006, no. 36, pp. 22–30.
- Dijk, D.E. van and Geertsema, H., Permian Insects from the Beaufort Group of Natal, South Africa, *Ann. Natal Mus.*, 1999, vol. 40, pp. 137–171.
- Dijk, D.E. van and Geertsema, H., A New Genus of Permian Plecoptera (Afroperla) from KwaZulu-Natal, South Africa, *Afr. Entomol.*, 2004, vol. 12, no. 2, pp. 268–270.
- Dijk, D.E. van and Gorochoy, A.V., The First Permian Representative of the Family Xenopteridae (Orthoptera: Ensifera), *Afr. Invertebr.*, 2011, vol. 52, no. 2, pp. 571–574.
- Dmitriev, V.Yu. and Ponomarenko, A.G., Dynamics of Insect Taxonomic Diversity, *History of Insects*, Rasnitsyn, A.P. and Quicke, D.L.J., Eds., Dordrecht: Kluwer Acad. Publ., 2002, pp. 325–331.
- Dmitriev, V.Yu. and Ponomarenko, A.G., One More Time about Diversity Curves, *Paleontol. Zh.*, 2009, no. 2, pp. 102–105.
- Dmitriev, V.Yu. and Zherikhin, V.V., Changes in Diversity of Insect Families Based on the Data of the Method of Accumulated Appearances, in *Melovoi biotsenoticheskii kpizic i evolyutsiya nacekomyx* (Cretaceous Biocenotic Crisis and Evolution of Insects), Moscow: Nauka, 1988, pp. 208–215.
- Edemskii, M.B., The Area of Distribution of Sand Lenses in the Northern Dvina River Basin, *Tr. Geol. Muz. Akad. Nauk SSSR*, 1928, vol. 4, pp. 197–240.
- Efremov, I.A. and Vjuschkov, B.P., Catalogue of Permian and Triassic Localities of Terrestrial Vertebrates in the USSR, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1955, vol. 46, pp. 3–185.
- Engel, M., A New Lower Permian Bristletail from the Wellington Formation in Kansas (Archaeognatha: Dasyleptidae), *Trans. Kansas Acad. Sci.*, 2009, vol. 112, nos. 1/2, pp. 40–44.
- Fet, V., Shcherbakov, D.E., and Soleglad, M.E., The First Record of Upper Permian and Lower Triassic Scorpions from Russia (Chelicerata: Scorpiones), *Euscorpius—Occas. Publ. Scorpil.*, 2011, no. 121, pp. 1–16.
- Golubev, V.K., Permian and Triassic Chroniosuchia and Biostratigraphy from the Upper Tatarian Deposits of Eastern Europe Based on Tetrapods, *Tr. Paleontol. Inst. Ross. Akad. Nauk*, 2000, vol. 276, pp. 1–174.
- Golubev, V.K., Molostovskaya, I.I., Minikh, A.V., and Minikh, M.G., A New Regional Stratigraphical Scale of the Tatarian Series of the Permian System of the East European Platform, in *Verkhniy paleozoi Rossii: stratigrafiya i fatsial’nyi analiz. Materialy Vtoroi Vserossiiskoi konferentsii, posvyashchennoi 175-letiyu so dnya rozhdeniya Nikolaya*

- Alekseevicha Golovkinskogo (1834–1897) (Kazan', 27–30 sentyabrya 2009 g.) (2nd All-Russia Conference on the Upper Paleozoic of Russia: Stratigraphy and Facies Analysis, Devoted to the 175th Anniversary of the Birthday of Nikolai Alekseevich Golovkinskii (1834–1897) (Kazan, September 27–30, 2009), Kazan: Kazan. Gos. Univ., 2009, pp. 175–176.
- Gomankov, A.V., Permian (Tatarian) Flora from the Kotelnich Locality (Kirov Region), *Stratigr. Geol. Korelyatsiya*, 1997, vol. 5, no. 4, pp. 3–12.
- Gomankov, A.V., Flora and Stratigraphy of the Tatarian Stage of the East Europe Platform, *Doctoral Dissertation in Geology and Mineralogy*, Moscow, 2002, pp. 1–48.
- Gomankov, A.V. and Meyen, S.V., Tatarinian Flora (Composition and Distribution in the Late Permian of Eurasia), *Tr. Geol. Inst. Akad. Nauk SSSR*, 1986, no. 401, pp. 1–175.
- Gorokhov, A.V., Permian Orthopterans of the Infraorder Oedischiiidae (Orthoptera, Ensifera), *Paleontol. Zh.*, 1987a, no. 1, pp. 62–75.
- Gorokhov, A.V., New Fossil Orthopterans of the Families Adumbratomorphidae fam. n., Pruvostitidae, and Propargyllacrididae (Orthoptera, Ensifera) from the Permian and Triassic Deposits of the USSR, *Vest. Zool.*, 1987b, no. 4, pp. 20–28.
- Gorokhov, A.V., New Orthopteran Taxa of the Families Bintoniellidae, Xenopteridae, Permelmcanidae, Elcanidae, and Vitimiidae (Orthoptera, Ensifera) from the Mesozoic of Asia, *Vest. Zool.*, 1989, no. 4, pp. 20–27.
- Gorokhov, A.V., New Fossil Orthoptera and Phasmoptera from the Mesozoic and Paleozoic of Mongolia, *Tr. Sovm. Ross.–Mongol. Paleontol. Eksped.*, 1992, vol. 41, pp. 117–121.
- Gorokhov, A.V., On Permian and Triassic Phasmoptera from Eurasia, *Paleontol. Zh.*, 1994, no. 4, pp. 64–75.
- Gorokhov, A.V., System and Evolution of Orthoptera of the Suborder Ensifera: Part 1, *Tr. Zool. Inst. Ross. Akad. Nauk*, 1995, vol. 260, pp. 1–224.
- Gorochoy, A.V., On the Higher Classification of the Polyneoptera (Short Course), *Acta Geol. Leopold.*, 2001, vol. 24, nos. 52/53, pp. 11–56.
- Gorochoy, A.V., New and Little Known Mesotitanidae and Paratitanidae (Titanoptera) from the Triassic of Kyrgyzstan, *Paleontol. Zh.*, 2003, no. 4, pp. 62–69.
- Gorokhov, A.V., Primitive Titanoptera and Early Evolution of Polyneoptera, *Chten. Pam. Kholodkovskogo*, 2004, no. 1, p. 54.
- Gorokhov, A.V., Review of Triassic Orthoptera with Descriptions of New and Little Known Taxa: Part 1, *Paleontol. Zh.*, 2005a, no. 2, pp. 178–186.
- Gorochoy, A.V., Review of Triassic Orthoptera with Descriptions of New and Little Known Taxa: Part 2, *Paleontol. Zh.*, 2005b, no. 3, pp. 46–54.
- Gorokhov, A.V., New and Little Known Orthopteroid Insects (Polyneoptera) from Fossil Resins: Communication 2, *Paleontol. Zh.*, 2007a, no. 2, pp. 39–50.
- Gorochoy, A.V., The First Representative of the Suborder Mesotitanina from the Paleozoic and Notes on the System and Evolution of the Order Titanoptera (Insecta: Polyneoptera), *Paleontol. Zh.*, 2007b, no. 6, pp. 31–35.
