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The Ufimian Stage of the East European Scale: Status, Validity, and Correlation Potential

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Abstract—The resolution of the Commission on the Permian System of the Interdepartmental Stratigraphic Committee (ISC) to exclude the Ufimian Stage from the General (East European) stratigraphic scale is questioned. This resolution led to substantial changes in the charactristics of several stage units and violated rules of the stratigraphic nomenclature. The paleontological characteristic of the Ufimian Stage differs from that of the Kungurian Stage in its initial volume. It is shown that the Ufimian Stage is characterized by its high correlation potential.

Key words: Permian, correlation, Kungurian Stage, Ufimian Stage.

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INTRODUCTION

The meeting of the Commission on the Permian System of the Interdepartmental Stratigraphic Committee (ISC) held in Kazan on September 27, 2007 confirmed the position of the lower boundary of the middle (Biarmian) and upper (Tatarian) series at the bases of the Kazanian and Severodvinskian stages, respectively. In addition, the Commission "decided it necessary to abandon the Ufimian Stage in the General stratigraphic scale." The paper is dedicated to discussion of this problem.

According to several resolutions of the ISC Commission on the Permian System that passed in the period of 2003–2007 and mostly approved by the ISC bureau, the Kungurian Stage comprises now five horizons: Sarana (traditionally attributed to the Artinskian Stage), Filippovskoe, Iren (together constituting the Kungurian Stage in its initial and traditional understanding), Solikamsk, and Sheshma (together constituting the Ufimian Stage in its initial and traditional understanding). This violated the general rules of the stratigraphic nomenclature adopted in the Stratigraphic Code of Russia (2006), and the term "Kungurian Stage" lost its historical sense. Therefore, we avoid using this term in its broad meaning in further discussions, considering the use of horizon names or the term "Kungurian Stage" in its initial understanding more correct.

In this work, the main attention is paid to the analysis of available data on the Kungurian–Ufimian stratigraphic interval of the East European region. The data concerning precisely the stratotype region of the Ufimian Stage were used for substantiating the validity the Ufimian Stage. The use of debatable materials on remote regions such as northeastern Russia (Kolyma, Verkhoyansk region) or North American basins is, in our opinion, methodically erroneous.

HISTORICAL REVIEW

Nechaev (1915) was the first to establish the Ufimian Stage corresponding to the "lower red-colored sequence" that was defined by Golovkinskii (1869). In his small article, Nechaev emphasized the autonomous position of the Russian "Zechstein" (defined by him as the Kazanian Stage), supraZechstein, and subZechstein red-colored sequences. This author proposed the term "Ufimian Stage precisely for the subZechstein red-colored sequence." He placed the lower boundary of the Kazanian Stage at the base of the "*Spirifer* Series" (which subsequently gained recognition as the *Licharewia* Beds). The detailed substantiation of the Ufimian and Kazanian stages is presented in his monograph (Nechaev, 1921).

The Kungurian Stage that underlies the Ufimian one was defined by Stuckenberg (1890). This author established its conformable contact with the Artinskian

Stage in the Sazhino Settlement section at the Bugalysh River (left tributary of the Ufa River in the Perm region) and characterized the section as best corresponding to the stratigraphic interval in question. Thus, despite the widespread opinion that the stratotype of the Kungurian Stage is unknown (*Main* …, 1984), Stuckenberg indicated clearly this section as most characteristic for the stage and defined its lower (top of sandstones with ammonoids) and upper (base of the red-colored sandy–clayey sequence by Golovkinskii (or Ufimian Stage, after the Nechaev) Stage) boundaries. Due to their insufficient paleontological characteristic, the Kungurian sediments were considered for a long time as an element of the enlarged Artinskian Stage (Ruzhentsev, 1956). Owing to subsequent works (Bogoslovkaya, 1988; Leonova and Dmitrieva, 1989; Chuvashov, 1997), the Kungurian Stage received its own paleontological characteristic.

Krasnopol'skii (1889) and Stuckenberg (1890) provided the lithological and paleontological substantiations of the Ufimian Stage (before its distinguishing as the autonomous unit). The biofacies feature was used as a basis for its defining: the replacement of lagoonal facies of the Kungurian Stage by the dominant continental Ufimian red beds overlain, in turn, by marine gray-colored sediments (the Nechaev's Kazanian Stage). Beginning from the Karsnopol'skii's works, the lower red-colored sequences was accepted as consisting of two "series": the lower (P_1^a) and upper (P_1^b) series corresponding to the marly–sandy sequence and group of red beds and cupriferous sandstones, respectively. Frederiks (1918) separated the Ufimian Stage in two horizons corresponding to Krasnopl'skii's (P_1^a) and (P_1^b) sequences. Subsequently, the last author (Frederiks, 1932) named the (P_1^a) sequence as the Solikamsk Horizon and attributed the latter to the Kungurian Stage, which was placed, in turn, into the upper series of the Permian System. In the 1940s–1960s, the discussion concerning the status of the Ufimian Stage as an autonomous stratigraphic unit was in progress. The detailed historical review of standpoints on this problem is available in (Grunt, 2005; table 2). In 1965, the Solikamsk Horizon received the official status as the lower regional stratigraphic unit of the Ufimian Stage (*Resolutions* …, 1965), which is consistent with Nechaev's concept. The Sheshma Horizon corresponding to Krasnopol'skii's (P_1^b) "series" was also attributed to the Ufimian Stage.

Recently, the Kungurian–Tatarian interval of the East European stratigraphic scale attracts attention in connection with development of the International stratigraphic scale. During the International Symposium "Upper Permian Stratotypes of the Volga Region," its participants arrived at the anonymous conclusion that stages of the East European stratigraphic scale should be preserved for estimating positions of extratropical postKungurian sections (*Memorandum* …, 1999). The memorandum's approval was preceded by a discussion between many Russian and foreign researchers. Recent attempts to restructure the East European stratigraphic scale, which is accepted as the General stratigraphic scale are reduced mostly to its correlation with the new International stratigraphic scale (ISS). Some authors (Kotlyar, 1997; Ganelin et al., 2001; Klets et al., 2001) proposed repeatedly including the Solikamsk Horizon into the Kungurian Stage. This suggestion is based on the possible correlation of the Sheshma Horizon of the East European scale with the Roadian Stage in the International stratigraphic scale and coincidence between lower boundaries of these two stratigraphic units. Subsequently, it became clear that these assumptions are incorrect.

