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Some Unsolved Problems of Triassic Stratigraphy in Eastern Europe

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Abstract—Two problems of the continental Triassic stratigraphy of East Europe are considered: (1) correlation between the Lower Triassic horizons of the Moscow syneclise and the northern Caspian region and (2) correlation of the Middle Triassic horizons of the southern Cis-Urals and northern Caspian region with subdivisions of the International Stratigraphic Scale. The interdepartmental meeting on Triassic stratigraphy of the northern Caspian region (1999, Saratov) decided to substitute the former Ershov and Baskunchak regional horizons by the Lower Triassic Vetluga and Yaren superhorizons of the Moscow syneclise, respectively. However, the unification, according to which the Yaren age is accepted for deposits with Baskunchak charophytes in the Moscow syneclise, is not substantiated by occurrence of associated terrestrial fossil vertebrates. There is evidence that the Yaren Superhorizon of the stratotype area may differ in range from the corresponding interval in Caspian sections, since the latter probably includes analogs of the upper Vetluga Superhorizon. The boundary position between two Middle Triassic units of the southern Cis-Urals, i.e., between the Donguz Horizon with the *Eryosuchus* fauna of tetrapods and the Bukobai Horizon with the "*Mastodonsaurus*" fauna (found also in the upper Inder Horizon of the Caspian region), remains controversial. According to micropaleontological data, it coincides with the Anisian–Ladinian boundary, being placed inside the upper Ladinian based on vertebrate faunas. The reasons responsible for controversial viewpoints may be as follows: (1) the Germanic and Alpine Triassic section used as a reference by dating the East European paleontological remains can be imprecisely correlated; (2) the vertebrate-based correlations are based on ornamentation on dermal bone of amphibians (plagiosaurs), the evolution rate of which could be different in Central and Eastern Europe); and (3) of microfauna and palynological records can be of insufficient resolution ability for the long-distance correlations.

Key words: Triassic, stages, horizons, correlation, terrestrial vertebrates, palynology, ostracods.

The latest scheme of Triassic stratigraphy in the Caspian syneclise, which was adopted in 1999 (*Resolution…*, 2001), is essentially different from the previous one (*Resolutions…*, 1982). However, the decision did not unambiguously solve the basic problems of Triassic stratification in Eastern Europe as a whole. Some of these problems are discussed below.

LOWER TRIASSIC

The most significant problem is correlation of the Lower Triassic deposits of the Caspian syneclise with their northerly counterparts in the Moscow syneclise and the Volga–Ural anteclise (Figs. 1–3, Table 1). Such a correlation is of prime significance for the Lower Triassic stratigraphy in the east of the East European platform. A.N. Mazarovich whose hypotheses contributed much to progressing of the continental Triassic stratigraphy suggested a simple solution of the problem, the facial persistence of corresponding deposits parallel to the Urals. Based on the idea, he distinguished the uniform formations extending them from the northern platform areas to the Mt. Bol'shoe Bogdo in the south. The principal subdivisions were the Buzuluk Formation included into the Vetluga regional stage and the Tananyk Formation eventually attributed to the Baskunchak regional stage of the Caspian region together with the overlying Bogdo Formation of marine facies.

Since the 1950s, when the drilling program was in progress, the new data showed a more complex structure of the Lower Triassic, and the formations after Mazarovich were abandoned. Blom and Ignat'ev (1955) suggested a new rhythmostratigraphic approach to deposits of the Moscow syneclise. Based on paleontological evidence (finds of *Ceratodus*), Blom recognized here the upper sedimentary rhythm (Fedorovka Horizon) correlative the Baskunchak strata. Later on, it was established however that rhythms, which were regarded as readily recognizable even without a sufficient paleontological characterization, appear to be unsuitable for a reliable correlation. For this reason, Blom failed to elaborate in detail a well-substantiated stratigraphic scheme. This was an

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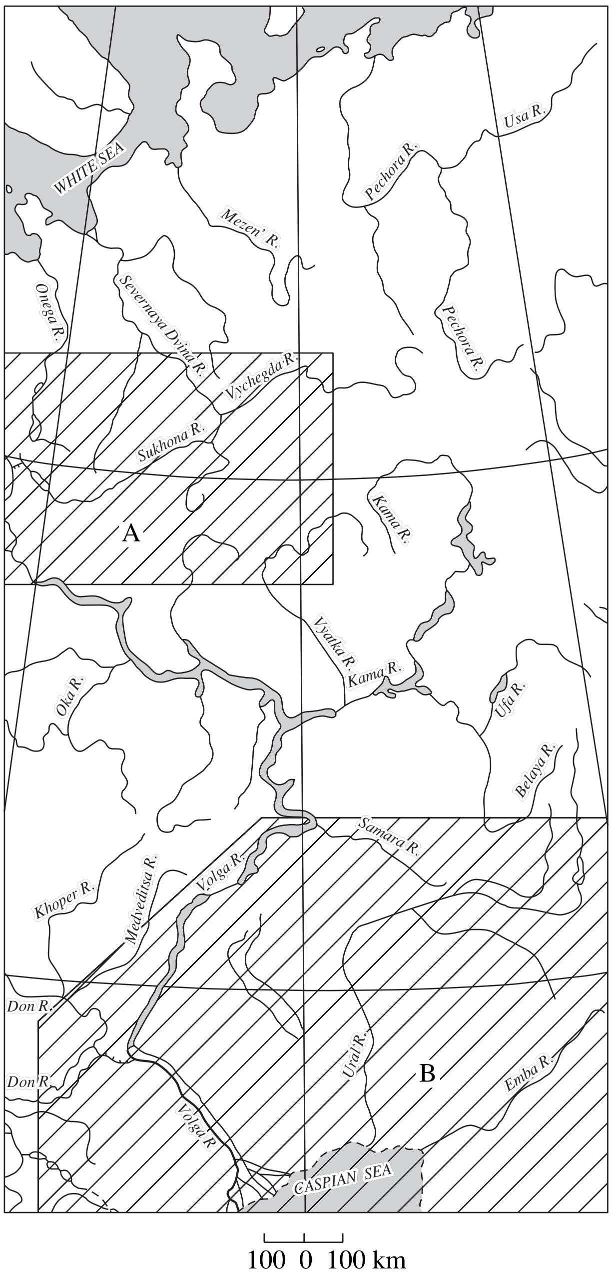

Fig. 1. Geographic areas of Triassic sections studied in Eastern Europe: (A) Moscow syneclise; (B) Cis-Urals and Caspian syneclise.