- Gorochoy, A.V. and Maehr, C.S.E., New Names for Some Fossil Taxa of the Infraclass Polyneoptera (Insecta), *Zoosyst. Ross.*, 2008, vol. 17, no. 1, p. 60.
- Gorochoy, A.V., A New, Enigmatic Family for New Genus and Species of Polyneoptera from the Upper Permian of Russia, *ZooKeys*, 2011, no. 130 (Advances in the Systematics of Fossil and Modern Insects: Honouring Alexandr Rasnitsyn, Shcherbakov, D.E., Engel, M.S., and Sharkey, M.J., Eds.), pp. 131–136.
- Gorochoy, A.V., Jarzembowski, E.A., and Coram, R.A., Grasshoppers and Crickets (Insecta: Orthoptera) from the Lower Cretaceous of Southern England, *Cretac. Res.*, 2006, vol. 27, pp. 641–662.
- Gorochoy, A.V. and Voltshenkova, N.A., A New Species of the Genus *Hemigyris* from Vietnam (Orthoptera: Tettigoniidae: Pseudophyllinae), *Zoosyst. Ross.*, 2001, vol. 10, no. 1, p. 40.
- Grimaldi, D. and Engel, M.S., *Evolution of Insects*, Cambridge: Univ. Press, 2005.
- Gusev, A.K., *Nemorskie dvustvorchatye mollyuski verkhnnei permi Evropeiskoi chasti SSSR* (Nonmarine Bivalves from the Upper Permian of the European USSR), Kazan: Kazan. Gos. Univ., 1990.
- Handlirsch, A., *Über einige Insektenreste aus der Permformation Russlands*, *Mém. l'Acad. Imper. Sci. St-Petersb.*, 1904, vol. 16, pp. 1–7.
- Handlirsch, A., *Die Fossilen Insekten und die Phylogenie der rezenten Formen: Ein Handbuch für Paläontologen und Zoologen*, Leipzig, 1906–1908.
- Handlirsch, A., Ein neues fossile Insect aus dem permischen Kupfer Schiefer der Kargala-Steppe (Orenburg), *Mitt. Geol. Ges. Wien*, 1909, vol. 2, p. 382.
- Handlirsch, A., *Fossilium Catalogus: I Animalia*, part 16 *Insecta palaeozoica*, Berlin: W. Junk, 1922.
- Ivakhnenko, M.F., Golubev, V.K., Gubin, Yu.M., Kalandadze, N.N., Novikov, I.V., Sennikov, A.G., and Rautian, A.S., Permian and Triassic Tetrapods of Eastern Europe, *Tr. Paleontol. Inst. Ross. Akad. Nauk*, 1997, vol. 268, pp. 1–216.
- Ivanov, V.D., Structure of Paleozoic Caddisflies of the Family Microptysmatidae (Insecta), *Paleontol. Zh.*, 1988, no. 3, pp. 64–69.
- Ivanov, V.D., A New Family of Caddisflies from the Permian of the Middle Ural Mountains (Insecta, Trichoptera), *Paleontol. Zh.*, 1992a, no. 4, pp. 31–35.
- Ivanov, V.D., Early Evolution of Caddisflies (Trichoptera), *Zool. Zh.*, 1992b, vol. 71, no. 12, pp. 58–67.
- Ivanov, V.D. and Sukacheva, I.D., Order Trichoptera Kirdy, 1813. The Caddisflies, in *History of Insects*, Rasnitsyn, A.P. and Quicke, D.L.J., Eds., Dordrecht: Kluwer Acad. Publ., 2002, pp. 199–220.
- Jell, P.A., The Fossil Insects of Australia, *Mem. Queensland Mus.*, 2004, vol. 50, pp. 1–124.
- Karasev, E.V., Replacement of Paleofloristic Assemblages in the Transitional Stratigraphical Segment at the Permian–Triassic Boundary of the Moscow Syncline, *Candidate's Dissertation in Geology and Mineralogy*, Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2009, pp. 1–29.
- Katalog kollektsii Lab. artropod PIN RAN, kollektsii iz Mongolii (2010)* (Catalogue of Collections of the Laboratory of Arthropods of the Paleontological Institute of the Russian Academy of Sciences, collections from Mongolia: 2010), http://www.palaeontomolog.ru/Collections/mong_loc.html
- Keyserling, A., *Wissenschaftliche Beobachtungen auf einer Reise in das Petschora-Land im Jahre 1843*, St. Pétersburg, 1846.

- Khodakovskaya, Yu.I., Gomankov, A.V., and Ignat'ev, I.A., Morphology and Environmental Conditions of the Triassic Club-Moss *Lycomeia* from the Tikhvinskoe Locality, *Materialy simpoziuma, posvyashchennogo pamyati Sergeya Viktorovicha Meiena (1935–1987)* (Symposium devoted to the Memory of Sergei Viktorovich Meyen: 1935–1987), Moscow, 2001: Geos, pp. 207–209.
- Korte, C., Jasper, T., Kozur, H.W., and Veizer, J., $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ of Permian Brachiopods: A Record of Seawater Evolution and Continental Glaciation, *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 2005, vol. 224, no. 4, pp. 333–351.
- Kotlyar, G.V., Correlation of the Middle–Upper Permian Deposits of Eurasia, in *Paleontologiya i stratigrafiya permi i triasa severnoi Evrazii. Materialy V Mezhdunarodnoi konferentsii, posvyashchennoi 150-letiyu so dnya rozhdeniya V.P. Amalitskogo (1860–1917)* (5th International Conference on the Paleontology and Stratigraphy of the Permian and Triassic of Northern Eurasia, Devoted to the 150th Anniversary of the Birthday of V.P. Amalitzky: 1860–1917), Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2010, pp. 102–107.
- Krassilov, V.A. and Karasev, E.V., First Evidence of Plant–Arthropod Interaction at the Permian–Triassic Boundary in the Volga Basin, European Russia, *Alavesia*, 2008, no. 2, pp. 247–252.
- Krassilov, V. and Karasev, E., Paleofloristic Evidence of Climate Change near and beyond the Permian–Triassic Boundary, *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 2009, vol. 284, nos. 3–4, pp. 326–336.
- Kukalova-Peck, J., Unusual Structures in the Paleozoic Insect Orders Megasecoptera and Palaeodictyoptera, with a Description of a New Family, *Psyche*, 1972, vol. 79, no. 3, pp. 243–268.
- Kukalova-Peck, J. and Willmann, R., Lower Permian “Mecopteroid-like” Insects from Central Europe (Insecta: Endopterigota), *Canad. J. Earth Sci.*, 1990, vol. 27, pp. 459–468.
- Labandeira, C., Early History of Arthropod and Vascular Plants Associations, *Ann. Rev. Earth Planet. Sci.*, 1998, vol. 26, pp. 329–377.
- Labandeira, C.C., The History of Associations between Plants and Animals, in *Plant–Animal Interactions: An Evolutionary Approach*, Herrera, C. and Pellmyr, O., Eds., Oxford: Blackwell Sci., 2002, pp. 26–74.
