ISSN 0869-5938, Stratigraphy and Geological Correlation, 2006, Vol. 14, No. 6, pp. 629–641. © MAIK "Nauka/Interperiodica" (Russia), 2006.
Original Russian Text © A.A. Shevyrev, 2006, published in Stratigrafiya. Geologicheskaya Korrelyatsiya, 2006, Vol. 14, No. 6, pp. 54–67.

Triassic Biochronology: State of the Art and Main Problems

A. A. Shevyrev†

Paleontological Institute, Russian Academy of Sciences, ul. Profsoyuznaya 123, Moscow, 117997 Russia

Received November 13, 2005

Abstract—According to known resolution of the IUGS, the International Stratigraphic Commission entrusted its subcommissions with a task to prepare proposals for the official approval of boundaries between Phanerozoic stages. Specially organized working groups were later renamed as special teams for seeking the Global Stratotype Sections and Points (GSSP) for these boundaries. In 2001, the GSSP of lower boundary for the Induan Stage, the basal one in the Triassic System, was officially approved to be in the Meishan section of southern China. The selection appeared to be lame, because the Permian–Triassic boundary layers of the stratotype section are lacking ammonoids. As a result, this boundary is now based only on the first occurrence level (FO) of conodont species *Hindeodus parvus.* Soon, the proposal of Chinese paleontologists to consider the western Pingdingshan section in the Anhui Province as the GSSP for the lower boundary of the Olenekian Stage may win the official recognition. This boundary between the Olenekian and Anisian stages, which is placed at the FO of conodont species *Neospathodus waageni* is the least debatable. The Mt. Desli Caira section in northern Dobrogea (Romania) is most appropriate for its global stratotype. In contrast, the Anisian–Ladinian boundary appeared to be most disputable. The Subcommission on Triassic Stratigraphy should select one of three GSSP candidates proposed. The lower Carnian boundary traditionally drawn at the *aon* Zone base suffered some changes. It is proposed to place it at the FO of the ammonoid genus *Daxatina* with the GSSP in the Dolomites of Italy. The Norian and Rhaetian boundaries are under discussion.

DOI: 10.1134/S0869593806060037

Key words: Triassic, stage boundaries, global stratotype sections and points.

Leo Tolstoy noted once: "All happy families are similar. Each unhappy family is unhappy in its own way." I think that stratigraphy of each geological system is nowadays unhappy in its own way.

One of misfortunes the Triassic stratigraphy suffers recently is connected with the fact that ammonite zonation, which served for more than a century as a basis of the international biochronological standard, is intensely forced out to be replaced gradually by the conodont standard. Stage boundaries previously substantiated by ammonoids are replaced sometimes by levels of conodont events hot always concurrent to event in ammonoid fauna. Examples are numerous.

LOWER BOUNDARY OF THE TRIASSIC SYSTEM AND ITS CORRELATION

According to proposal of Subcommission on Triassic Stratigraphy, the Executive Committee of the IUGS approved in March of 2001 the lower boundary of the Triassic System with the GSSP in the Meishan section of southern China (Orchard, 2001). It is placed at the FO of the conodont species *Hindeodus parvus* Kozur et Pjatakova (Yin et al., 2001) instead of its former position at the FO of ceratites from the genus *Otoceras.* It is now below the *Otoceras* Beds in the Central Himalayas and southern Tibet, in the middle of this unit in Kashmir, and, in fact, above the *Otoceras* Beds in the Boreal realm (from the Canadian Arctic to East Siberia).

Of interest is prehistory of this decision. In 1981, the Subcommission on Triassic Stratigraphy organized a special working group with a task to define the lower boundary of the Triassic System and select its global stratotype section. During inquiry of 1984, when the group was headed by Tim Tozer, a known expert in Triassic ammonoids, the majority of group members (16 of 18) tended at that time to accept the lower boundary of the Triassic System at the base of the *Otoceras* Beds. Ten years later, when the leadership changed and attitude in minds was under influence of active experts in conodonts, only two members of working group voted for that boundary position, while 13 members considered the FO of *H. parvus* as marking the onset of the Triassic. The opinion of working group predetermined voting results of 2000 by letters of inquiry to members of the Subcommission on Triassic Stratigraphy. Of 27 voting persons, 22 voted in favor of the conodont-based boundary in the Meishan section and only two members kept their adherence to the traditional position (Gaetani, 2000). In this case, the Napoleon's rule "The victory is always on the side of large battalions" had an effect.

† Deceased.

The GSSP selection in the Meishan section appears to be misleading, because ammonoids in this case cannot be used as an important tool of interregional correlation. Ammonoids are scarce in that section, and specimens that occur near the selected boundary are poorly preserved. According to Chinese paleontologists, black boundary clays (Bed 26) underlying the limestone member (Bed 27), in which the Permian–Triassic boundary is defined now, contain *Pseudogastrioceras, Otoceras?, Hypophiceras, Tompophiceras*, and *Pseudosageceras* (Wang, 1984; Yin et al., 1996). These ammonoids represent a mixed assemblage of Permian and Triassic forms (Dagys and Dagys, 1988; Shevyrev, 2000): *Pseudogastrioceras* with its spiral sculpture is a typical representative of the Dzhulfian–Dorashamian (Wuchapingian–Changhsingian) biota; *Otoceras* and *Hypophiceras* are characteristic of the basal Triassic; *Tompophyceras* is a Boreal genus, which appears above the *Otoceras* Beds; *Pseudosageceras* is known since the upper Induan. A surprising composition of the assemblage is obviously a result of incorrect identification of Meishan ammonoids because of their nasty preservation: shells are strongly deformed and lobe lines are usually unobservable. In such a situation, some araxoceratids could easily be taken for *Otoceras* forms. *Tompophiceras* is probably incorrectly identified *Paratirolites* or *Pseudotirolites*, while *Hypophiceras* is indistinguishable form of xenodiscids. Thus, by their paleontological characteristic, boundary clays belong to the classical Upper Permian and have nothing in common with the *Otoceras* Beds, which are usually missing from sections of the Paleo-Tethys (Djulfa, Iran, northern Thailand), the Meishan stratotype included (Shevyrev, 1999).