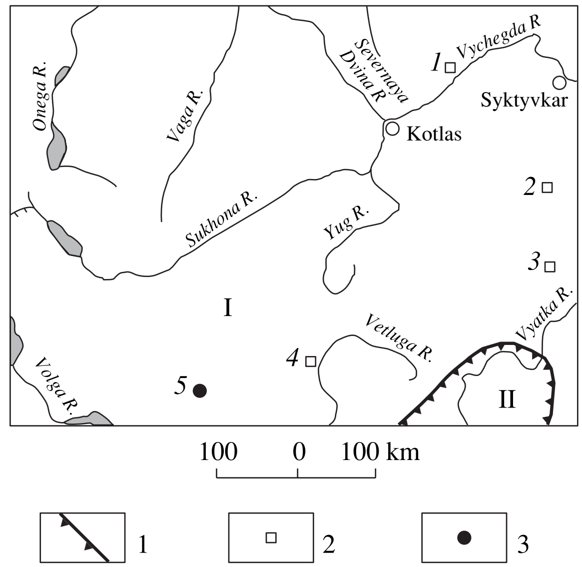

Fig. 2. Lower Triassic sections in the Moscow syneclise: (1) boundary of structural area; (2) natural exposure; (3) borehole; (I) Moscow syneclise; (II) Volga–Ural anteclise. Exposures and boreholes by sites: (*1*) Lopatino II, (*2*) Yagshordyn, (*3*) Fedorovka, (*4*) Zubovskoe, (*5*) Galich depression.

important lesson to remember. Nevertheless, the rhythmostratigraphic approach stimulated a comprehensive study of fossils distribution in the Lower Triassic sequences, especially of tetrapods, the most informative among the others.

The modern scheme of the Lower Triassic stratigraphy in the Moscow syneclise is based on terrestrial vertebrates. Being connected with early works by Efremov, it was elaborated by Shishkin who studied tetrapods and by Lozovsky who used the geological survey data to control of the succession of assemblages. As it turned out, the scheme based on all the data on terrestrial vertebrates (Shishkin and Ochev, 1967), fish remains (Minikh, 1977), and results of rhythmostratigraphy (obtained by Strok, Tverdokhlebov, and other researchers) is applicable in a vast area extending southward up to the Obshchii Syrt and southern Cis-Urals. With later corrections (Lozovsky *et al.*, 1968, 1991; Novikov *et al.*, 1990), it is possible to recognize here the Vokhma, Rybinsk, Sludka, and Ust'-Myla (insufficiently studied so far) horizons of the Vetluga Superhorizon and the Fedorovka and Gam horizons of the Yaren Superhorizon (Table 1).

In the northern Caspian region, where Triassic deposits penetrated by drilling are enormously thick (Figs. 1 and 3), their stratification is mainly based on micropaleontological records but not on tetrapod fauna, thus representing "a peculiar realm" as compared to stratigraphy of coeval deposits in northern areas of the platform. After recognition of thick Upper Triassic sequences, V.V. Lipatova and her collaborators obtained new important data. They proved a wide distribution of Middle Triassic marine deposits and worked out a new stratigraphic scheme of the Lower Triassic divided into the Ershov and Baskunchak horizons, which was approved in 1979 (*Resolutions...*, 1982). The Baskunchak Horizon stratotype corresponds to the synonymous group distinguished in the southwestern part of the syneclise, where it is divided (from the base upward) into the Akhtuba, Bogdo, and

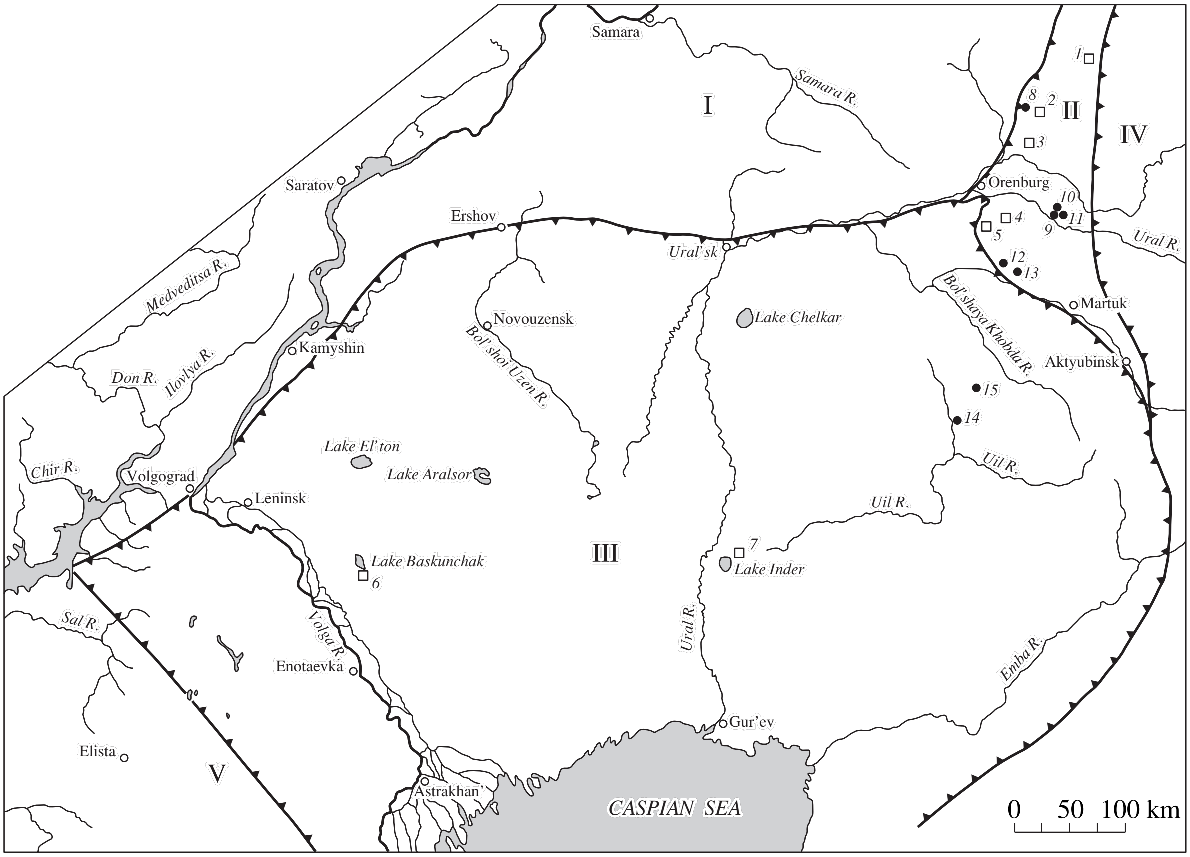

Fig. 3. Main Triassic sections in the Uralian foredeep and Caspian syneclise: (I) southeastern slope of the Volga–Ural anteclise; (II) Uralian foredeep; (III) Caspian syneclise; (IV) fold system of the Urals; (V) Karpinsky rampart; (*1*) Surakai, (*2*) Staroe Koltaevo, (*3*) Petropavlovka, (*4*) Bukobai, (*5*) Donguz, (*6*) Bol'shoe Bogdo and (*7*) Kara-Bala-Kantemir naturally exposed sections; (*8*) Borehole 150, Staroe Koltaevo site; (*9*) boreholes C-36, (*10*) 15 and (*11*) 17 in Novocherkassk basin; (*12*) Borehole 11-C, Tamarkuduk basin; (*13*) Borehole 5, Kairat site; (*14*) Khobda reference borehole; (*15*) borehole on Krasnoyar Dome (symbols as in Fig. 2).