The arguments in (Chuvashov et al., 2002) in favor of attributing the Solikamsk Horizon to the Kungurian Stage are unconvincing as well. The entire Lower Permian zonal scale of the Urals is based on fusulinids, ammonoids, and conodonts. At the same time, the fusulinids and conodonts as well as ammonoids from the boreal family of the Spirolegoceratidae, whose first appearance marks the Ufimian–Kazanian stage in the development of these organisms, are missing from the Solikamsk Horizon in the stratotype's locality and its analogues in East Europe. Chuvashov characterizes the boundary between the Solikamsk and Sheshma horizons using brachiopods, bivalves, ichtyofauna, charophytes, and macroflora based on data according to T.A. Grunt, V.V. Silant'ev, D.I. Yankevich, and N.K. Esaulova, although these authors rule out the reference of the Solikamsk Horizon to the Kungurian Stage (*Biota* …, 1998).

Suggestions to include the Sheshma Horizon into the Kazanian Stage (Golubev, 2002; Kotlyar et al., 2004) were also rejected. No factual data for extrapolating the paleontological characteristics of the Kazanian Stage on the Sheshma Horizon are available. Moreover, the faunas from the *Licharewia* (Kazanian) and *Sowerbina* beds in the continuous marine sections of the Kanin Peninsula and Spitsbergen differ significantly from each other (*Upper* …, 2006). As an autonomous stratigraphic unit of the stage rank (Kotlyar, 2002), the Sheshma Horizon has no real correlation potential. In case of both defining the Sheshma sediments as a stage-rank stratigraphic unit and their attribution to the Kazanian Stage, the selection of the satisfactory stratotype for the lower boundary of this unit is extremely difficult.

The Interdepartmental Stratigraphic Committee (*Resolution* …, 2006) attributed the entire Ufimian Stage to the lower (Cisuralian) series and in 2007, its Commission on the Permian System made a decision to abrogate the Ufimian Stage. It should be noted that the collective international work (Menning et al., 2006) presents two variants of the East European scale (*Resolutions* …, 2006 and Grunt, 2006). The arguments of

the Commission on the Permian System reduced to the statement that "… the problem of the Ufimian Stage validity in the stratotype region cannot be solved due to its laterally variable polyfacies composition and unsubstantiated lower boundary" (see the protocol of the meeting the ISC Commission on the Permian System of September 27, 2007) indicate the necessity of further research in this direction, not in the liquidation of the Ufimian Stage and, consequently, an object for further discussion.

Difficulties connected with recognition of its analogues beyond the stratotype region, its correlation with the Chisya (China) and Cathedral Mountain (North America) formations and the Tumarin and Khalalin horizons of the Verkhoyansk region included, also do not provide grounds for the liquidation of the Ufimian Stage. In the opinion of the ISC Commission on the Permian System, the occurrence of the Kungurian conodonts *Mesogondolella idahoensis* in the beds with *Epijuresanites* in the Canadian Arctic region serves as an additional argument in favor of the abolition of the Ufimian Stage. At the same time, this find indicates only the incorrect correlation of these beds with the Kungurian Stage, since neither the *Epijuresanites* nor *Mesogondolella idahoensis* occur in the Filippovskoe–Iren sediments of the stratotype region. In its resolution of 2007, the ISC Commission on the Permian System ignored, in fact, the opinion of many researchers, who consider it necessary to retain the Ufimian Stage in the European stratigraphic scale or at least to conduct additional investigation prior to making such decisions.

PALEONTOLOGICAL AND EVENT-STRATIGRAPHIC CHARACTERISTICS OF THE UFIMIAN AND CONJUGATE STAGES

Smaller Foraminifers

Sukhov (2003, 2007) established two local zones in the Kungurian Stage of the stratotype region: the *Nodosaria pseudoincelebrata* (Filippovskoe Horizon) and *Nodosaria circumita* (Iren Horizon). The Solikamsk Horizon comprises two subhorizons readily traceable through the entire Eurasian part of the Boreal realm: the lower and upper corresponding to the *Nodosaria monile* and *Nodosaria netschajewi* zones, respectively. The red-colored sequence of the Sheshma Horizon is barren of foraminifers.

The Kungurian–Ufimian boundary coincides with the boundary between the *Nodosaria circumita* and *Nodosaria monile* foraminiferal zones. Although the Ufimian assemblage is still dominated by genera *Ichtyolaria* and *Nodosaria*, it exhibits qualitative changes reflected in the appearance of diverse Upper Permian species, many of which are known from Kazanian and coeval sediments of the Volga and northern European regions (*Nodosaria krotowi* Tscherd., *N. cuspidatula* Gerke, *Tristix permiana* Gerke, and others). The Kazanian *Ichtyolaria–Nodosaria* assemblage is dominated by nodosariids: genera *Protonodosaria*, *Nodosaria, Pseudonodosaria, Retroglandulina, Dentalina, Lingulonodosaria, Lingulina, Geinitzina, Icthyolaria, Tristix, Pseudotristix, Astacolus, and Falsopalmula.*

Ammonoids

The postArtinskian stages in development of ammonoids are considered in detail by Bogoslovskaya in (*Upper* …, 2006, Fig. 15). According to this researcher, the ammonoids found in the European part of Russia belong mainly to two genera, widespread in Artinskian sediments. Nevertheless, a sharp reduction of the generic diversity, differences at the species level, and the appearance of a new genus *Tumaroceras* point to an autonomous position of the Kungurian ammonite assemblage. Bogoslovskaya (1997) established *Tumaroceras dignum* Bog. and *Medlicottia postorbigniana* Bog. in the lower part of the Liur'yaga Formation (Liur'yaga River, northeastern Poi-Khoi). In her opinion, representatives of genus *Tumaroceras* allow for the correlation with high-boreal sections of Northeast Asia.