I cannot agree with V.R. Lozovskii (Karaulov and Lozovskii, 2002), who argued that the traditional Triassic boundary should be lowered in the Meishan section to the base of white boundary clays (Bed 25). In this section, it is most likely at the base of the limestone member (Bed 27), i.e., slightly lower as compared with its level approved officially.

Inasmuch as, the Meishan section is lacking the *Otoceras* Beds, it is impossible to establish stratigraphic relations of these beds with the FO of *H. parvus*. In classical sections of Spiti (Central Himalayas), the *Otoceras* Beds corresponding to the lower limestone member of the Mikin Formation are divisible into four subunits: the *Otoceras woodwardi, Ophiceras tibeticum, Discophiceras*, and *"Pleurogyronites" planidorsatus* ammonoid zones (Krystyn and Orchard, 1996; Orchard and Krystyn, 1998; Krystyn et al., 2004). It is noteworthy that basal layers of the mentioned member are lacking ammonoids. However, *H. parvus* has been found at this level that can be correlated, therefore, with the *Otoceras fissiselatum (=O. latilobatum*) Zone of the Selong locality (Tibet). Higher in the section, *O. woodwardi* is associated with first conodonts *Isarcicella isarcica* Sweet. In the Guryul Ravine section, which was initially considered as a possible GSSP candidate but rejected because of political instability in this area of India, *H. parvus* was found in the upper half of the *Otoceras* Beds (the *woodwardi* Zone) corresponding to Member E_2 in the Khunamukh Formation (Nakazawa et al., 1975; Nakazawa, 1993; Kapoor, 1996). In the section near the Selong Settlement (southern Tibet), *H. parvus* appears below the *woodwardi* Zone in the layer with *Otoceras latilobatum* Wang (*O. fissisellatum* Diener) corresponding to the Kanshare Formation base that overlies with a hiatus the Changhsingian Selong Formation (Jin et al., 1996).

Thus, the new Triassic boundary corresponding to the FO of *H. parvus* is located in the southern coastal areas of the Tethys either at the base of the *Otoceras* Beds, when the beds are thin, rests on underlying strata with a hiatus (Central Himalayas, southern Tibet), or is distinguishable within the beds, when the beds' section is complete and thick (Kashmir).

Let us consider now the position of officially approved boundary in Boreal sections. In sections of eastern Greenland, which contain conodonts (Teichert and Kummel, 1976; Kozur, 1998), *H. parvus* appears in the *Ophiceras spathi* Subzone, the upper one in the *Metophiceras subdemissium* Zone (Grasmuck and Trumpy, 1969; Trumpy, 1969). This level can be correlated with the uppermost part of the *boreale* Zone of Arctic Canada and *Tompophiceras pascoei* Zone of the eastern Verkhoyansk region. Consequently, the new Triassic boundary in the Boreal realm is in the uppermost part of the *Otoceras* Beds (Kozur, 1998, 2003). If this positioning is admitted, practically the complete range of *Otoceras* Beds should be attributed in the Boreal realm to the Permian, while in the Tethyan realm, the *Otoceras* Beds belong to the Triassic (Table 1).

Not all the stratigraphers who studied ammonoids agree with the above considerations and suggest different correlation schemes for the boundary interval. For example, A.S. Dagys (Dagys and Dagys, 1988; Dagys and Ermakova, 1996) believed that the *boreale* Zone is an equivalent of the *woodwardi* Zone and attributed the *concavum* Zone having no analogues in the Tethyan realm to the basal Triassic. L. Krystyn (Krystyn and Orchard, 1996) stated that the *woodwardi* Zone should be at the higher stratigraphic position than the *boreale* Zone, because a lobe line of *O. woodwardi* is more complicated than that of *O. boreale*. In the Selong section (southern Tibet), the *woodwardi* Zone occurs above the layer with *O. fissisellatum* Diener from the *O. boreale* group, and I agree with this. E.T. Tozer, who was of opinion that *concavum* and *woodwardi* zones are equivalents, while the *boreale* Zone corresponds in the Himalayas to stratigraphically higher strata (Tozer, 1988, 1994b), tends now to admit that boreal zones are at least partly older than the *woodwardi* Zone of Himalayas (Tozer, 2003, p. 90) but should be attributed to the Triassic nevertheless.