Enotaevka formations (Table 1).[1] The Ershov and Baskunchak horizons were discriminated based on distribution of charophytes and correspond to charophyte zones I–II after Saidakovskii (zone I after Kiselevskiĭ) and zone III after Saidakovskii (zone II after Kiselevskii), respectively.

Before the meeting of 1979, the Lower Triassic was subdivided into the Vetluga and Baskunchak groups (stages of Mazarovich) in the entire eastern part of the platform. To the north of the Caspian syneclise, the boundary between groups separates, in terms of present-day nomenclature, the Ust'-Myla Horizon with its *Vetlugosaurus* fauna of tetrapods from the Fedorovka Horizon bearing the *Parotosuchus* fauna. In the Caspian region, this boundary was placed at the base of the Akhtuba Formation (Tananyk Formation of the Bol'shoe Bogdo section, according to Mazarovich). The horizons are mainly discriminated based on the mentioned charophyte zones. Representatives of the *Parotosuchus* tetrapod fauna characteristic of the northerly Fedorovka and Gam horizons are known only from the Bogdo Formation of the Caspian region, where underlying Triassic deposits yield no vertebrate remains. Accordingly, it is impossible to trace the boundary from northern to southern sections based on these poorly correlating paleontological records.

In accordance with recommendations of "The Stratigraphic Code of the USSR", the meeting of 1979 ranked former groups as regional horizons. Because the Baskunchak charophytes were detected at that time in the upper Vetluga deposits of the Moscow syneclise, the meeting discredited the unified horizons for the entire eastern part of the platform. In the north, where the Vetluga deposits were ranked as synonymous superhorizon, there was discriminated the Yaren Horizon (now a superhorizon; Lozovsky *et al.*, 1991) corresponding

[1] In the regional stratigraphic scheme of 1999, these formations are ranked as horizons, although the original subdivisions are untraceable outside the Caspian stratotype area. The horizons are incorporated into the Yaren Superhorizon, which includes the other horizons northward of the Caspian region. The situation like this is inconsistent with regulations of "The Stratigraphic Code" (1992), which unambiguously forbid a possibility to divide horizons into subhorizons, as it would be difficult to control synchronism of horizons and superhorizons over the area, where they are recognizable.

Table 1. Variants of correlation between Lower Triassic sections of the Moscow syneclise and Mt. Bol'shoe Bogdo area, one accepted at the meeting of 1999 (left) and the other one suggested in this work (right).

ISS		Moscow syneclise			Mt. Bol'shoe Bogdo area		
Stage	Substage	Super-horizon (Horizon)	Horizon	Paleomagnetic zone	Super-horizon (Horizon)	Formation, sequence	Paleomagnetic zone
Olenekian	Upper	Yaren (Baskunchak)	Gam	n_3T_1	Yaren (Baskunchak)	Enotaevka	?
				r_2T_1		Bogdo	
			Fedorovka	n_2T_1		Akhtuba	n_2T_1
	Lower	Vetluga	Ust'-Myla	m_2T_1			
			Sludka	n_2T_1	Vetluga (Ershov)	Bugrinskoe Fm. (sandstone-conglomerate and lower red clay sequences)	n_2T_1
			Rybinsk	r_1T_1			r_1T_1
Induan			Vokhma	n_1T_1			?
Tatarian	Upper		Byatka	r_3P			
				n_2P			
			Severodvinsk	r_2P			
				n_1P			

ISS		Moscow syneclise			Mt. Bol'shoe Bogdo area		
Stage	Substage	Super-horizon	Horizon	Paleomagnetic zone	Horizon	Formation, sequence	Paleomagnetic zone
Olenekian	Upper	Yaren	Gam	n_3T_1	Baskunchak	Enotaevka	?
				r_2T_1		Bogdo	n_2T_1
			Fedorovka	n_2T_1			
	Lower	Vetluga	Ust'-Myla	m_2T_1		Akhtuba	
			Sludka	n_2T_1	Ershov		
			Rybinsk	r_1T_1			
Induan			Vokhma	n_1T_1			
Tatarian	Upper		Byatka	r_3P	Byatka		
				n_2P		Sandstone-conglomerate sequence	n_2P
			Severodvinsk	r_2P	Severodvinsk	Lower red clay sequence	r_2P
				n_1P			?

M/z—magnetic polarity zones.

in range to the upper part of the Baskunchak Horizon of the Caspian region. The deposits below the Baskunchak Horizon, which were previously correlated with the entire Vetluga interval, were attributed based on charophytes to the Ershov Horizon of the Caspian region, which corresponds only to the Vokhma Horizon, the lower one in the Vetluga Superhorizon. Position of the Vetluga–Yaren boundary remained indefinite therewith in the south.

The stratigraphic position of beds with the Baskunchak charophyte assemblage (zone II after Kiselevskii) remains disputable in the Moscow syneclise. The assemblage is recovered not from the upper reference subdivisions of the Vetluga Superhorizon (Rybinsk and Sludka horizons), which yield tetrapod remains, but from structurally correlative sequence recovered by drilling in the Galich depression (Fig. 2) (Strok *et al.*, 1984). The correlation was doubted later on, and the sequence was attributed to the Pervushino Formation of the Yaren Age based on comparable cherry–red coloration of the Pervushino and Fedorovka clay beds (Lozovsky, 1992).

The new age interpretation of charophyte-bearing deposits of the Moscow syneclise persuaded the meeting of 1999 to return to the Lower Triassic stratigraphic scheme used until 1979 in the eastern part of the platform, in which the Akhtuba Formation of the Caspian region was included into the post-Vetluga interval (Table 1, left side). As a consequence, the meeting suggested to regard the Vetluga and Yaren superhorizons as units traceable throughout the region, which may substitute the Ershov and Baskunchak horizons, respectively, in the Caspian region. In our opinion, this decision is far from being unambiguous.

As noted above, the decision of 1999 (*Resolution*..., 2001) is based on the revised age of deposits with Baskunchak charophytes in the Moscow syneclise. Actually, there was no other reason for revision except for similarity between these deposits and clays of the Fedorovka Horizon. Such a diagnostic criterion is of little significance for Lower Triassic deposits of Eastern Europe. Moreover, the incorporation of the Caspian Akhtuba Formation into the Yaren Horizon is in disagreement with the following facts.

(1) The transitional assemblage of dipnoan *Gnathorhiza–Ceratodus* characteristic of the lower Yaren Horizon in northern areas (the Fedorovka, Lopatino I, Lopatino II, and Yagshordyn localities of Fedorovka age; Fig. 2) occurs high in the Baskunchak Horizon:

about 5 m below the top of the Akhtuba Formation that is not less than 55 m thick.