The Ufimian Stage is characterized by the index genus *Epijuresanites*, an initial form in the phylogenetic lineage of genera *Epijuresanites–Sverdrupites* from the family Spirolegoceratidae; these two genera correspond to evolutionary stages of the lineage, which are reflected in the phylogenetic succession: *E. primarius–E. musalitini–E. vaigachensis–E.* sp. (Leven and Bogoslovskaya, 2006). The lower half of the Tab'yus Formation in the Liur'yaga River basin referred to as the Solikamsk Horizon (Kotlyar et al., 1999) yielded the oldest and most primitive species of the genus (*E. promatius* Popov), which replaces Kungurian *Tumaroceras dignum* Bog. There are also different views (Leonova and Shilovskii, 2007, fig. 1) on the origin of the genus *Epijuresanites* from *Tumaroceras* in the initial Kungurian Age (? Sarana Horizon) and their parallel existence up to the onset of the Kazanian Age, although no factual data support these assumptions. No representatives of the genus *Epijuresanites* have been found so far in sections of the Filippovskoe and Iren horizons or their analogues in northern Europe. Unlike Bogoslovskaya's scheme, Leonova's scheme provides no idea on the stratigraphic distribution of the forms of the *Epijuresanites* genus species and their phylogenetic relationships, which prevents us from using it for detailed correlations. At the same time, it should be admitted that there are two viewpoints that currently exist on relations between the *Epijuresanites* and *Tumaroceras* genera and this problem requires further investigation.

The Kazanian (=Roadian) stage in the development of ammonoids is determined by the phylogenetic lineage of the genus *Sverdrupites*: *S. harkeri–S. amundseni–S.* aff. *amundseni* (Leven and Bogoslovskaya, 2006). The representative ammonoid assemblage that includes *Popanoceras* ex gr. *subtumarenese* Andr., *Sverdrupites*

ex gr. *harkeri* (Ruzh.), *S. amundseni* Nass., *Biarmiceras esaulovae* Leonova et al., *B. barskovi* Leonova et al., *B. kremeshkense* Leonova et al., *Altudoceras* (?) sp., and *Daubichites* sp. originates from the Kremeshki Quarry along the Vyatka River (Leonova et al., 2002). The remarkable feature of this assemblage is the co-occurrence of two *Sverdrupites* species in this locality. Usually, one of them *S. harkeri*) occurs only in the lower layers of the Roadian Stage, while another (*S. amundseni*) in its upper part. The cooccurrence of these species in the Kremeshki Quarry confirms the opinion of Leonova (Leonova et al., 2002) that this assemblage characterizes the uppermost part of the lower Kazanian or basal upper Kazanian substages.

Bivalves

Marine bivalves. According to G.P. Kanev in (*Biota* …, 1998), the Kungurian sediments of the Perm Urals region contain 47 species of marine bivalves belonging to 26 genera. The characteristic assemblages from the Filippovskoe and Iren horizons include 17 and 15 species, respectively. The taxonomically most representative genera are *Stutchburia* and *Schizodus*, which form mass burials, *Aviculopecten, Vorcutopecten, Streblopteria, Parallelodon, Edmondia*, and *Nuculopsis.* The Solikamsk Horizon yields 22 species belonging to 14 genera. Many species are typical representatives of the postKungurian molluscan fauna of northern Russia and that of the Zechstein in West Europe and Greenland (*Biota* …, 1998).

Nonmarine mollusks. The basal part of the Solikamsk Horizon in stratotype sections of European Russia is marked by the appearance of nonmarine bivalves from genus *Paleomutela* (Silant'ev, 2004). Based on the stages in the development of this genus, seven regional zones are established in the Ufimian and Tatarian stages: in the Solikamsk Horizon (two), Sheshma Horizon, Kazanian, Urzhumian, Severodvinskian, and Vyatkian stages (one in each unit).

Brachiopods

Similar to the entire Early Permian, brachiopods from the Filippovskoe and Iren horizons of the Middle Urals region continued as thermophilic organisms (Grunt, 2007), although due to the significant salinity of the basin their taxonomic composition appeared to be substantially impoverished. The assemblage from the Filippovskoe Horizon of this region is uniform, being represented by scarce athyrids and dielasmatids. In sections of northern Europe, the Filippovskoe Horizon corresponds to the *Thuleproductus arcticus–Neospirifer shestakensis, Spirifirella talbeica* regional zone. The Iren assemblage of the Middle Cisuralia region is best represented in sediments of the Nevolino Member outcropping in the Polazna Pier area at the Kama River. In northern Europe, this level is correlative with the *Thuleproductus subarcticus–Neospirifer shestakensis, Cyrtella kulikiana* regional zone.

By the terminal Iren time, the thermophilic subtropical marine biota was entirely replaced by that characteristic of basins of a temperate zone (*Biota* …, 1998). Brachiopods from the Solikamsk Horizon of the stratotype locality are scarce. *Lingula* sp., *Megouia* cf. *kuliki* (Fred.), *Cancrinella cancrini* (Vern.) are found only in the upper part of the upper Solikamsk Subformation. It should be emphasized that the last species is missing from the Lower Permian sediments being, however, widespread in the Kazanian Stage. In the northern European part of Russia, the Solikamsk Horizon corresponds to the *Sowerbina granulifera–Arcullina polaris, Timaniella festa r*egional zone. The substantially impoverished Sheshma assemblage is established only in the northern sections, where it is characteristic of the *Kochiproductus plexicostatus* regional zone (*Upper* …, 2006). The Kazanian Srage comprises two regional zones: *Aulosteges gigas–Licharewia schrencki, L. wimani* (lower substage) and *Craspedalosia pulchella–Pinegathyris alata* (upper substage).