Table 1. Correlation of Permian–Triassic boundary sediments according to (Kozur, 1998, 2003)

Standard			Meishan		Selong	Spiti	Kashmir	Greenland		Canada	Verkhoyansk region
Lower Triassic (Scythian)	Brahmanian	*Ophiceras tibeticum*	28-29	*Isarcicella isarcica*	*tibeticum*	*Ophiceras tibeticum-Discophiceras* cf. *wordiei*	*tibeticum*	*decipiens*		*strigatus*	*decipiens*
								commune		*commune*	*morphaeos*
		Otoceras woodwardi-Ophiceras bandoi	27c-27d	*Hindeodus parvus*	*woodwardi*	*woodwardi-bandoi*	*parvus*				
		Otoceras fissisellatum			*fissisellatum*			*subdemissum*	*spathi*	*boreale*	*pascoei*
Upper Permian	Dorashamian	*Hypophiceras changxingense*	27a-27b	*Clarkina meishanensis-Hindeodus praeparvus*			*woodwardi-bandoi*		*boreale*		*boreale*
			26					*martini*			
			25					*triviale*			
		Rotodiscoceras asiaticum-Pleuronodoceras occidentale	24	*Clarkina hauschkei*						*concavum*	*concavum*
		Paratirolites waageni									

Based on the conodont zonation, Kozur (1988, 2003) attributes to the Triassic the Tethyan *fissisellatum (=latilobatum)* and *woodwardi-bandoi* zones and their Boreal equivalents: the uppermost *commune* Zone of Arctic Canada and the *pascoei*–basal *morphaeos* zones of Siberia. With the same grounds, he refers the Boreal *concavum* and *boreale* zones (except for the uppermost part of the latter) to the Dorashamian (Changsingian) Stage correlating them with the upper Changsingian limestones (*Paratirolites waageni*, and *Rotodiscoceras asiaticum–Pleuronodoceras occidentale* zones), transitional clays (beds 25, 26), and basal part of the boundary limestone member (beds 27a, 27b; *"Hypophiceras" changxingense* Zone) of the Meishan section (Table 1).

Being involved into study of ammonoids during many years, I cannot accept such a correlation. First, ammonoids of the mentioned Boreal zones (*Otoceras, Hypophiceras, Vishnuites*) have nothing in common with the Changsingian assemblage (*Pseudogastrioceras, Paratirolites, Pseudotirolites, Rotodiscoceras, Pleuronodoceras, Xenodiscus*, and others). Second, in the genus *Otoceras* a lobe line is much more complicated and differentiated than in the ancestral genus *Julfotoceras* from the *Paratirolites* Beds of Iran (Bando, 1973). Third, the *boreale* Zone is marked by appearance of the genus *Hypophiceras* externally very similar to Permian xenodiscids, but differing from them in the lobe line patterns: additional internal lateral lobes are characteristic of in xenodiscids, while the umbonal lobes of *Hypophiceras* like in all the Triassic ceratiins (Shevyrev, 1990, figs. 1, 2). In distinction from Kozur, I see, like late Dagys, no stratigraphic equivalents of the *concavum* Zone in Tethyan sections, where it corresponds most likely to the stratigraphic hiatus at the Permian–Triassic boundary (Table 2). Some of these sections (for example, in Kashmir) are lacking also the *fissisellatum* Zone corresponding to the most part of the *boreale* Zone. In other words, the ammonoid standard proposed by Kozur (1998, 2003) for the Permian–Triassic boundary interval is lacking equivalents of the Boreal *concavum* Zone.

LOWER TRIASSIC STAGES

The next point to be concerned is name of the basal Triassic stage. After approval of the Triassic basal boundary, the Induan Stage of Kiparisova and Popov (1956) that was accepted by Subcommission on Triassic Stratigraphy in 1992 (Visscher, 1992) should get a firm official status, as one could expect. Nevertheless, this did not happen. The Induan Stage still irritates some people. Kozur, a German paleontologist living now in Hungary, is particularly active in rejecting appropriateness of the Induan Stage. He argues that this stage in its new range is analogous the Brahmanian Stage defined more than a century ago by known Viennese scientists E. Mojsisovics, W. Waagen, and C. Diener (Mojsisovics et al., 1895), and this name has historical priority. In addition, the name Induan is incorrect in opinion of Kozur, because the eponymous river is spelled Hindus in English and German and, consequently, the stage should be termed as Hindusian. These attacks are unsuccessful so far: the Induan Stage remains in the stratigraphic nomenclature of the Triassic System being of broad use in Russian literature and abroad. It is hardly reasonable to restore the old thoroughly forgotten name that was a century out of the use.

The Olenekian Stage also proposed by Kiparisova and Popov (1956) is admitted by the Subcommission on Triassic Stratigraphy, although the GSSP for its lower boundary is officially not approved so far. Five sections claim to this honorary role: one in Siberia (eastern Verkhoyansk region), two in the southern Primor'e (Cape Tri Kamnya and Abrek Bight), one in southern China, and one in the Central Himalayas (Spiti).

Adherents of the first section believe that the Olenekian boundary stratotype should be located in East Siberia, where this stage was first defined. Sections in the Tompo River basin, where the transition between the Induan and Olenekian stages is gradual, are considered most promising (Dagys, 1995, 1997; Ermakova, 2004). The Siberian sections contain remarkably abundant, diverse and well-preserved ammonoids, used to elaborate a detailed zonal scale for the Olenekian Stage (Dagys and Ermakova, 1993; Dagys, 1994, 1999; Dagys and Sobolev, 1995). The scale includes 7 zones (from the *Hedenstroemia hedenstroemi* to *Olenikites spiniplicatus* zones) and 12 subzones. It can rightfully be considered as the Boreal and global biochronologic standard of the Olenekian Stage (Shevyrev, 2002). The only disadvantage of Siberian sections is difficult accessibility.