- Labandeira, C.C., The Fossil Record of Insect Extinction: New Approaches and Future Directions, *Am. Entomol.*, 2005, vol. 51, pp. 14–29.
- Labandeira, C.C. and Sepkoski, J.J., Insect Diversity in the Fossil Record, *Science*, 1993, vol. 261, pp. 310–315.
- Lin, Qi-bin, Insecta, in *Palaeontological Atlas of East China*, vol. 2 *Late Palaeozoic*, Beijing: Geol. Publ. House, 1982, pp. 329–337.
- Lin, Qi-bin, Nel, A., and Huang, Di-Ying, The First Age-topanorpine Mecopteroid Insect from Middle Permian of China (Insecta: Mecoptera: Permochoristidae), *Ann. Soc. Entomol. Fr.*, 2010, vol. 46, nos. 1–2, pp. 62–66.
- Lozovskii, V.R., Afonin, S.A., Ponomarenko, A.G., Shcherbakov, D.E., Aristov, D.S., Yaroshenko, O.P., Kukhtinov, D.A., Burov, B.V., and Buslovich, A.L., On the Recognition of a New Member in the Composition of the Vokhminkian Formation of the Moscow Syncline, *Byull. RMSK Tsen. Yugu Russ. Platf.*, 2001, no. 3, pp. 151–163.
- Lozovskii, V.R. and Kukhtinov, D.A., The Vyazniki Stage, the Youngest Division of the Upper Permian of European Russia, *Byull. Mosk. O-va Ispyt. Prir. Otd. Geol.*, 2007, vol. 82, no. 6, pp. 17–26.
- Lozovskii, V.R., Olfer'ev, V.R., Novikov, I.V., Minikh, M.G., Minikh, A.V., and Sennikov, A.G., *Utochnennaya subregional'naya stratigraficheskaya skhema triasovykh otlozhenii zapada, tsentra i severa Vostochno-Evropeiskoi platformy (Pol'sko-Litovskaya, Moskovskaya i Mezenskaya sineklizy, Vyatsko-Kamskaya vpadina)* (Refined Subregional Stratigraphic Scheme of Triassic Deposits of the Western, Central, and Northern East European Platform: Polish–Lithuanian, Moscow and Mezen Syncline, Vyatka–Kama Depression), Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2011.
- Lyutkevich, E.M., Permian and Triassic Deposits of the Northern and Northwestern Russian Platform, *Tr. VNIGRI*, 1955, vol. 86, pp. 1–237.
- Martins-Neto, R.G., Mancuso, A.C., and Gallego, O.F., The Triassic Insect Fauna from Argentina: Blattoptera from Los Rastros Formation (Bermejo Basin) La Rioja Province, *Ameghiniana*, 2005, vol. 42, pp. 705–723.
- Martynov, A.V., Permian Fossil Insects of North-East Europe, *Tr. Geol. Muz. Akad. Nauk SSSR*, 1928, vol. 4, pp. 1–118.
- Martynov, A.V., New Fossil Insects of the Tikhie Mountains: Division 2. Neoptera, *Tr. Geol. Muz. Akad. Nauk SSSR*, 1931, vol. 8, pp. 149–212.
- Martynov, A.V., New Permian Palaeoptera with the Discussion on Some Problems of Their Evolution, *Tr. Paleozool. Inst. Akad. Nauk SSSR*, 1932, vol. 1, pp. 1–44.
- Martynov, A.V., Permian Fossil Insects from the Arkhangelsk Region: Part 2. Neuroptera, Megaloptera, and Coleoptera, with the Description of Two New Beetles from the Tikhie Mountains, *Paleontol. Zh.*, 1933a, no. 2, pp. 63–96.
- Martynov, A.V., Permian Fossil Insects from the Arkhangelsk District: Part. 1. The Order Mecoptera, *Tr. Paleozool. Inst. Akad. Nauk SSSR*, 1933b, vol. 2, pp. 23–62.
- Martynov, A.V., Permian Fossil Insects of Kargaly and Their Relationships, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1937, vol. 7, no. 2, pp. 8–91.
- Martynov, A.V., Sketches of Geologic History and Phylogeny of Insect Orders (Pterygota): Part I. Palaeoptera and Neoptera–Polyneoptera, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1938a, vol. 7, pp. 1–149.
- Martynov, A.V., On a New Permian Order of Orthopteran Insects, Glosselytrodea, *Izv. Akad. Nauk SSSR, Ser. Biol.*, 1938b, no. 1, pp. 187–206.
- Martynov, A.V., Permian Fossil Insects of Chekarda, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1940, vol. 11, no. 1, pp. 5–62.
- Martynova, O.M., Permian Mecoptera from Chekarda and Kargala, *Izv. Akad. Nauk SSSR, Ser. Biol.*, 1942, nos. 1–2, pp. 133–149.
- Martynova, O.M., The Order Glosselytrodea from the Permian Deposits of the Kemerovo Region, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1952, vol. 40 (Data on the Paleozoic Fauna), pp. 187–196.
- Martynova, O.M., New Insects from the Permian and Mesozoic Deposits of the USSR, in *Materialy k “Osnovam paleontologii”* (Material to the Fundamentals of Paleontology), Moscow, 1958, vol. 2, pp. 69–94.

- Martynova, O.M., Ilinka Faunal Assemblages: Erunakovo Faunal Assemblages, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1961, vol. 85 (Paleozoic Insects of the Kuznetsk Basin, Rohdendorf, B.B., Bekker-Migdisova, E.E., Martynova, O.M., and Sharov, A.G., Eds.), pp. 612–620.
- Meyen, S.V., The Permian–Triassic Boundary and Its Relation to with the Boundary of the Paleophyte and Mesophyte, in *S.V. Meyen. Evolyutsiya i sistematika vysshikh rastenii po dannym paleobotaniki* (S.V. Meyen. Evolution and Systematics of Higher Plants Based on the Data of Paleobotany), Moscow: Nauka, 1992, pp. 7–11.
- Meyen, S.V., Permian Conifers of Western Angaraland, *Rev. Palaeobot. Palynol.*, 1997, vol. 96, nos. 3–4, pp. 351–447.
- Minikh, M.G. and Minikh, A.V., Features of the Burial of Late Permian and Triassic Fishes, in *Teoriya i opyt tafonomii* (The Theory and Experience of Taphonomy), Saratov: Sarat. Gos. Univ., 1989, pp. 82–91.
- Minikh, A.V. and Minikh, M.G., *Ikhtiofauna permi Evropeiskoi Rossii* (Permian Ichthyofauna of European Russia), Saratov: Nauka, 2009.
- Mogucheva, N.K. and Kruglovkyh, V.V., New Data on the Stratigraphic Scheme of Triassic Deposits of the Tunguska Syncline and Kuznetsk Basin, *Stratigr. Geol. Korrelyatsiya*, 2009, vol. 17, no. 5, pp. 60–68.
- Molostovski, E.A., Molostovskaya, I.I., and Minikh, A.V., Stratigraphy of the Tatarian Stage of the Sukhona River Basin, *Izv. Vyssh. Ucheb. Zaved. Geol. Razved.*, 1979, no. 6, pp. 31–38.