(2) Labyrinthodont species *Parotosuchus bogdoanus* (Woodw.) known from the lower Bogdo Formation (Mt. Bol'shoe Bogdo locality) is closer to forms of the *P. orientalis* (Otschev) group occurring in the lowermost Yaren Horizon than to those of *P. orenburgensis* (Konzh.) group found higher in this horizon. These forms differ from each other in morphology of tabulare "horns," which are thicker and curved in early *Parotosuchus* forms, such as *P. orientalis* and *P. helgolandicus* (Schroeder) or non-described species from the Fedorovka Horizon section at the Fedorovka and Luza rivers, whereas younger *O. orenburgensis* and *P. nasutus* (Meyer) had flattened and straight horns. The right tabulare base preserved in a skull fragment of *P. bogdoanus* (collection of PIN, no. 2242/23) from the Bogdo Formation is thickened like in ancestral forms.

(3) The Bogdo Formation can be correlated based on ammonites with the lower part of the upper Olenekian (the *Tirolites harti* Zone, Lozovsky, 1992), i.e., with the Yaren Horizon base.

(4) Finally, the ostracod assemblage similar, in opinion of Kukhtinov, to the Baskunchak one was discovered by Starozhilova from the upper Vetluga Superhorizon of the Cis-Urals (the Kzyl-Sai Formation section near the village of Petropavlovka, the Orenburg oblast; Fig. 3). The assemblage includes *Darvinula postparallela* Mish., *D. sedecentis* Mand., *D. designata* Schn., *D. acuta* Mish., *D.* aff. *acmayica* Schl., *D.? dubia* Starozh., *Suchonella* aff. *buginella* Mish., *Darwinula oblonga* Schn., *D. parva* Schn., *D. aceris* Mish., *D. obliqua* Gleb., *D. temporalis* Mish., *Gerdalia clara* Mish., and other forms (Tverdokhlebov, 1967). It should be noted that the correlation between the Caspian and Moscow Triassic based on ostracods is ambiguous in general, although the above ostracod assemblage is from a bordering area that was likely connected with the Caspian region in terms of zoogeography. The ostracod-bearing bed is situated 25 m below the base of the Yaren Horizon (the stratotype section of the Petropavlovka Formation with remains of labyrinthodonts Trematosauridae at the base). The overall thickness of the Kzyl-Sai Formation enclosing remains of Vetluga labyrinthodont *Wetlugasaurus* is 114 m. Accordingly, the Baskunchak ostracod assemblage from the Caspian region may characterize both the Yaren and post-Vetluga times.

Data of independent methods (in this case paleomagnetic) may clarify ambiguous relationship between the Vetluga–Yaren and Ershov–Baskunchak boundaries. Paleomagnetic measurements have been carried out in the mentioned section of the Mt. Bol'shoe Bogdo near the Lake Baskunchak (Table 1). From the top downward there are exposed the fossiliferous lower Bogdo and Akhtuba formations and barren sandstone–conglomerate and lower red clay sequences commonly attributed to the Bugrinskoe Formation, an equivalent of the Ershov Formation distinguished in the northwest of the region. The boundary between the Akhtuba Formation and sandstone–conglomerate sequence is distinctly unconformable. It is exactly this boundary that was considered as corresponding to any of two significant biostratigraphic levels of the Lower Triassic of the Moscow syneclise, i.e., to either the Vokhma–Rybinsk (the meeting of 1979) or Vetluga–Yaren (the meeting of 1999) boundaries.

In the last case, we get a simple interpretation of paleomagnetic zones r_1T_1 and n_2T_1 established in the lower Sludka and upper Sludka–Fedorovka intervals of the section (Table 1, left side). However, the resolution of 1979 also admits a plausible interpretation that is connected with idea of Mazarovich who argued for occurrence of the Upper Permian red clays in the Bol'shoe Bogdo section, which are attributed now to the Bugrinskoe Formation. In addition, the conclusion of Rykov (1958) that the boundary between the sandstone–conglomerate sequence and overlying red-clay unit (now the Akhtuba Formation) corresponds to the Permian–Triassic boundary, deserves attention. In such a case, there may be a large hiatus spanning the uppermost Permian–lowermost Triassic interval. The Akhtuba interval in the normal polarity zone can be correlated then with n_2T_1 zone in the Sludka Formation sequence, whereas sandstone–conglomerate beds spanning the lower part of the normal polarity zone can be regarded as analogs of the Vyatka deposits within paleomagnetic zone n_2P (Table 1, right side). Correlation of the zone lower part with the interval n_2T_1 would be inconsistent with the fact that any noticeable unconformity corresponding to the Permian–Triassic boundary and recognizable throughout Eastern Europe is missing below. The occurrence of the upper Tatarian deposits on salt stocks and incompleteness of their Vyatka part are not the extraordinary facts in the western Caspian region. According to Kukhtinov, the relationships like these are inferable from microfaunal records.[2]

Accepting the above interpretation, we meet another contradiction, i.e., the absence of Subzone 2 in the interval n_2T_1, which should correspond to the Ust'-Myla Horizon of the upper Vetluga Superhorizon. In the correlation chart approved at the meeting of 1999, the subzone absence may be to the Lower Triassic hiatus between the Akhtuba Formation and the sandstone–conglomerate sequence belonging to the upper Bugrinskoe Formation. However, this subzone (which has not been detected in any continuous paleomagnetic records of the East European Triassic) may be discovered after additional detailed investigations. Because of the low

[2] The absence of Permian deposits in the Bol'shoe Bogdo exposures was suggested based on drilling data implying an enormous thickness of the Lower Triassic in the northern Caspian region (Ochev, 1967). The suggestion has not been proved by facts however. The absence of Permian deposits on highly elevated domes in the western part of the depression (Lozovsky *et al.*, 1973) is also of a little significance because of disputable position of the Permian–Triassic boundary in many sections.

sedimentation rate during the Akhtuba time, this subzone may be of a minor thickness. In general, the paleomagnetic scale of Eastern Europe is extremely generalized and lacking many polarity subzones established in marine sections. Comparing it with the scale recommended in "The Stratigraphic Code of Russia" (*Supplement…*, 2000), one easily see that many polarity reversals are missing.

The above review is aimed not to argue for one of the alternatives (Table 1) but to emphasize the impossibility to make a choice at present. In other words, the accepted correlation scheme for the Lower Triassic in Caspian and northern regions, which is based on unified superhorizons, creates an impression of clearness that has not been gained in fact. The problem can be solved if stratigraphically important microfossils (charophytes) will be found in association with informative vertebrate remains of the upper Vetluga Group. The large tetrapod burials, for example, that of *Wetlugasaurus angustifrons* Riab. in the Sludka Horizon near the village of Zubovskoe at the Vetluga River, are the best localities to seek for the microfossils. The indicated section includes thin interbeds of bluish gray clays (Efremov and V'yushkov, 1955) perspective for microfossil research. The mentioned Petropavlovka section of the southern Cis-Urals is also of a great potential.