One of the advantages of sections in the southern Primor'e region is presence of Boreal fossils, which make interregional correlation easier. Zakharov (1994), who heads the working group on the Induan–Olenekian boundary, considered first the section near Cape Tri Kamnya in the western part of the Ussuri Bay as a GSSP candidate. Later on, he and his team proposed the section in the Abrek Bight of the Strelok Bay for this role (Zakharov et al., 2002). In this section, the base of the Olenekian Stage corresponds to the *Hedenstroemia bosphorensis* Zone, although the stage begins, in fact, with the first appearance of *Meekoceras boreale* Diener, not of index species.

Some stratigraphers think that the global stratotype section and point for the lower boundary of the Olenekian Stage should be located in the Tethyan realm, since GSSPs of all other Triassic stages are selected in this region. They consider the Pingdingshan section near Chaohu in the Anhui Province of eastern China as the best candidate. Zakharov (2004) tends to accept this view. It is proposed to place the lower boundary of the Olenekian Stage in this section at the FO of conodont species *Neospathodus waageni* Sweet. The problem is, however, that this taxon is represented in that section by

Table 2. Correlation of Permian–Triassic boundary sediments that seems most reasonable

		Standard	Meishan		Selong	Spiti	Kashmir	Greenland		Canada	Verkhoyansk region
Lower Triassic	Induan	*Ophiceras tibeticum*	28-29	*isarcica*	*tibeticum*	*tibeticum*	*tibeticum*	*commune*		*commune*	*morphaeos*
		Otoceras woodwardi			*woodwardi*	*woodwardi*	*woodwardi-bandoi*	*subdemissum*	*spathi*	*boreale*	*pascoei*
		Otoceras fissisellatum	27	*parvus*	*fissisellatum*	*fissisellatum*?			*boreale*		*boreale*
								martini		*concavum*	*concavum*
								triviale			
Upper Permian	Dorashamian (Changhsingian)	*Xenodiscus changxingensis*	25-26	*meishanensis-praeparvus*							
		Rotodiscoceras asiaticum-Pleuronodoceras occidentale	24	*hauschkei*							
		Paratirolites waageni									

three morphotypes *N. waageni* subsp. A, *N. waageni* subsp. B, and *N. waageni waageni*, which appear at different stratigraphic levels (Zhao et al., 2004; Tong et al., 2005): 26, 3, and 48 cm, respectively, above the stage base placed at the basal level of the *Flemingites–Euflemingites* Zone. Chinese stratigraphers support the last variant, because the gap between the ammonite- and conodont-substantiated boundaries is 0.5 m in this case. In order to make the boundaries closer, Kozur (2003, Table 1) placed the conodont-based boundary lower at the FO of *Chengyuania nepalensis* (Kozur et Mostler), which coincides, in his opinion, with the base of the *Flemingites flemingianus* ammonite zone, the basal Olenekian zone in the Salt Range.

The western Pingdingshan section is well exposed, thoroughly studied, easily accessible, and convenient for investigations. As a candidate for the GSSP, it has a real chance to win this status, and Chinese scientists are perfectly aware of that. In order to achieve this purpose, they invited in May of 2005 the International Symposium on Triassic Chronostratigraphy and Biotic Renovation, the participants of which had opportunity to get acquainted with sections in the Chaohu vicinity. They enclose five conodont and four generic ammonite Olenekian zones: *Flemingites–Euflemingites, Anasibirites, Columbites–Tirolites*, and *Subcolumbites* (Tong and Zakharov, 2004; Tong et al., 2004b, 2005). It should be noted that ammonoids, particularly Olenekian specimens, are usually preserved in these sections as impressions, which are practically unsuitable for determination of their species affinity.

Finally, one more section of Induan–Olenekian boundary sediments is known long ago near Mufa in the Central Himalayas. Recently, it was studied by Italian and Austrian paleontologists (Krystyn et al., 2004). According to preliminary data, the ammonoid-based boundary does not coincide here, like in China, with the conodont-substantiated one being below the FO of *N. waageni.* The Himalayan section is less thoroughly studied as compared with the Pingdingshan one. At the same time, it surpasses the latter in diversity and preservation degree of ammonoids from boundary layers. Classical sections of the Salt Range in Pakistan rich in Early Triassic ammonoids should also be kept in mind, when selecting the GSSP.

MIDDLE TRIASSIC STAGES AND GLOBAL STRATOTYPES OF THEIR BOUNARIES

The Olenekian–Anisian (or Lower–Middle Triassic) boundary is likely one of the safest. In anonymous opinion of participants of the International Working Meeting held in Tulcea (June 7–10, 2000), the section of massive thick-bedded limestones located at Mt. Desli Caira in northern Dobrogea (Romania) is most suitable for the relevant GSSP. Uniform lithology, continuous sedimentary succession, and representative paleontological characteristic make it advantageous among other boundary sections of this stratigraphic interval in the Tethyan realm (Albania, Greek Chios Island, the Kocaeli Peninsula in Turkey). The lower boundary of the Anisian Stage is defined here at the level of synchronous appearance of conodont species *Chiosella timorensis* (Nogami) and ammonoid genera *Paracrochordiceras, Aegeiceras*, and *Japonites* (Gradinaru, 2000; Gradinaru et al., 2002). In North America, excellent sections of Lower–Middle Triassic boundary sediments are known in the Humboldt Range, Nevada, where this boundary is located between the *Neopopanoceras haugi* Zone and with *Japonites welteri* Bucher Beds. These boundary sediments yielded recently bed-by-bed described ammonoid assemblages with new genera and species (Bucher, 1989; Guex et al., 2005a, 2005b). Sections of the Russkii Island, the Primor'e region, are also promising for the study of Olenekian–Anisian boundary sediments (Zakharov et al., 2004).