- Murchison, R.I., Verneuil, E. de, and Keyserling, A., *The Geology of Russia in Europe and the Ural Mountains*, vol. 1: *Geology*, London: John Murray, Albemarle st., 1845.
- Naugolnykh, S.V., Vyazniki Flora and Nature of Permo–Triassic Extinction, *Tr. Geol. Inst. Ross. Akad. Nauk*, 2006, vol. 580 (Cause-and-Effect Relationships and Factors of Global Biosphere Reorganizations in the Phanerozoic), pp. 42–71.
- Nel, A., Marchal-Papier, F., Béthoux, O., and Gall, J.-C., A “Stick Insect-like” from the Triassic of the Vosges (France) (“Pre-Tertiary Phasmatodea”), *Ann. Soc. Entomol. Fr. Nov. Ser.*, 2004, vol. 40, no. 1, pp. 31–36.
- Newell, A.J., Sennikov, A.G., Benton, M.J., Molostovskaya, I.I., Golubev, V.K., Minikh, A.V., and Minikh, M.G., Disruption of Playa–Lacustrine Depositional Systems at the Permo–Triassic Boundary: Evidence from Vyazniki and Gorokhovets on the Russian Platform, *J. Geol. Soc. London*, 2010, vol. 167, pp. 695–716.
- Novokshonov, V.G., Early Evolution of Caddisflies (Trichoptera), *Zool. Zh.*, 1992, vol. 71, no. 12, pp. 58–67.
- Novokshonov, V.G., Caddis Flies (Insecta, Trichoptera, Microptysmatidae), *Paleontol. J.*, 1993, vol. 27, no. 1A, pp. 90–101.
- Novokshonov, V.G., Permian Scorpionflies (Insecta, Panorpida) of the Families Kaltanidae, Permochoristidae, and Robinjohniidae, *Paleontol. Zh.*, 1994, no. 1, pp. 65–76.
- Novokshonov, V.G., Permian Scorpionflies (Insecta: Panorpida) of the Family Permochoristidae, *Paleontol. Zh.*, 1995, no. 1, pp. 64–75.
- Novokshonov, V.G., Taxonomic Position of Some Late Permian Neuropterans (Insecta: Myrmeleontida–Neuroptera), *Paleontol. Zh.*, 1996, no. 1, pp. 65–71.
- Novokshonov, V.G., Rannyaya evolyutsiya skorpionnits (Insecta: Panorpida), (Early Evolution of Scorpionflies (Insecta: Panorpida)), Moscow: Nauka, 1997.
- Novokshonov, V.G. and Sukacheva, I.D., Fossil Scorpionflies of the “Suborder” Paratrachoptera (Insecta: Mecoptera), *Paleontol. Zh.*, 2001, no. 2, pp. 66–75.
- Novokshonov, V.G., Sukacheva, I.D., and Aristov, D.S., An Early Triassic Scorpionfly (Panorpida = Mecoptera) of the Vologda Region, *Paleontol. J.*, 2004, vol. 38, suppl. no. 2, pp. 214–215.
- Novokshonov, V.G. and Zhuzhgorova, L.V., Discussion of the System and Phylogeny of the Order Palaeomantodea (=Miomoptera) with Description of New Representatives of the Genus *Permosialis* Mart. from the Late Permian of Kirov Region and Triassic of Kyrgyzstan, *Paleontol. J.*, 2004, vol. 38, suppl. 2, pp. 173–184.
- Olfer'ev, A.G., On the Correlation of the Stratotypic Sections of the Upper Tatarian Substage, *Izv. Akad. Nauk SSSR, Ser. Geol.*, 1974, no. 10, pp. 123–132.
- Opornyi razrez tatarskogo yarusa reki Sukhony* (Reference Section of the Tatarian Stage of the Sukhona River), Saratov: Sarat. Gos. Univ., 1981, p. 116.
- Pakhtusova, N.A., On the Permian–Triassic Boundary in Northern Dvina Basin, in *Materialy po geologii i poleznym iskopayemym severo-zapada RSFSR* (Materials on Geology and Resources of the Northwestern Russian Federation), *Gostoptekhizdat*, 1962, vol. 3, pp. 3–18.
- Papier, F. and Grauvogel-Stamm, L., Les Blattodea du Trias: le genre *Voltziablatta* n. gen. du Buntsandstein supérieur des Vosges (France), *Paleontogr. A*, 1995, vol. 235, nos. 4–6, pp. 141–162.
- Papier, F., Nel, A., Graufogel-Stamm, L., and Gall, J.-C., La diversité des Coleoptera (Insecta) du Trias dans le nord-est de la France, *Geodiversitas*, 2005, vol. 27, pp. 181–199.
- Pesenko, Yu.A., *Printsipy i metody kolichestvennogo analiza v faunisticheskikh issledovaniyakh* (Principles and Methods of Quantitative Analysis in Faunal Studies), Moscow: Nauka, 1982.
- Pinto, I.D. and Purper, I., A New Genus and Two New Species of Plecopteran Insects from the Triassic of Argentina, *Pesquisas Inst. Geociénc. UFRGS*, 1978, vol. 10, pp. 77–86.
- Plotnikov, M.A., On the Stratigraphy of the Speckled Sediments in the Northern Dvina Basin, *Sov. Geol.*, 1948, vol. 33, pp. 55–59.
- Plotnikov, M.A., On the Tatarian Fauna of the Sukhona and Lesser Northern Dvina Rivers, *Ezhegod. VPO Gosgeolizdat*, 1949, vol. 13, pp. 91–98.
- Ponomarenko, A.G., The Paleozoic Beetles Cupedidea of the European Part of the USSR, *Paleontol. Zh.*, 1963, no. 1, pp. 70–85.
- Ponomarenko, A.G., Historical Development of Coleopterans–Archostemata, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1969, vol. 125, pp. 1–239.
- Ponomarenko, A.G., Paleozoic Representatives Megalopterans (Insecta), *Paleontol. Zh.*, 1977, no. 1, pp. 78–86.
- Ponomarenko, A.G., Paleobiology of Angiospermization, *Paleontol. J.*, 1998, vol. 32, no. 4, pp. 325–331.
- Ponomarenko, A.G., New Alderflies (Megaloptera: Parasialidae) and Glosselytrodeans (Glosselytrodea: Glosselytridae) from the Permian of Mongolia, *Paleontol. J.*, 2000a, vol. 34, suppl. no. 3, pp. 309–311.

- Ponomarenko, A.G., New Beetles from the Permian of European Russia, *Paleontol. J.*, 2000b, vol. 34, suppl. no. 3, pp. S312–S316.
- Ponomarenko, A.G., The First Beetles (Permosynidae, Coleoptera) from the Upper Tatarian Deposits of European Russia, *Paleontol. Zh.*, 2003, no. 2, pp. 65–68.
- Ponomarenko, A.G., Beetles (Insecta, Coleoptera) of the Late Permian and Early Triassic, *Paleontol. J.*, 2004, vol. 38, suppl. no. 2, pp. 185–196.