The reliable Triassic correlations need also in revision of the paleomagnetic scale. The scale available at present includes many subzones of different ranks hardly usable in practice, and this created a tendency to generalize the real patterns at the expense of details. For example, prior to the meeting of 1979, the normal polarity subzones of zone r_1T_1 were established by Molostovskii and Tverdokhlebov in the Obshchii Syrt section (Tverdokhlebov, 1975) and by Ochev (1987) in the Vokhma Horizon exposures along the Vetluga River. The subzones have not been included however in the paleomagnetic scale adopted at the meeting. The tendency to generalize the scale disagrees with interests of experts in bio- and lithostratigraphy who need subzones for detailed correlation. The detailed paleomagnetic records have been successfully by correlation of the Lower Triassic deposits in the Obshchii Syrt and southern Cis-Urals and by substantiation of the Ust'-Myla Horizon.

MIDDLE TRIASSIC

As for the Middle Triassic deposits in European Russia, which are widespread in the Cis-Urals and Caspian syneclise (Figs. 1, 3; Table 2), the problematic issue concerns their real stratigraphic range and correlation with subdivisions of the International stratigraphic scale (ISS). The problem of prime significance is position of the Anisian–Ladinian boundary in the regional reference sections. In the Lower Triassic correlation scheme substantiated by Shishkin and Lozovsky, the Vokhma Horizon corresponds to the Induan, the Rybinsk and Sludka horizons to the lower Olenekian, and the Yaren Superhorizon, to the upper Olenekian that is accepted widely. On the contrary, correlation of the Middle Triassic with the ISS is ambiguous, meeting serious contradictions, which were discussed in several publications (Kukhtinov, 1999; Ochev, 1999; Shishkin and Ochev, 2002). The main way to eliminate the uncertainties is a thorough study of highly fossiliferous Middle Triassic sequences widespread in the southern Cis-Urals and northern Caspian region. Their stratigraphic intervals (Table 2) correspond to the Donguz and Bukobai formations in the former region and to the El'ton, Inder, Masteksai, and Akmamyk formations and their analogs in the latter region (nomenclature after the unified regional stratigraphic schemes; Kukhtinov *et al.*, 2001). The long-distance correlations are mainly based on palynological and ostracods assemblages, and on remains of terrestrial vertebrates. Ages of subdivisions are usually inferred based on correlation with the Triassic deposits in the Germanic basin and, directly or indirectly, with the Alpine scale.

In general, there are three variants of correlation and dating the Middle Triassic deposits in Eastern Europe: (1) the basic variant shared by majority of experts in micropaleontology (Tuzhikova, 1975, 1979; Makarova, 1975; Makarova and Vergaĭ, 1995; Kukhtinov, 1999; Il'ina, 2001; Yaroshenko *et al.*, 2001), (2) the variant based on tetrapod distribution (Ochev and Shishkin, 1989; Shishkin and Ochev, 1992, 1999), and (3) an essentially different variant of Movshovich (Movshovich and Kozur, 1975; Movshovich, 1980, 1998), which is based on ostracod records interpreted by Kozur (Table 2). Some principal points of the variants and their substantiation are analyzed below in order to reveal possible reasons of the discrepancies. We use therewith the correlation of Triassic deposits of the Germanic basin with the ISS, as proposed by Kozur (1974, 1998).

In the Caspian region, the most significant point of controversy is positioning of the Inder–Masteksai boundary, as it is defined based on different microfossils. According to the ostracod data, this boundary is inside the basal lower Ladinian (Fassanian), and the *Pulviella aralsorica* Zone, the upper one of two Inder zones, can be attributed to the upper Anisian–lower Ladinian interval (Kukhtinov (1999). This version is accepted by all Russian palynologists who studied the northern Caspian region. For example, the spore–pollen subassemblage PA-III (1) with *Microcachryidites–Distalanulisporites* from the upper Kiil Subformation of the reference Khobda Borehole section (the age analog of the upper Inder Formation in the eastern Caspian depression) ranges from the upper Anisian to the lower Ladinian (Yaroshenko *et al.*, 2001), but it may be confined to the upper Anisian only, as suggested by Il'ina (2001).

Formerly, it was also suggested, based on pelecypod and charophyte distribution, that the Inder Horizon corresponds to the Ladinian. The recent revision (Zhidovi-

Table 2. Alternative correlations between the ISS units and Middle Triassic subdivisions in the South Caspian syneclise and Cis-Urals region

ISS		Movshovich, 1998		Shishkin and Ochev, 1999		Kukhtinov *et al.*, 2001	
Stage	Substage	Southern Cis-Urals	Northern Caspian region	Southern Cis-Urals	Northern Caspian region	Southern Cis-Urals	Northern Caspian region
Ladinian	Upper	Surakai Fm.	Lower Khobda Fm. Akmamyk and Masteksai Fms.	Bukobai Fm. Donguz Fm.	Akmamyk and Masteksai Fms. Inder and El'ton Fms.	Bukobai Horizon	Akmamyk and Masteksai horizons
	Lower	Bukobai Fm.					
Anisian	Upper	Yushatyr Fm.				Donguz Horizon	Inder and El'ton horizons
	Middle						
	Lower	Donguz Fm.	Kill (Inder) Fm.				

nov, 1998) showed however that the Inder pelecypods characterize only the Middle Triassic as a whole. Saidakovskii and Kiselevskii (1985) considered the charophyte assemblage with *Stellatochara hoellviciensis* and *Stenochara donetziana* (Zone IV spanning the Inder and Masteksai horizons) as comparable with charophytes from the upper *Ceratites* Beds and the lower Keuper of Germany, where these subdivisions are attributed to the upper Ladinian. Bilan (1988) established in Poland the analogs of the *Stellatochara hoellviciensis* Zone within the range of Upper Muschelkalk, which corresponds, according to Kozur (1998), to the greater part of Illyrian, Fassanian, and a part of Longobardian. Thus, the above charophyte assemblage implies the upper Anisian–upper Ladinian interval for host deposits, being unsuitable for a more accurate dating.

In the southern Cis-Urals (Fig. 3, Table 2), micropaleontological data indicate that the Donguz Horizon with the *Eryosuchus* tetrapod fauna is an approximate age analog of the El'ton and Inder horizons of the Caspian region. The basal part of the stratotype Donguz Formation, the eponymous river locality, is attributed based on palynological data to the middle–upper Anisian (Makarova and Vergaĭ, 1995; Il'ina, 2001; Yaroshenko *et al.*, 2001).[3] The upper part of the formation is dated in another section near the village of Staro-Koltaevo, southern Bashkiria, where deposits yield tetrapod remains. According to Tverdokhlebov who studied natural exposures of the same formation along the Bol'shoi Yushatyr River, the unit was recovered by Borehole 150 immediately below the basal Bukobai member (the stratotype of the Yushatyr' Formation after B.P. V'yushkov). At the level of 26 m below the top of the Donguz Formation (overall thickness 156 m), Makarova found the spore–pollen assemblage including the Alpine Illyrian (late Anisian) taxa *Distalanulisporites puncus* Klaus, *Concentricisporites nevesi* Antonescu, and *Triadispora crassa* Klaus, all known from the *Paraceratites trinodosus* Zone.[4]

The overlying Bukobai Formation characterizing the synonymous horizon was studied in the Bukobai Gully stratotype section near the village of Mikhailovka at the Berdyanka River (the left tributary of the Ural River). The formation encloses the *Mastodonsaurus* tetrapod fauna and rests unconformably on the erosional surface of the Donguz Formation. It is usually correlated with the Masteksai Horizon and now with the overlying Akmamyk Horizon of the Caspian region (Kukhtinov *et al.*, 2001). Specialists unanimously attributed the spore–pollen assemblages of the unit to the Ladinian Stage (Tuzhikova, 1975, 1979; Makarova, 1975; Makarova and Vergai, 1995; Yaroshenko *et al.*, 2001), whereas assemblages from the overlying gray deposits of the Surakai type are not older

[3] This correlation is substantiated in the text (Yaroshenko *et al.*, 2001) in disagreement with position of the *Paratrilites minor* assemblage shown in the table.