The Anisian–Ladinian boundary is the most debatable stage boundary in the Triassic System. The problem was discussed at the International meeting held in Vespreme (September 6–8, 2002). Being unanimous that this boundary should be placed somewhere between the Alpine *trinodosus* and *curionii* zones, specialists diverge significantly in their opinions concerning its position within this stratigraphic interval (Shevyrev, 2003). Three possible variants of its position, which are under debates, correspond to basal levels of the *reitzi* or *avisianum* subzones and of the *curionii* Zone (Table 3).

Some stratigraphers suggest placing the lower Ladinian boundary at the base of the *reitzi* Subzone with the GSSP near Felsöörs on the Balaton Highland in Hungary (Vörös et al., 2003). In opinion of Kozur (2003), precisely this variant is most preferable. This boundary has the historical priority. In addition, this level is characterized by sharp changes in the composition of radiolarian assemblages; slightly lower, the composition of foraminifers and sporomorphs changes notably as well. On the other hand, there are no substantial changes in evolution of ammonoids recorded across this boundary. Besides, species *Reitziites reitzi* (Böckh), whose FO event marks the boundary, is of a relatively low correlation potential: it is widespread in the Tethyan realm being unknown in North America.

Other researchers propose to define the Anisian–Ladinian boundary slightly higher, at the base of the *avisianum* Subzone with the GSSP near Bagolino in the Lombardian Alps of Italy (Mietto et al., 2003a, 2003b). They refer to a significant renovation of ammonoids at this level, widespread occurrence of zonal species *Aplococeras avisianum* (Mojsisovics,) in the Southern Alps and Balaton Highland, and to presence of close species in Nevada sections. As for disadvantages of this variant, I should point to scattered distribution of *A. avisianum* in the Southern Alps and problems in defining FO of this species that is scarce or absent in distal basinal facies and has poorly developed morphological features to be identified confidently (Brack et al., 2003). In addition, this boundary is characterized by insignificant changes in radiolarian assemblages being poorly distinguishable also based on conodonts (Kozur, 2003).

In opinion of some experts, the most appropriate for the Ladinian lower boundary is the base of the *curionii* Zone with the GSSP in one of the sections near Bagolino (Brack et al., 2003). As for arguments against this variant, its acceptance would narrow the range of the lower Ladinian (Fassanian) by one–two ammonoid zones, the substage would be twice smaller so that the typical Ladinian dasicladacean assemblage *Diplopora annulata* turned out to be in the Anisian (Balini, 2003; Kozur, 2003).

According to Kozur (2003), the Bagolino section proposed for the GSSP is lacking radiolarians that play an important role in Middle Triassic biostratigraphy. The correlation potential of the section is limited in this aspect, and its sediments subjected to thermal alteration are inappropriate for isotopic and magnetostratigraphic studies.

Nevertheless, I prefer precisely this variant (Shevyrev, 2003). First, genus *Eoprotrachyceras*, a progenitor of the superfamily Trachycerataceae, which is an important taxon of Triassic ammonoids, appears at this level. Second, the boundary at the base of the *curionii* Zone is readily traceable in the Old and New World, being concurrent to basal levels of the *subasperum* and *matutinum* zones in Nevada (the United States) and British Columbia (Canada), respectively. Some opponents (Kozur, 2003, p. 58; Mietto et al., 2003a, p. 452; Vörös et al., 2003, p. 44) cast doubts on the synchronous appearance of *E. curionii* (Mojsisovics), *E. subsasperum* (Meek), and *E. matutinum* Tozer, but nobody proved the reverse. It should be noted also that conodonts of the genus *Budurovignathus*, which can also be used for correlation of this boundary (Kozur, 2003), appears in the middle of the *curionii* Zone (between the *curionii* s. str. and *recubariense* subzones). As for the Bagolino section as a GSSP candidate, despite its all shortages, it has the undoubted and important advantage: abundant and diverse ammonoids occur here as a continuous succession of zonal assemblages (Brack and Rieber, 1993; Brack et al., 1995, 2003; Mietto et al., 2003a, 2003b)). It is suggested to select a supplementary section with representative palynomorph assemblages and sediments favorable for magnetostratigraphic studies in the Dolomites (Balini, 2003, p. 51). The section in the Humboldt Range (Nevada) could be the reference one for the Anisian–Ladinian boundary sediments in the North American continent.

Italian stratigraphers (Mietto and Manfrin, 1995; Mietto et al., 2003a) proposed recently the detailed ammonoid zonation for the Middle Triassic of the Tethyan realm, which was established in the Southern Alps. In turn, Russian specialists proposed similar well-substantiated zonation for the Boreal realm (Dagys and Konstantinov, 1986, 1995; Dagys, 1988; Dagys et al., 1991; Konstantinov, 1991, 2000). Detailed stratigraphic schemes were suggested also for Anisian and Ladinian sections of British Columbia (Tozer, 1984, 1994a) and the western United States (Silberling and Tozer, 1968; Silberling and Nichols, 1982).