- Ponomapenko, A.G., A New Beetle Species of the Genus *Taldycupes* (Taldycupedidae, Coleoptera) from the Permian of the Tunguska River Basin, *Paleontol. Zh.*, 2006, no. 3, pp. 61–62.
- Ponomapenko, A.G., Coleopterans (Insecta) of the Second Part of the Permian of Angaraland both Gondwana, in *Paleontologiya i stratigrafiya permi i triasa severnoi Evrazii. Materialy V Mezhdunarodnoi konferentsii, posvyashchennoi 150-letiyu so dnya rozhdeniya V.P. Amalitskogo (1860–1917)* (5th International Conference on the Paleontology and Stratigraphy of the Permian and Triassic of Northern Eurasia, Devoted to the 150th Anniversary of the Birthday of V.P. Amalitzky: 1860–1917), Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2010, pp. 102–107.
- Ponomapenko, A.G., New Beetles (Insecta, Coleoptera) from Vyazniki Locality, Terminal Permian of European Russia, *Paleontol. Zh.*, 2011, no. 4, pp. 55–63.
- Ponomarenko, A.G. and Mostovski, M.B., New Beetles (Insecta: Coleoptera) from the Late Permian of South Africa, *Afr. Invertebr.*, 2005, vol. 46, pp. 253–260.
- Ponomarenko, A.G. and Shcherbakov, D.E., New Lacewings (Neuroptera) from the Terminal Permian and Basal Triassic of Siberia, *Paleontol. J.*, 2004, vol. 38, suppl. no. 2, pp. S197–S203.
- Prevec, R., Labandeira, C.C., Neveling, J., et al., Portrait of a Gondwanan Ecosystem: A New Late Permian Fossil Locality from KwaZulu-Natal, South Africa, *Rev. Palaeobot. Palynol.*, 2009, vol. 156, pp. 454–493.
- Pritykina, L.N., New Triassic Dragonflies of Central Asia, *Tr. Paleontol. Inst. Ross. Akad. Nauk*, 1981, vol. 183 (New Fossil Insects from the Territory of the USSR), pp. 5–42.
- Rasnitsyn, A.P., New Paleozoic and Mesozoic Insects, *Paleontol. Zh.*, 1977, no. 1, pp. 64–77.
- Rasnitsyn, A.P., The Origin and Evolution of Hymenopteran Insects, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1980, vol. 174, pp. 1–192.
- Rasnitsyn, A.P., Triassic and Jurassic Insects of the Genus *Shurabia* (Grylloblattida; Geinitziidae), *Paleontol. Zh.*, 1982, no. 3, pp. 78–87.
- Rasnitsyn, A.P., The Problem of the Global Crisis of Terrestrial Biocoenoses in the Middle of the Cretaceous Period, in *Melovoi biotsenoticheskii kpizic i evolyutsiya nasekomykh* (Cretaceous Biocoenotic Crisis and Evolution of Insects), Moscow: Nauka, 1988, pp. 191–207.
- Rasnitsyn, A.P., Dynamics of the Insect Families and the Problem of the Cretaceous Biocoenotic Crisis, in *Osadochnaya obolochka Zemli v prostranstve i vremeni. Stratigrafiya i paleontologiya* (Sedimentary Envelope of the Earth in Space and Time: Stratigraphy and Paleontology), Sokolov, B.S., Ed., Moscow: Nauka, 1989, pp. 35–40.
- Rasnitsyn, A.P., Testing Cladograms by Fossil Record: The Ghost Range Test, *Contrib. Zool.*, 2000, vol. 69, no. 4, pp. 251–258.
- Rasnitsyn, A.P., Subclass Scarabeona Laicharting, 1781. The Winged Insects (=Pterigota Lang, 1888), *History of Insects*, Rasnitsyn, A.P. and Quicke, D.L.J., Eds., Dordrecht: Kluwer Acad. Publ., 2002, pp. 73–84.
- Rasnitsyn, A.P., Dynamics of Taxonomic Diversity: Concluding Remarks of 2004, in *Rasnitsyn, A.P., Izbrannye trudy po evolyutsionnoi biologii* (Rasnitsyn, A.P., Selected Works on Evolutionary Biology), Moscow: KMK, 2005, pp. 247–248.
- Rasnitsyn, A.P., Molecular Phylogenetics, Morphological Cladistics, and Fossils, *Entomol. Obozr.*, 2010, vol. 89, no. 1, pp. 85–132.
- Rasnitsyn, A.P., When the Life Was not Going to Die, *Priroda*, 2012, no. 9, pp. 39–48.
- Rasnitsyn, A.P. and Aristov, D.S., Two New Insects from the Upper Permian (Tatarian) of Belmont, New South Wales, Australia (Insecta: Hypoperlida: Anthracoptilidae = Permarrhaphidae; Grylloblattida: Sylvaphlebiidae), *Paleontol. J.*, 2004, suppl. no. 2, pp. 158–163.
- Rasnitsyn, A.P., Aristov, D.S., Gorokhov, A.V., Rowland, J.M., Sinitshenkova, N.D., and Sukatsheva, I.D., Important new fossil insects from Carrizo Arroyo and the Permo-Carboniferous faunal boundary, *New Mexico Mus. Natur. Hist. Sci. Bull.*, 2004, vol. 25 (Carboniferous–Permian Transition, Lucas, S.G. and Ziegler, K.E., Eds.), pp. 215–246.
- Rasnitsyn, A.P., Aristov, D.S., and Rasnitsyn, D.A., Insects at the Borderline between the Permian and the Early Triassic (Urzhum–Olenek) and the Problem of Permian-Triassic Biodiversity Crisis, *Zh. Obshch. Biol.*, vol. 74, no. 1, pp. 43–65.
- Rasnitsyn, A.P. and Dijk, D.E. van, The First Gondwanan Epimastax from the Lopingian of KwaZulu-Natal, South Africa (Insecta: Palaeomanteida = Miomoptera: Permosialidae, *Afr. Invertebr.*, 2011, vol. 52, no. 1, pp. 207–209.
- Rasnitsyn, A.P. and Quicke, D.L.J., Eds., *History of Insects*, Dordrecht: Kluwer Acad. Publ., 2002.
- Reshenie Mezhdedomstvennogo regional'nogo stratigraficheskogo soveshchaniya po srednemu i verkhnemu paleozoju Russkoi platformy s regional'nymi stratigraficheskimi skhemami. Leningrad, 1988. Permская система* (Resolution of the Interdepartmental Regional Stratigraphical Conference on the Middle and Upper Paleozoic of the Russian Platform, with the Regional Stratigraphic Schemes, Leningrad, 1988: Permian System), Leningrad: VSEGEI, 1990.
- Resolution on the Modernization of the Upper Series of the Permian System of the General (East European) Stratigraphic Scale, *Postanovl. Mezhdedomstv. Stratigr. Komit. Post. Komis.*, 2006, no. 36, pp. 14–16.
- Reichow, M.K., Pringle, M.S., Al'Mukhamedov, A.I., et al., The Timing and Extent of the Eruption of the Siberian Traps Large Igneous Province: Implications for the End-Permian Environmental Crisis, *Earth Planet. Sci. Lett.*, 2009, vol. 277, pp. 9–20.