[4] The spore–pollen assemblage, which was previously attributed to the upper Donguz Formation and dated as Ladinian in age (Makarova and Vergai, 1995), was obtained not from the stratotype area but from the borehole the near the village of Kairat of the Martuk district, Aktyubinsk oblast. The enclosing deposits are referred now to the Donguz Formation conventionally, and the assemblage is defined as the Anisian in age (Yaroshenko *et al.*, 2001).

than the early Carnian, like their counterparts from the Surakai Formation stratotype in the eponymous basin.

It is still difficult to define the Bukobai Formation age more precisely. Some experts in palynology attribute this formation, completely (Makarova and Vergai, 1995) or without the basal beds (Tuzhikova, 1975, 1979), to the upper Ladinian. According to the other opinion (Il'ina, 2001), this subdivision spans the entire Ladinian. According to above publications, spore–pollen assemblages are uniform throughout the Bukobai Formation section and have been referred to the single of *Florinites pseudostriatus–Minutosaccus potoniei* local zone.[5]

At present, the thorough study of Middle Triassic spore–pollen assemblages from the Khobda reference borehole in the Caspian region clarified palynology of the Bukobai deposits (Yaroshenko *et al.*, 2001). In the Khobda section, the former assemblage of the Bukobai Formation is divided into the *Microcachryidites–Distalanulisporites* (partly), *Converrucosisporites conferteornatus–Illinites chitonoides*, and *Leschikisporites–Todisporites* spp. subassemblages, the second one attributed by researchers to the lower Ladinian. However, the palynological stratification that is necessary to specify the age range of Bukobai deposits has not been performed. Thus, the available data on microfossils suggest that the Inder–Masteksai and Donguz–Bukobai boundaries approximately correspond to the Anisian–Ladinian boundary.

Correlating the Middle Triassic deposits under consideration with concurrent sediments of the Germanic basin (Table 2) based on vertebrate remains, we arrive at different age assessments. The *Eryosuchus* and *"Mastodonsaurus"* faunas dominated by amphibians of the order Temnospondyli, which occur in the Donguz and Bukobai horizons respectively, are most important for stratigraphy of the southern Cis-Urals. The Germanic Middle Triassic includes three main intervals with non-marine tetrapods (predominantly amphibians of the same order). These are the Rhaetian (lower Anisian) *Eocyclotosaurus* fauna, which may include poorly studied fossils from the Lower Muschelkalk (basal middle Anisian), the Muschelkalk–Lettenkeuper boundary beds ("Grenzbonebed") with poorly studied amphibian remains, and the Lettenkeuper proper with the *Mastodonsaurus* assemblage. According to correlation charts by Kozur (1974, 1998), two latter intervals with tetrapod remains known mainly from Baden-Württemberg site correspond to the upper Ladinian.

Sections in the Cis-Ural lack analogs of the *Eocyclotosaurus* fauna and the early Anisian palynological assemblages. On the other hand, they host faunas similar to two younger Germanic assemblages in appearance and abundance of close amphibian-plagiosaur genera of the family Plagiosaurinae occurring nowhere else except Europe until the early Late Triassic. Successive species of these genera (*Plagiosuchus* of Central Europe and *Plagioscutum* of the Cis-Urals) demonstrate the same evolution pattern of dermal bone ornamentation from "vermiform" to "pustulate" (Shishkin, 1987). In the Lettenkeuper of the Germanic section, *Plagiosuchus pustuloglomeratus* Huene from Grenzbonebed[6] was succeeded by "pustulate" *P. pustuliferus* Fraas (Huene, 1922). According to this criterion, the *Eryosuchus* fauna from the Donguz Horizon of the Cis-Urals is correlative with fauna of the Muschelkalk upper horizon adjacent to Grenzbonebed, and the *Mastodonsaurus* fauna of the Bukobai Horizon is comparable with the Lettenkeuper tetrapod remains. In addition, both the Bukobai and Lettenkeuper tetrapod assemblages are dominated by giant amphibians mastodonsaurids, although the Uralian form described as *Mostodonsaurus* actually belongs to another close genus (Shishkin and Ochev, 1992). Since the Upper Muschelkalk and Lettenkeuper correspond to the upper Ladinian of the Alpine section, the boundary between two Middle Triassic horizons of the Cis-Urals can be defined based on the faunal evolution discussed above. The Bukobai Horizon with its tetrapod fauna should be not older than the upper Ladinian, and the upper limit of the Donguz Horizon is corresponding to the lower part of the upper Ladinian (Shishkin and Ochev, 1992).

Taking into account the present inadequate dating of horizons in the southern Cis-Urals (and a hiatus between them), ages estimated based on tetrapods do not differ much from inferences based on micropaleontological data. In particular, the late Anisian palynological assemblage of the upper Donguz Formation does not exclude a possibility that the *Eryosuchus* fauna might have its last occurrence in the Ladinian.

We can only state that burials of *Eryosuchus* and *Mastodonsaurus* faunas join each other at the boundary between the upper Donguz Formation (upper Anisian) and the Bukobai Formation (upper or unspecified Ladinian) that unconformably rests on erosional surface of the former. It may be possible that a large part of the Ladinian corresponds to the break in sedimentation and the renewal of fauna took place in the late Ladinian. In this case, the biostratigraphic boundary between corresponding horizons is at the same level.

In addition, plagiosaur remains of the Donguz type (*Plagioscutum ochevi?* Shishkin; Shishkin, 1987),

[5] Tuzhikova (1979) considered the palynological assemblage from the basal Bukobai sandstones (the former Yushatyr Formation) as older than that from the Bukobai Formation proper, which she attributed to the upper Ladinian. In contrast, Makarova believed that distinction between assemblages is a consequence of facies peculiarity of their host deposits (stream sediments), and that fluvial activity increased proportion of large forms with coarse ornamentation, which impart an "older" outlook to the Yushatyr assemblage.

[6] In the latest revision of the Germanic plagiosaurs (Hellrung, 2003), the holotype of *Plagiosuchus pustuloglomeratus* (a fragment of pectoral girdle) is attributed to *Gerrothorax*, but judging from the published photographs, its bad preservation gives little grounds for this interpretation.

which were found in association with ostracods of the *Lutkevichinella bruttanae* Schn. Zone and with the early–middle Anisian palynological assemblage (Makarova, 1975; Il'ina, 2001) in the El'ton Horizon of the Caspian region, can be indicative of the lower age limit of the *Eryosuchus* fauna.