Table 3. Possible variants of the Anisian–Ladinian boundary

Lower Ladinian (Fassanian)	*Eoprotrachyceras curionii*	*Xenoprotrachyceras recubariense*
		Eoprotrachyceras curionii
—— 3 ——		
Upper Anisian (Ilerdian)	*Nevadites secedensis*	*Chieseiceras chiesense*
		Serpianites serpianensis
		Ticinites crassus
	Reitziites reitzi	*Aplococeras avisianum*
—— 2 ——		
		Reitziites reitzi
—— 1 ——		
		Hyparpadites liepoldi
		Kellnerites felsoeoersensis
	Paraceratites trinodosus	*Lardaroceras pseudohungaricum*
		Asseretoceras camunum

UPPER TRIASSIC STAGES AND GLOBAL BOUNDARY STRATOTYPES

The next problem of concerns is position of the Ladinian–Carnian (or Middle–Upper Triassic) boundary. Until recently, this boundary was most stable in the Triassic. For more than a century, it was placed at the base of the *Trachyceras aon* Zone in the Alps, *Trachyceras desatoyense* Zone in the United States and British Columbia, and *Stolleyites tenuis* Zone of Spitsbergen and Siberia (Table 4). It was thought that first representatives of the genus *Trachyceras* in Alpine sections appeared at this level. At the end of the last century, two species of this genus, namely *T. bipunctatum* (Munster) and *T. muensteri* (Wissman), were however found in the Dolomites slightly below the *aon* Zone together with first representatives of the genus *Daxatina* and superfamily Clydonitaceae. The respective *Daxatina* cf. *canadiensis* Subzone corresponds to the basal part of the *Trachyceras* Zone (Mietto and Manfrin, 1995) or to the *Daxatina canadensis–Frankites sutherlandi* Zone (Kozur, 2003). It was suggested to define the Carnian

Table 4. Former (1) and new (2) Ladinian–Carnian boundaries and their correlation

<table>
<tr><th>1</th><th>2</th><th>Alps</th><th>United States</th><th colspan="2">British Columbia</th><th>Spitsbergen</th><th>Siberia</th></tr>
<tr><td rowspan="2">Carnian</td><td rowspan="3">Carnian</td><td>Trachyceras aonoides</td><td rowspan="2">Trachyceras desatoyense</td><td colspan="2" rowspan="2">Trachyceras desatoyense</td><td rowspan="2">Stolleyites tenuis</td><td rowspan="2">Stolleyites tenuis</td></tr>
<tr><td>Trachyceras aon</td></tr>
<tr><td rowspan="4">Ladinian</td><td>Daxatina cf. canadensis</td><td rowspan="2">Frankites sutherlandi Beds</td><td rowspan="2">sutherlandi</td><td>Asklepioceras laurenci</td><td>Daxatina canadensis</td><td>Nathorstites lindstroemi</td></tr>
<tr><td rowspan="3">Ladinian</td><td>Frankites regoledanus</td><td>Frankites glaber</td><td rowspan="2">Nathorstites macconnelli</td><td>Nathorstites macconnelli</td></tr>
<tr><td rowspan="2">Protrachyceras archelaus</td><td rowspan="2"></td><td colspan="2">Maklearnoceras maclearni</td><td>Nathorstites maclearni</td></tr>
<tr><td colspan="2">Meginoceras meginae</td><td>Indigirites tozeri</td><td>Indigirites krugi</td></tr>
</table>

Stage lower boundary at the base of these units. The Prati-di-Stuores (or Stuores Wiesen) section in the southern flank of the ridge separating the Badia and Cordevole river valleys in the Dolomitic Alps of Italy is suggested to be the GSSP for the new boundary (Broglio Loriga et al., 1999).

As far as it possible to judge from published data, West European stratigraphers are in favor of this Carnian base. It is of a high correlation potential and readily distinguishable, for example, in sections of the Central Himalayas (Balini et al., 2004; Krystyn et al., 2004), although, in my opinion, it is in second place after the traditional one. For example, the new boundary is insufficiently well traceable in North America, where it is inside the *Frankites sutherlandi* Beds of the United States or in the *sutherlandi* Zone of British Columbia (Table 4). According to Kozur (2003, p. 64), the new Carnian boundary is substantiated by palynomorphs, which are of a high potential for correlation with continental facies, because *Patinosporites densus* Leschik and *Vallasporites ignacii* Leschik in the Prati-di-Stures section appear slightly above the ammonoid-based boundary.

The problem of subdividing of the Carnian into substages remains unsolved. Long ago, Mojsisovics divided this stage into the lower or Cordevolian, middle or Julian, and upper or Tuvalian substages (Mojsisovics et al., 1895). He defined one zone per each substage: *aon, aonoides*, and *subbullatus* in the Cordevolian, Julian, and Tuvalian, respectively. When developing the Triassic zonal standard, Tozer (1967) noted affinity of ammonoids from the *aon* and *aonoides* zones and suggested to divide the Carnian Stage in two substages. Krystyn (1974, 1978) who supported this suggestion lowered the rank of two above zones to subzones of the new *aonoides* Zone. After this, the Cordevolian and Julian substages became practically synonymous and Krystyn suggested to retain name Julian for the lower Carnian substage.