Ostracods

The Iren Horizon corresponds to the *Acratia similaris* ostracod zone. In addition to the index species, its assemblage includes other marine ostracod species such as *Bairdia frequens* Guss., *B. extensa Guss., B. indefita* Guss., *B. irenica* Guss., *B. rostriformis* Guss., *Acratia magna* Delo, and *A. similaris* Morey.

The Solikamsk Horizon is marked by the first appearance of nonmarine ostracods. Their occasional finds are recorded in the Solikamsk Formation of the stratotype locality, where the lower clayey–marly sequence yields *Darwinula breviformis* Zhern., *Iniella beresnikensis* Kash. and its upper terrigenous–carbonate sequence contains *Darwinula angusta* Mand. accompanied by marine *Bairdia.* The section of the upper Solikamsk Subformation near the Tyul'kino Settlement at the right side of the Kama River encloses nonmarine *Darwinula angusta* Mand., *D.* aff. *timanica* Kash., *Suchonella* aff. *onega* Bel., *Whipplella* cf. *urasovi* (Pal.), and *W.* aff. *circulosa* (Mand.). In the Solkamsk basin, *Darwinula angusta* Mand., *D. digita* Zhern., *Kemoroviana ellipsoides* Mand,. *Tomiella tschernyschevi* Mand., *Iniella* cf. *polenovi* Kash., and *Volganella spizharskyi* Kash. are found in the upper marly–dolomitic–limy subformation. In one of the best studied sections of the Ufimian Stage recovered by Borehole 1047 near the Durino Settlement of the Perm region, nonmarine ostracods appear in the upper terrigenous–carbonate sequence of the Solikamsk Formation. By its taxonomic composition, the ostracod assemblage represented by 24 species differs substantially from that found in the overlying Sheshma Formation of the same section. In western Bashkortostan, representing the stratotype region of the Sheshma Horizon, Kochetkova (1970) defined an assemblage consisting

of approximately 40 species. The specific composition of ostracods is characteristic of the lower (Kamyshensk), middle (Buraevo), and upper (Chermagush) sequences; the last of them is similar to the penultimate one, although being impoverished. The nonmarine Solikamsk ostracods occur only in the northern and middle Cisuralian region, while their Sheshma counterparts are distributed through the entire East European Platform.

Thus, ostracods exhibit the gradual replacement of marine biocoenoses of the Kungurian Age by Ufimian nonmarine assemblages. The regressive gradually desalinated Solikamsk basin was intensely colonized by new ostracod groups, including everyhaline *Darwinulocopina*. The appearance of these taxa in the East European Platform at the onset of the Ufimian Age is presumably related to the expansion of the Siberian and Kazakhstan basins, which represented their former habitat regions. Their first representatives appear in the early Solikamsk time, which seems most significant. In the late Solikamsk time, they became widespread, although the peak of their abundance and diversity corresponds to the Sheshma time. In fact, we can speak about the slightly prolonged biotic event determined by paleogeographic reorganization.

Insects

This review is based on the data on the distribution of Permian insects from (Shcherbakov, 2008), although the inference of this author on the unity of the Kungurian–Ufimian stage in their development seems insufficiently substantiated. Among Kungurian localities, the most diverse at the family level is the Chekarda section: the assemblage from this area includes representatives of 21 families of grilloblattids alone. The assemblage is typical of the early Permian. It contains relatively abundant Paleozoic taxa, including forms sucking out immature seed embryos, accompanied by subordinate younger species. This is well exemplified by homopterans, which sucked out saps from plants, and beetles that fed on wood damaged by fungi. The Early Permian beetles are represented by the only Chekardocoleidae family. In addition to the early Archescitinidae species, characteristic of the early Permian, the Kungurian homopterans include representatives of three families, which are, however, rare.

The localities of Ufimian insects in European Russia are confined to the Cisuralian region with the richest of them in the Pechora basin. Central Russia hosts only four localities of fossil insects, which probably all characterize the Solikamsk Horizon. Approximately hundred specimens have been sampled near the Tyul'kino Village. This assemblage is dominated by mosquito hawks. The other locality (near the village of Mogil'nikovo) yielded exclusively mosquito hawks, whose abundance is usually characteristic of marine burials. At the same time, these insects are less abundant in close-in-age lagoonal sediments of the Chekarda (Kungurian Stage) and Soyany (Kazanian Stage) localities. The second peculiar feature of the Tyul'kino locality is the extreme abundance of Blattisnopseidae forms. This group was particularly abundant in the terminal Carboniferous–initial Permian. Homopterans in this locality are very rare. In the almost complete lack of cockroaches, the Tyul'kino assemblage is similar to early Kazanian localities and in the high abundance of aqueous forms, to its counterparts from the Urzhumian and younger localities. Thus, judging from the taxonomic composition of the Tyulkino assemblage, the insect fauna from the Solikamsk Horizon differs from the Kungurian and early Kazanian communities. The taxonomic specificity of this insect fauna is still low; until today, only one endemic genus of scorpionflies has been described, which is probably explained by the poor knowledge of fossil insects in this area.

Most of the insects (approximately 50 specimens), which are useful for solving the problem under consideration, are sampled in the Vorkuta Formation of the Pechora basin. Unfortunately, it is unclear so far, which of these insects should be considered as Ufimian in age. As noted in the description of this collection (Rasnitsyn et al., 2005), the insects are sampled from most parts of the Lekvorkut and Inta formations. No agreement exist among geologists concerning the volume of the Kungurian Stage in this area: some of them consider its upper boundary as corresponding to that between the Ayachaga and Rudnitskaya subformations of the Lekvorkut Formation (*Biota* …, 1998), while others attribute the entire Vorkuta Group to the Kungurian Stage (Pukhonto, 1998). The analysis of sampled insects reveals that they form a single assemblage and the difference between their remains from the lowermost and uppermost parts of the group is insignificant as compared with that between the Kungurian and Ufimian assemblages. Taking into consideration the evolution of insects in the Permian, there are no grounds to speak about the significant difference in age of different parts of the Vorkuta Group. The assemblage of insects is relatively of low diversity and includes forms, characteristic of both the Kungurian and Kazanian stages and rare Carboniferous relicts. In this respect, it exhibits some similarity with the assemblages from localities of the Urals region, which are considered to be Ufimian in age, although in the Pechora basin they contain relatively abundant representatives of old Paleoptera, which are missing from the Urals region. The assemblage in question is impoverished also in homopterans. Among insects sampled from Member Ia of the Inta Fornation, one third are represented by Blattinopseidae forms. The assemblage of Vorkuta insects is characterized by abundant cockroaches and low-diversity grilloblattids against a background of abundant and diverse aqueous forms. Thus, despite some similarity, the insect assemblages from the Urals region and Pechora basin demonstrate significant differences.