At the same time, the absence of equivalent tetrapod fauna (plagiosaurs of the "vermiform" type) in the middle Anisian–lower Ladinian of the Germanic basin can be accounted for by the fact that this interval (Muschelkalk) is mainly composed of epicontinental sea facies unfavorable for preservation of terrestrial vertebrate remains (Shishkin *et al.*, 2000). All known "vermiform" plagiosaurines (attributed to *Plagiosuchus pustuloglomeratus*) from Thuringia and Lorraine of Central Europe and from Württemberg are confined to the Upper Muschelkalk of the upper Ladinian (Schoch and Werneburg, 1998).

In contrast to Middle Triassic subdivisions of the Cis-Urals, the microfossil-based ages of concurrent units in the Caspian region are in evident disagreement with inferences based on tetrapods. The main reference level here is that of tetrapod fauna buried in the upper Inder Formation at the Kara-Bala-Kantemir site near the Lake Inder (Fig. 3; Ochev, 1973, 1987; Ochev and Smagin, 1974). The fauna includes mastodonsaurs of the Cis-Urals type and abundant "pustulate" *Plagioscutum caspiense* Shishkin that is morphologically more advanced than "vermiform" *P. ochevi* of the Donguz Formation (Shishkin, 1987). Hence, this fauna is an analog of the Bukobai *"Mastodonsaurus"* fauna and may be attributed, like the latter, to the upper Ladinian. The Inder tetrapods are obviously younger than the *Eryosuchus* fauna. According to this but contrary to the common opinion, at least the upper part of the Inder Formation (the *Pulviella aralsorica* Zone) should be younger than the Donguz Formation of the Cis-Urals.

Meanwhile, as mentioned above, the upper ostracod zone of the Inder Formation is dated back to the late Anisian–early Ladinian (Kukhtinov, 1999). Palynological data imply that the upper Kiil Formation, the age analog of above zone in the left bank of the Ural River, is either concurrent (Yaroshenko *et al.*, 2001) or the late Anisian (Il'ina, 2001). In the latest correlation scheme suggested for Triassic deposits in the Cis-Ural and Caspian region (Kukhtinov *et al.*, 2001), the entire Inder Formation is referred to the Anisian despite all the disagreements with respect to microfossil-based age interpretation of its upper part, which have not been taken into account (Table 2). Thus, estimating the Inder Formation stratigraphic range based on either vertebrate remains or microfossils, we get difference equal to one substage at least.

As an argument against correlation of the *Pulviella aralsorica* Zone (or its part) with the Ladinian Stage, we should mention a opinion that the tetrapod-bearing lens of greenish gray clays belongs in the Kara-Bala-Kantemir section not to the Inder Formation, but in fact to the lower part of the overlying Masteksai Formation (*Gemmanella schweyeri* Zone of the lower Fassanian). This opinion is based on conclusions of M.N. Shelekhova who argued that palynological assemblages from the bone-bearing lens and the Masteksai Formation are similar and correlative with the Bukobai assemblage of palynomorphs (Movshovich, 1998; Lozovsky *et al.*, 2002).

The Masteksai but not Inder age of the vertebrate fauna under consideration is doubtful however. First, Starozhilova found the ostracod assemblage typical of the *Pulviella aralsorica* Zone immediately above the bone-bearing lens of the Kara-Bala-Kantemir section (Ochev and Smagin, 1974). Second, immediately below the lens, dark clays with limestone interbeds, which undoubtedly belong to the Inder Formation, enclose rare remains of the same *"Mastodonsaurus"* fauna as in the lens. It is especially important that we found at this level not the "unidentifiable bones" (Movshovich, 1998, p. 23) but remains of "pustulate" plagiosaurine *Plagioscutum caspiense* (Shishkin, 1987, p. 9), which are stratigraphically significant (Shishkin and Ochev, 2002). All these data imply an insignificant age difference between the upper Inder and lower Masteksai strata and suggest diachronism of changes in ostracod and palynological assemblages in the considered interval of the section. The hiatus between the Inder and Masteksai formations and their analogs appears to be small (if there is any) or developed locally in opinion Kukhtinov.

Thus, stratigraphic ranges of the Middle Triassic units and position of the Anisian–Ladinian boundary are still problematic in the Caspian and the Cis-Urals regions (Fig. 3, Table 2). As for the former region, it is impossible at present to suggest a model that would reconcile the mentioned discordance in age estimates based on microfossils and vertebrate fauna.

Hence, the Ladinian age of the Bukobai Formation is adopted in both correlation models discussed above. Nevertheless, they suggest a limited but different stratigraphic range for the upper part of Inder Formation: the upper Anisian–lower Ladinian interval based on microfossils or to the upper Ladinian time span based on vertebrates.

A sharply different opinion was argued for in works by Movshovich (Movshovich and Kozur, 1975; Movshovich, 1980, 1998). This researcher did not extend the Inder Formation range higher than the middle Anisian and correlated the Bukobai Formation of the Cis-Urals (without its upper part) with the upper Anisian (Table 2). In other words, he suggested a much higher position of the Anisian–Ladinian boundary in the East European sections as compared with its levels in the other correlation schemes.

Conclusions of Movshovich are based on identifications of Triassic ostracods (mostly in Caspian sections), which have been done by Kozur, and on related generalized stages in development of the Middle Triassic sedimentation in Europe. As he concluded, at the level of Inder–Masteksai boundary in the Caspian region (and correspondingly, of the Donguz–Bukobai boundary in the southern Cis-Urals) there is a hiatus spanning the upper Pelsonian–lower Illyrian and reflecting a regression episode recorded in the Middle Muschelkalk of the Germanic basin. Accordingly, the lower part of Masteksai Formation and the greater (or entire, as supposed earlier, Movshovich, 1980) interval of the Bukobai Formation have been attributed to the upper Anisian.

It is interesting that the same interval of Caspian sections (the Inder and Masteksai horizons), where Movshovich saw signs of the middle Illyrian regression, shows, in opinion of other stratigraphers, the records of progressing Illyrian–Fassanian transgression that culminated at the level of mid-Upper Muschelkalk of the Germanic basin (Lozovsky *et al.*, 2002). In this interpretation, the Inder and Masteksai formations are attributed to the upper Anisian and Fassanian, respectively.

It is obvious that conclusions of Movshovich are hardly compatible with views of other specialists based on distribution of different fossils, ostracods included, in the Middle Triassic sections of Eastern Europe. In the Caspian region, the Inder–Masteksai boundary cannot be older than the late Anisian according to the unanimous opinion (Kukhtinov, 1999; Ochev, 1999; Shishkin and Ochev, 1999; Il'ina, 2001; Yaroshenko *et al.*, 2001). In addition, neither ostracod nor vertebrate faunas suggest a noticeable hiatus between these two subdivisions (see above) and, hence, the record of regression (Lozovsky *et al.*, 2002).