Ulrichs (1994) argued against this suggestion. Restoring the zonal rank of the *aon* and *aonoides* subzones, he replaced the name Julian for Cordevolian because both zones are better presented in the Dolomites, a type area of the *aon* Zone (i.e., of the Cordevolian), than in the Julian Alps, the type area of the *aonoides* Zone and Julian Substage.

Kozur (2003) found a simplest solution of the problem. He suggested to return to former three-member division of the Carnian into the Cordevolian, Julian, and Tuvalian substages with the *canadiensis–sutherlandi* and *aon* zones in the first, *aonoides* and *austriacum* zones in the second, and *dilleri, welleri*, and *macrolobatus* zones in the third. Inasmuch as all the American and Russian stratigraphers accepted already the two-member division of the Carnian, it is hardly reasonable to return to the variant of Mojsisovics. In addition to the Alps, detailed zonal scales of the Carnian are developed also for British Columbia (Tozer, 1994a) and Siberia (Konstantinov and Sobolev, 1999a, 1999b).

The intricate history of the Norian Stage is described elsewhere (Shevyrev, 1986). It should be noted only that it is divided into three substages; proper names Lacian, Alaunian, and Sevatian proposed by Mojsisovics (Mojsisovics et al., 1895) for the substages are adopted in the West European stratigraphy. E.T. Tozer, a Canadian geologist, contributed much to the current Norian stratigraphy. In the course of detailed study in British Columbia, he defined a distinct ammonoid succession and grounded relevant zonation of the Norian Stage (Tozer, 1965), which differed from the Mojsisovics scheme in some intervals. Tozer placed the Norian lower boundary at the base of the *Mojsisovicsites (=Stikiniceras) kerri* Zone that overlies the uppermost analogues of the Alpine Carnian. The Tozer's study stimulated Austrian geologists to propose a new zonation for the Alpine Norian close to the North American standard (Krystyn, 1974; Krystyn et al., 1980). The last author defined at the base of the Norian Stage the *Guembelites jandianus* Zone equivalent to the Canadian *kerri* Zone. Thus, basal levels of the *jandianus* and *kerri* ammonoid zones were taken for the Norian lower boundary in the Tethyan and North American regions, respectively.

Changes in conodont assemblages across or near this boundary are of correlation value. According to Krystyn et al. (2002), the boundary coincides with the FO of *Metapolygnathus communisti* B in the Tethyan realm. Kozur (2003) correlated it with the appearance levels of *Epigondolella orchardi* Kozur and *Norigondolella navicula* (Huckriede) in the Tethyan realm and of *Metapolygnathus primitius* (Mosher) in North America. Based on the study of sections in British Columbia, Orchard (2004) admits three variants of the boundary position: at FOs of *Metapolygnathus* n. sp. A, *M. primitius* (Mosher), and *M. parvus* Kozur.

Sections of several localities are proposed as the GSSP candidates for the Carnian–Norian boundary: *Silická Brezová* in Slovakia (Channel et al., 2003), Pignola in the Southern Apennines (Mastandrea et al., 2004), Pizzo Mondello in Sicily (Muttoni et al., 2001), Kavalaani in Turkey (Gallet et al., 2000), and Black Bear Ridge in British Columbia (Orchard et al., 2001). Some of them correspond to strongly condensed thin Hallstatt limestones (Silická Brezová, Kavalaani) with comprehensive paleontological characterization, while the others contain conodonts and radiolarians, but are lacking ammonoids and bivalves. The Pardonet Hill section in British Columbia, where the Carnian–Norian boundary strata contain conodonts and ammonoids (Orchard, 1991; Tozer, 1994a) is likely a best candidate for the GSSP.

Let as consider now the Rhaetian Stage and relevant problems. Gümbel (1859) was first to define this stage as the upper unit of the Alpine Keuper and named it the Rhaetian Group or Formation. In his understanding, the unit included the Kessen Beds and Dachstein Limestone widespread in the Northern Calcareous Alps. The lower boundary corresponds to the top of the Plattenkalk and Hauptdolomit members and the upper one coincides with the base of the Hettangian *planorbis* Zone. Characteristic Rhaetian fossils are brachiopods and diverse bivalve species, one of which is index species of the *Rhaetavicula contorta* zone. The Kessen Formation section in the Kendelbachgraben southeast of Salzburg is accepted as the Rhaetian stratotype.

Since the basal part of the Kessen Formation composed of shallow-water sediments overlying lagoonal limestones is lacking stratigraphically significant fossils, it is impossible to determine its lower boundary in the Upper Triassic zonal standard. Therefore, the base of the Kessen Formation is unsuitable for the GSSP of the Rhaetian lower boundary (Golebiowski, 1990; Krystyn, 1990; Tozer, 1990). Taking this into consideration, the last author proposed in the initial 1980s to repudiate the Rhaetian as an autonomous stage and include equivalent strata into the upper Norian (Sevatian), since late Norian and Rhaetian ammonoid assemblages are similar (Tozer, 1980, 1981). Later on, he tried to use as an argument the uppermost Triassic layers in the North Caucasus, where, he argued, Norian ammonoids were found inside beds with Rhaetian brachiopods, in a peculiar "Rhaetian–Norian sandwich" in his formulation (Tozer, 1988, p. 13). I think that Canadian geologist was led astray. In this particular case, we deal with smooth-shelled (leostracean) ammonoids belonging to long-lived genera (*Placites, Megaphyllites, Phacophyllites, Arcestes*), which are known in both the Norian and Rhaetian sediments. Therefore, their association with Rhaetian brachiopods is quite natural (Shevyrev, 1995). The Tozer's "sandwich" appeared to be a lame metaphor.