The Ufimian insect fauna of European Russia, which includes both relatively primitive and advanced forms, resembles the assemblage from the Lodévois basin in southern France (Grand et al., 1997) that represents the past playa lake. Its age is estimated in the interval from the Sakmarian to Tatarian ages, although it is difficult to imagine that such an ephemeral basin could exist for tens of millions of years.

In conclusion, it should be stated that an autonomous Ufimian stage is definable in the evolution of insects, which is untraceable beyond East Europe due to insufficient data. This stage is partly transitional between the Kungurian and early Kazanian stages, differing from them by some specific features reflected in the occurrence of old relicts and the lack of many typical Early Permian groups. Despite these characteristics in common, insect assemblages from the Pechora basin and Cisuralian region demonstrate significant differences; the first of them should be considered as a single assemblage.

Conodonts

No conodonts are found both in the Solikamsk and Sheshma horizons of the stratotype locality and their analogues in northern Europe or Northeast Russia; therefore, extrapolation of the data on their distribution in the Sarana–Iren stratigraphic interval onto the Ufimian Stage is incorrect. Conodonts found in the stratotype of the Kazanian Stage belong to genera *Kanagnathus* and *Stepanovites. K. khalimbadghai* Chern. and *K. volgensis* are found in the basal part of the Kazanian Stage (Baitugan Beds) and in the upper Kazanian Substage, respectively. Of *Stepanovites* representatives, only *St. alienus* Kozur et Movsch. (Baitugan Beds) and *St. meyeni* Kozur et Movsch. (lower part of the upper Kazanian Substage) are recorded.

V.V. Chernykh (Chernykh and Silant'ev, 2004) established a similarity between Pa elements in *Kamagnathus* representatives and their counterparts described as *Sweetina triticum* Wardlaw et Collinson from the *Neogondollela serrata–Neostreptognathus newelli–Pennicularis bassii* Zone (Wardlaw and Collinson, 1986) in the Dry Bread Hollow locality (Utah, the United States) subsequently renamed as the *Neogondollela nankingensis* Zone. This served as an indirect argument in favor of correlating the lower Kazanian (Baitugan) beds in the stratotype section of the Kazanian Stage (East European scale) with the base of the Roadian Stage in the International stratigraphic scale. The lack of *Merrillina* representatives at this level (similar to the Kazanian Stage), which appears in the Wordian Stage, provided additional grounds for the correlation between the lower boundaries of the Roadian and Kazanian stages (Chernykh and Silant'ev, 2004, p. 86). In this situation, the authors tolerate a significant degree of "inaccuracy." In fact, they mean the Road Canyon Formation, while the Roadian Stage corresponds only partly with the latter: its lower boundary is placed inside the synonymous formation at the base of the *Neogondollela nankingensis* conodont zone. This is clearly shown in (Lambert et al., 2000).

It would be more logical to accept the level in the Road Canyon Formation marked by the first appearance of a conodont form, transitional between *M. idahoensis* and *M. nankingensis*, as representing the lower boundary of the Roadian Stage, instead of the level approved at the base of the *Mesogondollela nankingensis* Zone. The first level coincides with the appearance of the Roadian ammonoid assemblage consisting of *Texoceras, Peritrochia, Paraceltites*, and others (Leven and Bogoslovskaya, 2006). This level represents an event boundary, not a voluntarily selected one, corresponding to one of the episodes (although important) in the conodont evolution. The consequences of such an approach of the International Commission on Stratigraphy to the problem of geological boundaries, when some conodont levels are preferred instead of significant event boundaries was previously illustrated in (Karaulov and Lozovsky, 2002) using the Permian–Triassic boundary as an example. If the conodont level at the base of the Kazanian Stage really corresponds really to the level at the base of the Roadian Stage, it falls inside the major stage in the historical development of ammonoids. In this case, the Kazanian Stage should be underlain by a certain stratigraphic gap, which should be filled by the Ufimian Stage.

Fishes

The Artinskian and Kungurian sediments of the Urals region contain representatives of actinopterygian (*Elonichthys, Acrolepis, Rhadinichthys, Platysomus*) and cartilaginous (*Cladodus*, *Campodus, Petalodus, Helicoprion, Parahelicoprion*) fishes well-known from the Permian sections of West and East Europe (*Biota* …, 1998; Yankevich, 2001). In the northern areas of the platform, species of the cartilaginous genus *Pinegocaptus* appear in the uppermost part of the Kungurian Stage (Minikh et al., 2003).

The Iren–Solikamsk boundary beds are marked by a major change in the taxonomic composition of fishes both at the specific and, largely, generic levels. Their typical Biarmian forms appeared at the onset of the Ufimian Age to continue their development until the end of the Urzhumian Age; some of them existed through the Tatarian Age as well.