- Riek, E.F., Fossil Mecopteroid Insects from the Upper Permian of New South Wales, *Rec. Austral. Mus.*, 1953, vol. 23, no. 2, pp. 55–87.
- Riek, E.F., Fossil Insects from the Triassic Beds at Mt. Crossby, Quinslend, *Austral. J. Zool.*, 1955, vol. 3, no. 4, pp. 654–692.
- Riek, E.F., A Re-examination of the Mecopteroid and Orthopteroid Fossils (Insecta) from the Triassic Beds at

- Denmark Hill, Queensland, with Description of Further Specimens, *Austral. J. Zool.*, 1956, vol. 4, no. 1, pp. 98–110.
- Riek, E.F., Undescribed Fossil Insects from the Upper Permian of Belmont, New South Wales (with the Appendix Listing the Described Species), *Rec. Austral. Mus.*, 1968, vol. 27, no. 15, pp. 303–310.
- Riek, E.F., New Upper Permian Insects from Natal, South Africa, *Ann. Natal Mus.*, 1976, vol. 22, pp. 755–789.
- Rohdendorf, B.B., The Order Coleoptera or Beetles, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1961, vol. 85 (Rohdendorf, B.B., Bekker-Migdisova, E.E., Martynova, O.M., and Sharov, A.G., Paleozoic Insects from the Kuznetsk Basin), pp. 393–469.
- Rohdendorf, B.B., Bekker-Migdisova, E.E., Martynova, O.M., and Sharov, A.G., Paleozoic Insects from the Kuznetsk Basin, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1961, vol. 85, pp. 1–705.
- Rohdendorf, B.B. and Rasnitsyn, A.P., Eds., *Istoricheskoe razvitiye klassa nasekomykh* (Historical Development of the Class Insecta: Tr. Paleontol. Inst. Akad. Nauk SSSR, vol. 175), Moscow: Nauka, 1980.
- Ross, A.J., Jarzembowski, E.A., and Brooks, S.J., The Cretaceous and Cenozoic Record of Insects (Hexapoda) with Regard to Global Changes, in *Biotic Responses to Global Change, the Last 145 Million Years*, Culver, S. and Rawson, P., Eds., Cambridge: Cambridge Univ. Press, 2000, pp. 288–302.
- Sadovnikov, G.N., On the Correlation of the Boundary Deposits of the Continental Permian and Triassic, in *Iskopaemye rasteniya i stratigrafiya pozdnego paleozoya Angaridy i sopredel'nykh territorii* (Fossil Plants and Stratigraphy of the Late Paleozoic of Angaraland and Adjacent Territories), Moscow: Geos, 2009, pp. 60–62.
- Sadovnikov, G.N. and Orlova, E.F., The Taimyrian Stage—Terminal Stage of the Permian, *Dokl. Ross. Akad. Nauk*, 1994, vol. 338, no. 5, pp. 658–661.
- Sadovnikov, G.N. and Orlova, E.F., New Data on the Stratigraphy of the Permo–Triassic Volcanogenic Strata of the Central Part of the Tunguska Syncline, *Stratigr. Geol. Korrelyatsiya*, 1995, vol. 3, no. 1, pp. 34–42.
- Schneider, J., Die Blattodea (Insecta) des Paläozoikums: Teil 1. Systematik, Ökologie und Biostratigraphie, *Freib. Forschung.*, 1983, vol. 382, pp. 106–145.
- Sellards, E.H., Types of Permian Insects: Part III. Megaseoptera, Oryctoblattinidae and Protorthoptera, *Am. J. Sci.*, 1909, vol. 27, no. 4, pp. 151–173.
- Sennikov, A.G. and Golubev, V.K., Boundary Deposits of the Permian and Triassic in the Area of the Towns of Vyazniki and Gorokhovets (Vladimir Region), in *Paleontologiya i stratigrafiya permi i triasa severnoi Evrazii. Materialy V Mezhdunarodnoi konferentsii, posvyashchennoi 150-letiyu so dnya rozhdeniya Vladimira Prokhorovicha Amalitskogo (1860–1917)* (5th International Conference on the Paleontology and Stratigraphy of the Permian and Triassic of Northern Eurasia, Devoted to the 150th Anniversary of the Birthday of Vladimir Prokhorovich Amalitsky: 1860–1917), Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2010, pp. 102–107.
- Sharov, A.G., The First Find of a Permian Megalopteran Larva from Kargaly, *Dokl. Akad. Nauk SSSR*, 1953, vol. 89, no. 4, pp. 731–732.
- Sharov, A.G., The Order Paraplecoptera, in *Osnovy paleontologii. Chlenistonogie, trakheinye i khelitsery* (Fundamentals of Paleontology: Arthropods, Tracheates, and Chelicerates), Moscow: Akad. Nauk SSSR, 1962, pp. 119–134.
- Sharov, A.G., On the Position of the Orders Glosselytrodea and Galoneurodea in the System of Insecta, *Paleontol. Zh.*, 1966, no. 3, pp. 84–93.
- Sharov, A.G., Phylogeny of Orthopteran Insects, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1968, vol. 118, pp. 1–217.
- Shcherbakov, D.E., System and Phylogeny of Permian Cicadomorpha (Cimicida, Cicadina), *Paleontol. Zh.*, 1984, no. 2, pp. 89–101.
- Shcherbakov, D.E., New Cicadina of the Late Mesozoic of Transbaikalia, *Paleontol. Zh.*, 1988, no. 4, pp. 55–66.
- Shcherbakov, D.E., A New Genus of the Paleozoic Order Hypoperlida, *Russ. Entomol. J.*, 1995, vol. 3, nos. 3/4, pp. 33–36.
- Shcherbakov, D.E., Permian Faunas of Homoptera (Hemiptera) in Relation to Phytogeography and the Permo–Triassic Crisis, *Paleontol. J.*, 2000, vol. 34, suppl. no. 3, pp. 251–S267.
- Shcherbakov, D.E., Extinct Four-Winged Precoccids and the Ancestry of Scale Insects and Aphids (Hemiptera), *Russ. Entomol. J.*, 2007, vol. 16, pp. 47–62.
- Shcherbakov, D.E., On Permian and Triassic Entomofaunas in Connection with Biogeography and Permo–Triassic Crisis, *Paleontol. Zh.*, 2008, no. 1, pp. 15–33.
- Shcherbakov, D.E., Insect Faunas of Angaraland and Subangaraland at the Transition from the Permian to Triassic, in *Iskopaemye rasteniya i stratigrafiya pozdnego paleozoya Angaridy i sopredel'nykh territorii* (Fossil Plants and Stratigraphy of the Late Paleozoic of Angaraland and Adjacent Territories), Moscow: Geos, 2009, pp. 63–65.
- Shcherbakov, D.E., Kabanov, P.B., Ponomarenko, A.G., and Esin, D.N., New Data on the Fauna and Lithology of the Mal'thevo Group of the Kuznetsk Basin, in *IV Vserossiiskaya konferentsiya "Paleontologiya i stratigrafiya permi i triasa Severnoi Evrazii"* (4th All-Russia Conference on Paleontology and Stratigraphy of the Permian and Triassic of Northern Eurasia), Moscow: Paleontol. Inst. Ross. Akad. Nauk, 2002, pp. 100–101.