Views of Movshovich are similarly incompatible with the known paleontological characterization of the Middle Triassic in the Cis-Urals, where Kozur identified ostracods from Borehole C-36 in the east of the Novocherkassk basin, 60 km eastward of the Donguz and Bukobai formations stratotype areas (Fig. 3). Basing on predominantly sediment coloration, Movshovich (1980), who followed geologists of the Gir'yal Geological Survey Team, attributed the gray colored deposits with ostracods to the Surakai Formation base above the Bukobai red beds. In opinion of Kozur, the ostracod assemblage he studied spans the interval from the upper Anisian (Illyrian) to the lower Ladinian (Fassanian).[7] The Bukobai Formation was considered therefore as corresponding to the upper Anisian (or upper Anisian–basal Fassanian in Movshovich, 1998, pp. 19, 23) and the Donguz Formation was consequently regarded as the older subdivision (Table 2).

Conclusions of Movshovich have been already commented (Shishkin and Ochev, 1992), but he insisted on them in his latest work (Movshovich, 1998) and we decided to present below some additional critical remarks. First, it is difficult to understand the reasons that compelled him to attribute the Bukobai Formation (or its larger part) to the Anisian and the Surakai Formation to the Ladinian. It is general opinion that the Bukobai Formation stratotype yields only the Ladinian assemblages of palynomorphs (Makarova, 1975; Tuzhikova, 1975, 1979; Makarova and Vergaĭ, 1995; Yaroshenko *et al.*, 2001), concurrent vertebrate remains (Shishkin and Ochev, 1992), and the Ladinian–Carnian flora (Dobruskina, 1980), whereas palynomorphs of the Surakai Formation are not older than the Carnian (Tuzhikova, 1975). These data logically imply that the ostracod assemblage from the Novocherkassk basin should be older than the Surakai Formation, and that the gray ("Surakai") color of rocks, which is characteristic of different Middle Triassic levels in sections of the Cis-Urals, cannot be used in itself as an age indicator.

For instance, Tverdokhlebov and Makarova (1976) who studied stratigraphy of disjunctive basins in the southern Cis-Urals clearly showed that the lower limit of predominantly gray deposits characteristic of the Surakai Formation is diachronous, slipping down and crossing the Bukobai and even Donguz horizons. Critical remarks of Tuzhikova (1975) cited by Movshovich (1980) only doubted their observation without concrete disproving arguments. The arguments in favor of that observation have been obtained by drilling in a peripheral area of the Tamarkuduk basin, the Sol'-Ilets district of the Orenburg oblast (Borehole 11-c Fig. 3). I.S. Makarova who studied core samples collected by V.A. Efremov showed that gray-colored deposits, which were previously referred to the Middle Jurassic (depth level of 60 m), yield the Bukobai palynological assemblage. In deposits of the same color (formerly Upper Triassic) from the depth of 142 m, she identified palynomorphs characteristic of the Donguz Horizon.

Finally, Movshovich attributes the Bukobai Formation to the Anisian Stage referring to presence of Illyrian–Fassanian ostracods at the "Surakai" Formation base in the Novocherkassk basin. However, this conclusion is in obvious disagreement with the fact that the Bukobai (Ladinian) spore–pollen assemblage found in the basin is similar in composition to palynomorphs typical of the formation stratotype. The assemblage studied by Makarova includes characteristic Bukobai species *Minutosaccus potoniei* Madl., *M. acutus* Madl., *Carnisporites mesozoicus* Klaus, *Acanthotriletes ilekensis* Kopyt., *Florinites walchius* Kopyt., *F. pseudostriatus* Kopyt., *Alisporites australis* Jersey, *Sulcatisporites reticulatus* Scheuring, *S. sulcus* Klaus and was found at the depth level of 55 m in Borehole 17 drilled by the Gir'yal Geological Survey Team (Fig. 3). Palynological assemblage typical of the Donguz Formation was detected here at the depth of 87 m.

It is difficult to understand also why Movshovich (1998) thinks that work by Dobruskina (1980) on Middle–Upper Triassic *Scytophyllum* flora from the Cis-Urals supports the Ladinian age of the Surakai Forma-

[7] Kukhtinov suggests the Fassanian interval for the assemblage.

tion. That flora is of a wider Ladinian–Carnian range and cannot help to figure out a narrower time span for sediments in question. In reality, the Late Triassic age of the Surakai Formation is substantiated by palynoflora found in this subdivision.

In addition, all the units of the Caspian region (the lower Sarpinskii Subformation and the upper part of the Masteksai Formation in the Krasnoyar dome area; Starozhilova and Shelekhova, 1987), which have been placed by Movshovich at the level the "Surakai" ostracod assemblage from the Novocherkassk basin of the Cis-Urals are correlative, in opinion of many micropaleontologists (Kukhtinov, Yaroshenko, and others), with the Bukobai Horizon of the Cis-Urals. Exactly this variant of correlation has been adopted in 1999 at the meeting on Triassic stratigraphy of the Caspian syneclise.

In general, it is clear that the key problem of the Middle Triassic stratigraphy in Eastern Europe lies in surmounting discordances between age determinations based on microfossils and vertebrates remains. It would be purposeless to extend the "interval of uncertainty" taking into account the conclusions of Movshovich (1998), which contradict all the other data.

Differences in stratigraphic position of boundaries between the Middle Triassic horizons of the southern Cis-Urals and between the Inder and Masteksai horizons of the Caspian region are undoubtedly related to subjective interpretation of some facts considered above. Each of the fossil groups studied has merits and disadvantages. Frequently occurring ostracods are facies-dependent. The long-distance correlations may be incorrect because of asynchronous appearance of particular ostracod taxa in different regions, may have concurrent ranges in some region and succeed each other in the other sections (Kukhtinov, 1999). Vertebrate remains open a wide perspective for using the evolutionary method, but they are often fragmentary and occur within very limited stratigraphic intervals. Moreover, the method of comparative evolutionary levels does not exclude a possibility of heterochronous parallelism, as the same forms could have diverging rates of evolution in different biogeographic areas. Palynomorphs occur in a more complete successions, but changes in their assemblages are less distinct than in tetrapod faunas.

Difficulties in solving the problem under consideration may be also connected with miscorrelation between Triassic deposits of the Germanic basin and Alpine region. Correlating the East European Triassic deposits with either the Alpine, or the Germanic basin scales, one will get different results in such a case.

A real way to solve this problem is to study in detail successive changes in all leading fossil groups useful for dating the East European Middle Triassic. This approach is promising much with respect to palynostratigraphy of the Bukobai Formation in the southern Cis-Urals. To rapidly establish the complete successions of diagnostic vertebrate remains is a more difficult task in the Cis-Urals and West Europe.

At the present stage of knowledge, we have no reliable base to correlate unambiguously the Middle Triassic subdivisions of the Caspian region and southern Cis-Urals with the Anisian and Ladinian stages, as it was attempted at the meeting of 1999.

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