Of the above-mentioned taxa, only the *Elonichthys*, *Acrolepis, Platysomus* (actinopterygian), and *Pinegocaptus* (cartilaginous) cross the Kungurian–Ufimian boundary. Genera *Usolia, Ufalepis*, and *Akanolepis*, new species of *Elonichthys* and *Acrolepis* known since the Carboniferous, as well as *Alilepis* and *Varialepis*, characteristic of postKungurian sediments appear in the basal part of the Ufimian Stage. The Sheshma Horizon is marked by the appearance of genera *Adzvalepis* and *Grigorichthys. Alilepis* representatives occur in the

stratotypes of the Solikamsk and Sheshma horizons. Scale ichtyolites of this genus originate from the Lekvorkut and Inta formation and from the basal layers of the Seida Formation of the Ufimian Stage in the Pechora basin as well as from the Kozhimrudnitskaya and Inta formations of the Kozhim River basin (*Biota* …, 1998). In addition, representatives of genus *Alilepis* are established in the Kazanian Stage of the Kanin Peninsula (*Upper* …, 2006) and *A. esini* A. Minich is recorded in the lower Kazanian sediments of the Golyusherma and Tikhie Gory localities at the Kama River and Ust-Koin locality of the Vym River basin. The younger *Alilepis* species (*A. kolguensis* A. Minich and *A. secunda* A. Minich) are found in presumable analogues of the Severodvinskian Stage in Kolguev Island. Some species of paleoniscoid fishes such as *Elonichthys natalis* Yankevich, *Acrolepis frequens* Yankevich, *Akanolepis allae* Minich, *Usolia orsa* Yankevich, *U. vicina* Ynakevich, and *U. eximia* Yankevich are characteristic only of the Ufimian Stage in the East European Platform. All of them occur universally in the Ufimian sediments of the Pechora basin and stratotype sections of the Ufimian Stage in the Middle Urals region (*Biota* …, 1998). *Varialepis* forms that appeared in the Ufimian Age, colonized the Kazanian and Urzhumian basins of the East European Platform and lived there until the Vyatkian Age. Sharks from the genus *Pinegocaptus* (characteristic of the Kozhimrudnitskaya and Inta formations of the Ufimian Stage in the Vorkuta–Pechora basin) occur also in the Kazanian Stage of southerly located areas of the East European Platform.

Thus, the taxonomic composition and distribution of the ichtyofauna in the Kungurian–Ufimian boundary layers points convincingly to the beginning of the next (Biarmian) stage in the development of the Permian fishes in the Ufimian Age, which continued in the East European platform until the terminal Urzhumian Age.

Tetrapods

The appearance of tetrapsids became the most important event in the evolution of terrestrial vertebrates in the mid Permian (Lozovsky, 2004). The oldest tetrapsids are known from the *Eodicynodon* Zone of South Africa; judging from isotopic geochronologic measurements (private communication by B.S. Rubidzh), they are younger than 271 Ma. According to (Ivakhnenko et al., 1997), the oldest tetrapsids of Russia are reported from the basal strata of the Kazanian Stage in the Urals region (*Microsiodon, Parabradisaurus*). The old tertapod fauna from the Ufimian Stage of the Pechora River basin consists of the dominant Early Permian amphibians (Eriopidae and Intasuchidae), small primitive forms of the subclasses Anthracosauromorpha (Enosuchidae and Eogurinidae) and Captorhinomorpha (Captorhinidae and Bolosauridae) (Ivakhnenko, 2001). Their host sediments are joined to the *Clamorosaurus nocturnes* provincial zone (Ivakhnenko et al., 1997). This fauna originates from two (Inta and Pechora) localities, one of which is confined to abandoned mines and another is poorly known. At the same time, there are several promising sites with vertebrate finds In the Pechora River valley, corresponding to the same stratigraphic interval (Chalyshev and Varyukhina, 1968), which need urgent investigation.[1]

Flora, Palynological Complexes

In the stratotype locality, the Kungurian Stage is characterized by the so-called "Bardin" assemblage originating from many localities and containing abundant remains of Arthrophyta, Equisetales, Filicales, Pteridospermales, so-called Angara Cordaitales (families Vojnovskyaceae and Rufloriaceae sensu S. Meyen), Dicranophyllaceae, and conifers (Naugol'nykh, 2007). The Bardino phytocomplex is subdivided in two subcomplexes: Filippovskoe and Iren (*Biota* …, 1998).

The complex from the Solikamsk Horizon is known from several localities: near the village of Tyul'kino in the upper reaches of the Kama River; along the Kolva, Vishera, and Chusovaya rivers; near the Sylva River mouth. The onset of the Solikamsk time is marked by the replacement of extremely abundant and diverse Kungurian vegetation by the uniform flora represented by lepidophytes *Viatscheslavia vorkutensis* Neub., their phylloids *Viatscheslaviophyllum vorcutense* Neub., and leafy mosses *Intia variabilis* Neub. In the opinion of Naugol'nykh, this event marks the regional early Ufimian (Solikamsk) ecological crisis caused by climate aridization (*Climate* …, 2004; Naugol'nykh, 2007).

When analyzing the rich palynological spectra, N.A. Koloda arrived at a similar conclusion. His results are discussed in detail in *Biota* …, 1998; *Upper* …, 2006). In the Pechora basin, the boundary between the Kunguruan Stage and Solikamsk Horizon is traditionally placed between the Lekvorkut and Inta formations of the Vorkuta Group, inasmuch as the Member "M" of the Rudnitskaya Formation in the stratotype section of the Lekvorkut Formation along the Vorkuta River is marked by the appearance of the *Viatscheslavia vorkutensis* Neub., *Viatscheslaviophyllum vorcutense* Neub., and the mosses *Vorcutannularia plicata* (Pog.) Neub. (Pukhonto, 1998). At the same time, in the hypostratotype of the Lekvorkut Formation along the Bokovoi Creek (Pukhonto, 1999), the appearance of the first *Viatscheslavia* sp. and *Viatscheslaviophyllum* sp. is recorded in the uppermost part of the Ayach'yaga Formation (top of the Member R), which points most likely to the Rudnitskaya Formation belonging to the Solika-

[1] In this connection, of interest is the study of a group of Mezen localities confined to the Leshukon Member of the Krasnaya Shchel Formation (Lozovsky, 1998). The Mezen fauna, undoubtedly younger as compared with the Kazanian one, is known from approximately 20 localities studied in rich collections. As a whole, it is characterized by the archaic Early Permian appearance with single finds of Middle Permian tetrapsids (Ivakhnenko, 2001).

msk Horizon, not the Kungurian Stage in its initial range.