- Shcherbakov, D.E., Makarkin, V.N., Aristov, D.S., and Vasilenko, D.V., Permian Insects from the Russky Island, South Primorye, *Russ. Entomol. J.*, 2009, vol. 18, no. 1, pp. 7–16.
- Shi, G.R., Waterhouse, J.B., and McLoughlin, S., The Lopingian of Australasia: A Review of Biostratigraphy, Correlations, Palaeogeography and Palaeobiogeography, *Geol. J.*, 2010, vol. 45, pp. 230–263.
- Shishkin, M.A., On the Ternary Division of the Upper Tatarian Substage of the Upper Permian Based on the Terrestrial Vertebrate Fauna, *Byull. Mosk. O-va Ispyt. Prir., Otd. Geol.*, 1990, vol. 65, no. 2, p. 117.
- Signer, P. W., III and Lipps, J. H., Sampling bias, gradual extinction patterns, and catastrophes in the fossil record. *Geol. Soc. Am. Spec. Pap.* 1982. 190: 291–296.
- Sinitshenkova, N.D., Historical Development of Stoneflies, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1987, vol. 221, pp. 1–143.
- Sinitshenkova, N.D., Two New Species of Insecta (Insecta: Dictyonurida—Palaeodictyoptera, Perlida = Plecoptera) from Late Permian of Mongolia, in *New Species of Fossil Invertebrates of Mongolia: Joint Russian–Mongolian Palaeontological Expedition*, Grunt, T.A., Ed., Moscow: Nauka, 1992, pp. 498–501.

- Sinitshenkova, N.D., 2.2.1.2.3. Superorder Dictyoneuridea Handlirsch, 1906, *History of Insects*, Rasnitsyn, A.P. and Quicke, D.L.J., Eds., Dordrecht: Kluwer Acad. Publ., 2002, pp. 115–124.
- Sinitshenkova, N.D., New Stoneflies of the Family Palaeonemouridae from the Upper Permian of Udmurtiya and the Orenburg Region (Insecta: Perlida = Plecoptera), *Paleontol. J.*, 2004, vol. 38, suppl. no. 2, pp. S164–S172.
- Sinitshenkova, N.D., The Role of Stoneflies in the Benthos of Runny Streams in the Permian Time: Urgent Problems of Ecology, in *Materialy V Vserossiiskoi nauchnoi konferentsii "Aktual'nye problemy ekologii i sokhraneniya bioraznobraziya Rossii i sopredel'nykh stran"* (5th All-Russia Scientific Conference on the Urgent Problems of Ecology and Preservation of Biodiversity of Russia and Adjacent Countries), Vladikavkaz: Izd-vo Khutagurov SOGU, 2011, pp. 137–141.
- Sinitshenkova, N.D., New Mayflies (Insecta: Ephemeroptera) from the Intertrappean Deposits of the Tunguska Basin, Siberia, *Paleontol. Zh.*, 2013, no. 1, pp. 64–67.
- Sinitshenkova, N.D. and Aristov, D.S., New Permian Stoneflies of the Family Palaeonemouridae (Insecta: Perlida = Plecoptera) from the Isady Locality, *Paleontol. Zh.*, 2010, no. 1, pp. 46–48.
- Sinitshenkova, N.D. and Aristov, D.S., The Biggest Fossil Mayfly (Insecta: Ephemera = Ephemeroptera) from the Upper Permian Locality of Isady, Northern European Russia, *Far East. Entomol.*, 2012, no. 255, pp. 8–10.
- Sinitshenkova, N.D. and Vassilenko, D.V., The Latest Find of the Mayflies of the Family Protoreismatidae Sellards, 1907 (Ephemera = Ephemeroptera) and New Species of the Family Mithodotidae Tillyard, 1932 in the Upper Permian of Europe, *Paleontol. Zh.*, 2012, no. 1, pp. 60–64.
- Storozhenko, S.Yu., Grylloblattid Insects of the Upper Permian of Eastern Kazakhstan, *Paleontol. Zh.*, 1991, no. 2, pp. 110–114.
- Storozhenko, S.Yu., New Mesozoic Grylloblattid Insects (Grylloblattida) from Central Asia, *Paleontol. Zh.*, 1992a, no. 1, pp. 67–75.
- Storozhenko, S.Yu., New Fossil Grylloblattid Insects (Insecta: Grylloblattida) from Mongolia, *Tr. Sovm. Ross.-Mongol. Paleontol. Eksped.*, 1992b, vol. 41 (New Taxa of Fossil Insects from Mongolia), pp. 122–129.
- Storozhenko, S.Yu., Revision of the Family Megakhosaridae (Grylloblattida), *Tr. Paleontol. Inst. Ross. Akad. Nauk*, 1993, vol. 252 (Mesozoic Insects and Ostracodes of Asia), pp. 100–112.
- Storozhenko, S.Yu., Permian Fossil Insects of North-East Europe: New Atactophlebiidae, Ideliidae and Megakhosaridae (Grylloblattida), *Zoosyst. Ross.*, 1994, vol. 3, pp. 49–52.
- Storozhenko, S.Yu., New Triassic Mesorthopteridae (Insecta, Grylloblattida), *Spixiana*, 1996, vol. 19, no. 1, pp. 115–127.
- Storozhenko, S.Yu., Classification of Order Grylloblattida (Insecta) with Description of New Taxa, *Far East. Entomol.*, 1997, no. 42, pp. 1–20.
- Storozhenko, S.Yu., *Sistematika, filogeniya i evolyutsiya Grylloblattidovykh nasekomykh (Insecta: Grylloblattida)* (Systematics, Phylogeny, and Evolution of Grylloblattid Insects), Vladivostok: Dal'nauka, 1998.
- Storozhenko, S.Yu. and Novokshonov, V.G., To the Knowledge of the Fossil Family Permosialidae (Insecta: Miotoptera), *Far East. Entomol.*, 1999, no. 76, pp. 1–5.
- Strok, N.I. and Buslovich, A.L., Stratigraphy of the Tatarian Deposits of the Sukhona River Basin, *Byull. Mosk. O-va Ispyt. Priro. Otd. Geol.*, 1979, vol. 54, no. 6, pp. 60–68.
- Strok, N.I. and Trofimova, I.S., The Influence of the Ural and Baltic Feeding Provinces on the Formation of the Upper Permian and Lower Triassic Deposits of the Moscow Syncline, *Byull. Mosk. O-va Ispyt. Priro. Otd. Geol.*, 1976, vol. 51, no. 1, pp. 100–110.
- Sukacheva, I.D., New Caddisflies (Trichoptera) from the Mesozoic of Central Asia, *Paleontol. Zh.*, 1973, no. 3, pp. 100–107.
- Sukatsheva, I.D., Caddisflies of the Suborder Permotrichoptera, *Paleontol. Zh.*, 1976, no. 2, pp. 94–105.
- Sukatsheva, I.D., Historical Development of the Order Trichoptera, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1982, vol. 197, pp. 1–112.