Paleogeographic and Biogeographic Analyses. Results of Event–Stratigraphic Studies

In the Kungurian period, the Middle Uralian basins were located in a warm arid zone, as a result of which they experienced salinization and desiccation. By the end of the Iren period, the paleogeographic reorganization in the European basins was finished. The latter determined changes in the entire ecosystem reflected in the replacement of warm-water habitat conditions by settings, characteristic of temperate latitudes and, correspondingly, thermophilic marine fauna according to the biota typical of such basins, the disappearance of the last reefal buildups, and the replacement of the carbonate sedimentation by a terrigenous one. The water exchange with the Paleo-Tethys appeared to be broken. Precisely the beginning of the Solikamsk time coincided with distinct changes in the paleo- and biogeographic structures of all the basins located in the European territory. Since that time, the influence of the Barents Sea shelf on the basins of European Russia notably increases (*Biota* …, 1998; *Upper* …, 2006).

The event–stratigraphic approach provides important data for substantiating the boundary between the Solikamsk and Iren horizons in the East European scale *Biota* …, 1998; Malysheva et al., 2001; Kotlyar et al., 2004). These works are dedicated to the study of the sections in the Timan–Pechora region using the complex methodology of the sequence stratigraphy (Mitchum, 1977). The paleogeographic reconstructions are performed for the base of the Kozhimrudnitskaya Formation and its analogues corresponding to the lower system tract of the first sequence of the Solikamsk time. This stage was marked by regional shallowing of the basin and initiation of the intense removal of sandy material. The first Solikamsk sequence is represented by sediments of the maximal regression phase. They are overlain by distinctly transgressive, relatively deep-water shelf sediments, which are readily recognizable based on lithology, paleontological remains, and log records. The sediments of the upper system tract reflecting the initial regression phase are poorly distinguishable. As a whole, the lithological–facies analysis of 20 sections and boreholes that recovered the Iren–Solikamsk stratigraphic interval in the Timan–Pechora region revealed a major transgressive "Solikamsk" event, whose peak is confined to the middle part of the Kozhimrudnitskaya Formation and its analogues in the northern part of European Russia. The beginning of the transgressive cycle, substantiated by both lithological and complex paleontological data is registered at the base of this formation. In the opinion of one of the authors (*Biota* …, 1998; Malysheva et al., 2001), the onset of the "Solikamsk" event reflected in the renewal of the marine and partly terrestrial biota through the entire East European region coincides with the lower boundary of the Kozhimrudnitskaya Formation and its analogues in the northern part of European Russia. In the opinion of other researchers (Kotlyar et al., 2004), the "Solikamsk" event is the single-stage one and corresponds to the middle part of the Kozhimrudnitskaya Formation in the section outcropping along the middle reaches of the Kozhim River with a distinct peak of the synonymous transgression. The original data obtained by the above-mentioned authors indicate the major regional "Solikamsk" event, which marked the onset of the autonomous historical–geological and biotic stage in the development of the East European region. The difference consists in the fact that Malysheva et al. (2001) register the onset of this event at the base of the Kozhimrudnitskaya Formation, while Kotlyar et al. (2004) fix the peak of the same event in the middle part of the formation. Thus, the inferences indicate, in fact, the coincidence of the views of these researchers. It is clear that the rank of the "Solikamsk" event is substantially higher as compared with that of both the intra- and interstage levels. It is evident also that the "Solikamsk" event cannot be interpreted as crowning the regressive phase of the Artinskian–Kungurian stage in terms of paleogeographic, biogeographic, or faunal aspects.

SERIES OF THE EAST EUROPEAN SCALE: CORRELATION WITH THE INTERNATIONAL AND TETHYAN SCALES

In the modern International Stratigraphic Scale, the Permian System is subdivided into three series with their own names: Cisuralian, Guadalupian, and Lopinguian. The traditional East European stages are retained only for the lower (Cisuralian) series, while the North America (Roadian, Wordian, and Capitanian) and South China (Wuchapingian and Changsinian) stages are used for the subdivision of the middle (Guadalupian) and upper (Lopingian) series, respectively.

The available data on the duration of the series in the International stratigraphic scale exhibit the distinct disproportion of its three-member variant. With the general duration of the Permian Period estimated to be approximately 45 Ma, the duration of the early (Cisuralian) epoch is approximately 22 Ma, which corresponds to the duration of the combined Guadalupian and Lopingian epochs (Menning et al., 2006). In the East European region, the Permian scale was subdivided until recently in two series with the boundary between them accepted at the base of the Solikamsk Horizon (*Resolutions* …, 1965). Based on the resolution of the All-Russian meeting on "The Structure and Status of the East European Stratigraphic Scale…" (Kazan, 2004) and subsequent "Resolution on the modernization of the upper series of the Permian System…" accepted by the enlarged meeting of the Interdepartmental Stratigraphic Committee, it was decided to subdivide the General stratigraphic scale into three, instead of two traditional, series (the Cisuralian, Biarmian, Tatarian),

in order to correlate the East European scale with the international one. The modernized variant of the East European scale proposed in (*Upper* …, 2006), retained its traditional two-member structure with two subsystems each separated in two series (table). The two main units of the Tethyan scale are also considered in the subsystem ranking, with each separated in two series with its own name (Leven, 2004). The base of the Solikamsk Horizon in the Tethyan scale corresponds most likely to the base of the Kubergandian Stage (Leven and Bogoslovskaya, 2006). If the Ufimian Stage is eliminated, the lower boundary of the Kubergandian Stage (and upper Tethyan Subsystem) falls inside the Kungurian Stage being unrecognizable both in the East European and International stratigraphic scales (Leven and Bogoslovskaya, 2006; Menning et al., 2006). The four-member North American regional scale (Wolfcampian, Lenardian, Guadalupian, Ochoan series) is structurally closest. The South China scale is historically four-member as well (the Mapin, Chisya, Maokou, and Loping series). No three-member variant of the Permian scale is planned for the subdivision of the Permian sediments of the Kolyma–Omolon (Ganelin et al., 2001; Byakov, 2008) and Verkhoyansk–Okhotsk (Klets, 2005) regions. Thus, all the researchers argue in favor of the two-member (or more detailed four-member) regional scales of the Permian System. None of the Russian or foreign researchers support the three-member structure of any regional scale.

THE "KUNGURIAN" STAGE OF THE GENERAL STRATIGRAPHIC SCALE: NOMENCLATURE AND PALEONTOLOGICAL CHARACTERISTIC

The change of the initial (author's) concept of the stratigraphic unit volume is regulated by paragraph 10 of chapter XII of the Stratigraphic Code of Russia (2006), which states that "if the volume of a stratigraphic unit is changed (specified), its name is preserved, when the change does not exceed one third of the latter." Inasmuch as the Sarana Horizon was previously referred to as the Kungurian Stage (*Resolutions* …, 1998), the additional attribution of the Ufimian Stage to the latter contradicts Stuckenberg's views and general rules of the stratigraphic nomenclature. The decision concerning the broad interpretation of the Kungurian Stage resulted in fact in discrediting the validity of stage units and the East European scale as a whole. The "Kungurian" Stage in its extensive interpretation appeared to include typical elements of many Artinskian groups of marine invertebrates and biotic groups characteristic of Kazanian sediments, which eventually deprived this stage of its autonomous paleontological characteristic. This resulted in the depreciation of the detailed scale, which was previously used for the stratigraphic interval under consideration. According to (Menning et al., 2006), the duration of the "Kungurian" interval from the base of the Sarana Horizon to the base of the overlying (in the International stratigraphic scale) Roadian Stage is approximately 8 Ma, which is twice as long as compared with that of any stage units of the Permian System.

CONCLUSIONS

The decision of the Interdepartmental Stratigraphic Committee of Russia (*Resolution* …, 2006) to attribute the Ufimian Stage to the lower (Cisuralian) series of the Permian System and, moreover, the decision of the ISC Commission on the Permian System to exclude the latter from the General Stratigraphic Scale approved in 2007 is absolutely unsubstantiated. These decisions are made, in fact, with only purpose: to adjust the General Stratigraphic Scale in accordance with the units of the International Stratigraphic Scale. In practical activity, they introduce a great deal of confusion into the traditional well substantiated East European standard, widely used for subdividing and dating the Permian sections of the Boreal and Notal climatic zones, violate nomenclature principles, and, make, in fact, the further use of this scale impossible.

In the contradictory situation with the East European scale, the best way forward is to observe the rules of the International Stratigraphic Guide (2002, p. 31), according to which " … the route toward recognition of uniform global units is by means of local or regional stratigraphic scales. Moreover, regional units will probably always be needed whether or not they can be correlated with the standard global units. It is better to refer strata to local or regional units with accuracy and precision rather than to strain beyond the current limits of time correlation in assigning these strata to units of a global scale." In the situation under consideration, the regional boundary between the Iren and Solikamsk horizons, well studied and substantiated in a spacious region, is preferable to the virtual boundary between the "Kungurian" and Roadian stages of the International stratigraphic scale.

In any case, the decision to exclude the Ufimian Stage from the East European stratigraphic scale contradicts the tasks of its further perfection and increase of its correlation potential. This decision is hasty and unsubstantiated, ignores recent data on the stratigraphic interval in question, violates the nomenclature of the traditional scale, is at variance with the Stratigraphic Code of Russia, and blocks the paths for further discussion.

As E.Ya. Leven notes justly, the problem consists in the fact that ratification of the lower boundary of the Guadalupian Series gave birth to a contradiction in the initial understanding of the Kungurian Stage of the East European scale and the "Kungurian" Stage of the International Stratigraphic Scale, which automatically included the Ufimian Stage of the latter. In addition, the correlation of the lower boundaries of the Kazanian and Roadian stages, which is based on unrepresentative pale-

Variants of the modernized East European scale and its correlation with the International and Tethyan scales

International Stratigraphic Scale (Gradstein et al., 2004)		General stratigraphic scale (*Resolutions*…, 2006)			Restructured East European scale (*Upper*…, 2006)				Tethyan scale (Leven, 2004)		
Lopingian Series	Changsinian Stage	Tatarian Series	Vyatkian Stage		Vyatkian Subsystem	Tatarian Series	“Vyatkian” Stage		Tethyan Subsystem	Lopingian Series	Doramshanian Stage
	Wuchapingian Stage		Severodvinskian Stage				Severodvinskian Stage	upper substage			Dzhulfian Stage
Guadalupian Series	Capitanian Stage							lower substage			
	Wordian Stage	Biarmian Series	Urzhumian Stage			Biarmian Series	Urzhumian Stage			Changsinian Series	Midian Stage
	Roadian Stage		Kazanian Stage	Povolzh’e Horizon			Kazanian Stage	Krasnovidovian Substage			Murgabian Stage
				Sok Horizon				Kamian Substage			
Cisuralian Series	Kungurian Stage	Cisuralian Series	Kungurian Stage	Sheshma Horizon			Ufimian Stage	Sheshma Horizon			Kubergandian Stage
				Solikamsk Horizon				Solikamsk Horizon			
				Iren Horizon	Cisuralian Subsystem	Cisuralian Series	Kungurian Stage	Iren Horizon	Cisuralian Subsystem	Darvazian Series	Bolorian Stage
				Filippovskoe Horizon				Filippovskoe Horizon			
				Sarana Horizon			Artinskian Stage	Sarana Horizon			Yakhtashian Stage
	Artinskian Stage		Artinskian Stage	Sarga Horizon				Sarga Horizon			
				Irgin Horizon				Irgin Horizon			
				Burtsev Horizon				Burtsev Horizon			
	Sakmarian Stage		Sakmarian Stage			Uralian Series	Sakmarian Stage			Uralian Series	Sakmarian Stage
	Asselian Stage		Asselian Stage				Asselian Stage				Asselian Stage

ontological evidence, is doubtful. Precisely this assumption led, in fact, to the hasty and unsubstantiated liquidation of the Ufimian Stage and the subsequent distortion of the consistency of the entire Permian scale.

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