- Sukacheva, I.D., Beattie, R., and Mostovski, M.B., *Permomerope natalensis* sp. n. from the Lopingian of South Africa, and a Redescription of the Type Species of *Permomerope* (Trichoptera: Protomeropidae), *Afr. Invertebr.*, 2007, vol. 48, no. 2, pp. 245–251.
- Tan, J.-j. and Ren, D., *Mesozoic Archostematan Fauna from China*, Beijing: Sci. Publ. House, 2009.
- Tatarskie otlozheniya reki Sukhony (Tatarian Deposits of the Sukhona River), Molostovski, E.A. and Minikh, A.V., Eds., Saratov: Nauchn. Kniga, 2001.
- Tillyard, R.J., Kansas Permian Insects: Part 5. The Orders Protodonata and Odonata, *Am. J. Sci. Ser. 5*, 1925, vol. 10, pp. 41–73.
- Tillyard, R.J., Upper Permian Insects of New South Wales: Part 12. The Orders Mecoptera, Paramecoptera and Neuroptera, *Proc. Linn. Soc. NS Wales*, 1926, vol. 51, pp. 265–282.
- Tillyard, R.J., Upper Permian Insects of New South Wales: Part 5. The Order Perlaria or Stone-Flies, *Proc. Linn. Soc. NS Wales*, 1935, vol. 60, pp. 385–391.
- Vasilenko, D.V., Feeding Damage on Upper Permian Plants from the Sukhona River, *Paleontol. J.*, 2007, vol. 41, no. 2, pp. 207–211.
- Vasilenko, D.V. and Rasnitsyn, A.P., Fossil Ovipositions of Dragonflies: Review and Interpretation, *Paleontol. J.*, 2007, vol. 41, no. 11, pp. 1156–1161.
- Vassilenko, D.V., The First Record of Endophytic Insect Oviposition from the Tatarian of European Russia, *Paleontol. J.*, 2011, vol. 45, no. 3, pp. 333–334.
- Verkhnepermские и нижнетриасовые отложения Московской синеклизы (Upper Permian and Lower Triassic Deposits of the Moscow Syncline), Moscow: Nedra, 1984.
- Verzilin, N.N., Kalmykova, N.A., and Suslov, G.A., Large Sandy Lenses in Upper Permian Deposits of the Northern Part of the Moscow Syncline, *Tr. St. Peterb. O-va Estestvoispyt.*, 1993, vol. 83, no. 2, pp. 1–112.
- Vishniakova, V.H., New Paleozoic and Mesozoic Lophioneurids (Thripida, Lophioneuridae, *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1981, vol. 183 (New Fossil Insects from the USSR, Vishniakova, V.H., Dlussky, G.M., and Pritykina, L.M., Eds.), pp. 43–63.
- Vishniakova, V.N., New Paleozoic Spiloblattinidae from Russia, *Paleontol. J.*, 1993, vol. 27, suppl. no. 1, pp. 135–147.

- Vishniakova, V.N., Cockroaches (Insecta, Blattodea) from the Triassic Madygen Locality, Central Asia, *Paleontol. J.*, 1998, no. 5, pp. 69–76.
- Vršanský, P., Decreasing Variability—from the Carboniferous to the Present! (Validated on Independent Lineages of Blattaria), *Paleontol. J.*, 2000, vol. 34, suppl. no. 3, pp. 374–379.
- Vršanský, P., Origin and the Early Evolution of Mantises, *AMBA Projekty*, 2002a, vol. 6, no. 1, pp. 1–16.
- Vršanský, P., *Jantarimantis* nom. nov. and Jantarimantidae nom. nov., New Replacement Names for the Genus *Archimantis* Vršanský, 2002, and the Family Archinmantidae Vršanský, 2002 (Insecta, Mantodea), *AMBA projekty*, 2002b, vol. 6, no. 1, p. 1.
- Vršanský, P., *Phyloblatta grimaldii* sp. nov.—a New Triassic Cockroach (Insecta, Blattaria) from Virginia, *Entomol. Probl.*, 2003a, vol. 33, nos. 1–2, pp. 51–53.
- Vršanský, P., Unique Assemblage of Dictyoptera (Insecta - Blattaria, Mantodea, Isoptera, Mantodea) from the Lower Cretaceous of Bon Tsagaan Nuur in Mongolia, *Entomol. Probl.*, 2003b, vol. 33, nos. 1–2, pp. 119–151.
- Vršanský, P., Mass Mutations of Insects at the Jurassic/Cretaceous Boundary?, *Geol. Carpath.*, 2005, vol. 56, no. 6, pp. 473–781.
- Vršanský, P., Late Jurassic Cockroaches (Insecta, Blattaria) from the Houtiyn-Hotgor Locality in Mongolia, *Paleontol. J.*, 2008a, vol. 42, no. 1, pp. 36–42.
- Vršanský, P., New Blattarians and a Review of Dictyopteran Assemblages from the Lower Cretaceous of Mongolia, *Acta Palaeontol. Polon.*, 2008b, vol. 53, no. 1, pp. 129–136.
- Vršanský, P., Albian Cockroaches (Insecta, Blattida) from French Amber of Archingeay, *Geodiversitas*, 2009, vol. 31, no. 1, pp. 73–98.
- Vršanský, P., Cockroach As the Earliest Eusocial Animal, *Acta Geol. Sin.*, 2010a, vol. 84, no. 4, pp. 793–808.
- Vršanský, P., A New Genus and Species of Cockroach (Blattida: Phyloblattidae) from the Permian/Triassic Boundary Beds of Tunguska Basin in Eastern Siberia, Russia, *Zootaxa*, 2010b, no. 2353, pp. 55–61.
- Vršanský, P. and Ansorge, J., Lower Jurassic Cockroaches (Insecta: Blattaria) from Germany and England, *Afr. Invertebr.*, 2007, vol. 48, no. 1, pp. 103–126.
- Vršanský, P. and Aristov, D., Enigmatic Late Permian Cockroaches from Isady in Russia (Blattida: Mutoviidae fam. n.), *Zootaxa*, 2012, no. 3247, pp. 19–31.
- Vršanský, P., Vishniakova, V.N., and Rasnitsyn, A.P., Order Blattida Latreille, 1810, *History of Insects*, Rasnitsyn, A.P. and Quicke, D.L.J., Eds., Dordrecht: Kluwer Acad. Publ., 2002.
- Zalessky, G.M., Sur de nouveaux insectes permien, *Ann. Soc. Géol. Nord.*, 1933, vol. 57, pp. 135–144.
- Zalessky, M.D., Observations sur un nouvel insecte fossile du Permien de Kargala, *Bull. Soc. Geol. Fr. Ser. 4*, 1926, vol. 26, no. 4, pp. 75–84.
- Zalessky, M.D., On New Insects from the Permian Deposits of the Kama, Vyatka, and Belaya River Basins, *Tr. Ob-va Estestvoispyt. Kazan. Gos. Univ.*, 1929, vol. 52, no. 1, pp. 3–30.
- Zherikhin, V.V., Development and Replacement of Cretaceous and Cenozoic Faunal Assemblages (Tracheate and Chelicerate), *Tr. Paleontol. Inst. Akad. Nauk SSSR*, 1978, vol. 165, pp. 1–200.