Despite all his efforts, Tozer failed to persuade European stratigraphers in his standpoint. They refused to reject the Rhaetian Stage. Ager (1987), an English paleontologist declared openly his love of the Rhaetian. An immediate answer of Tozer (1988, p. 9) was that this love made Ager blind. Golebiowski (1990, p. 25), who interfered in their duel, declared that such a dispute threatens to turn into a soap opera with the Rhaetian playing a role of a guileful lover.

Defending the Rhaetian as an autonomous stage, stratigraphers diverged in their views on its range (Table 5). Tollman (1985) placed the Rhaetian lower boundary at the base of the upper Norian (Sevatian), i.e., at the base of the *Monotis* Beds. Krystyn (1990; Krystyn and Kürschner, 2004) correlated the Rhaetian Stage with the *Vandaites stuerzenbaumi* (lower Rhaetian) and *Choristoceras marshi* (upper Rhaetian) zones. The married couple Algirdas and Alevtina Dagys (Dagys and Dagys, 1994) proposed a compromise variant placing the Rhaetian lower boundary at the base of the *Sagenites reticulatus* Zone, i.e., at the top of the *Monotis* Beds. Based on British Columbia sections, Orchard and Tozer (1997, p. 685) arrived at the conclusion that the base of the *Paracochloceras amoenum* ammonoid zone and coeval *Epigondolella (=Orchardella) mosheri* conodont zone is the most suitable level for the Rhaetian lower boundary in North America. Kozur (2003) believes that this boundary should be correlated with the FO of the ammonoid genus *Cochloceras* (the *C. suessi* Zone) and conodont

Table 5. Views on position of the Rhaetian lower boundary

<table>
<tr><th colspan="3">Tollmann, 1985</th><th colspan="4">Krystyn, 1990</th><th colspan="2">Dagys and Dagys, 1994</th><th colspan="3">Orchard and Tozer, 1997</th><th colspan="3">Kozur, 2003</th></tr>
<tr><td rowspan="7">Rhaetian</td><td rowspan="4">Isontian</td><td rowspan="4">marshi</td><td rowspan="4">Rhaetian</td><td rowspan="2">upper</td><td rowspan="2">marshi</td><td>marshi</td><td rowspan="6">Rhaetian</td><td rowspan="2">marshi</td><td rowspan="5">Rhaetian</td><td colspan="2" rowspan="4">crickmayi</td><td rowspan="5">Rhaetian</td><td rowspan="2">marshi</td><td>marshi</td></tr>
<tr><td>ammonitiforme</td><td>ammonitiforme</td></tr>
<tr><td rowspan="2">lower</td><td rowspan="2">stuerzenbaumi</td><td>stuerzenbaumi</td><td rowspan="2">stuerzenbaumi</td><td rowspan="2">stuerzenbaumi</td><td>stuerzenbaumi</td></tr>
<tr><td>haueri</td><td>haueri</td></tr>
<tr><td rowspan="3">Sevatian</td><td rowspan="3">suessi</td><td rowspan="5">Norian</td><td rowspan="3">Sevatian</td><td colspan="2" rowspan="2">reticulatus</td><td rowspan="2">reticulatus</td><td colspan="2">amoenum</td><td colspan="2">Cochloceras suessi</td></tr>
<tr><td rowspan="4">Norian</td><td rowspan="2">upper</td><td rowspan="2">cordilleranus</td><td rowspan="4">Norian</td><td rowspan="2">Sevatian</td><td>reticulatus</td></tr>
<tr><td colspan="2">quinquepunctatus</td><td rowspan="3">Norian</td><td>quinquepunctatus</td><td>quinquepunctatus</td></tr>
<tr><td rowspan="2">Norian</td><td rowspan="2">Alaunian</td><td>macer</td><td rowspan="2">Alaunian</td><td colspan="2">macer</td><td>macer</td><td rowspan="2">middle</td><td rowspan="2">columbianus</td><td rowspan="2">Alaunian</td><td>macer</td></tr>
<tr><td>hogarti</td><td colspan="2">hogarti</td><td>hogarti</td><td>hogarti</td></tr>
</table>

species *Misikella posthernsteini* in the Tethyan realm and with the FO of ammonoid *Paracochloceras amoenum* and conodont species *Orchardella mosheri* in North America.

The ammonoid-bearing Zlambach Formation in the Kleine Zlambachgraben near Bad Goisern, Austria (Krystyn, 1990; Krystyn and Kürschner, 2004) and Sandylands Formation in the Charlotte Islands, Canada (Carter and Orchard, 2004) with substantial changes in radiolarian and conodont assemblages at this level are proposed as candidates for the Rhaetian GSSP.

It is a pleasure to note that after long and implacable fight, Tozer accepted finally the Rhaetian as an autonomous stage of the Triassic System (Orchard and Tozer, 1997). There is a hope that the world community of experts in the Triassic stratigraphy will be able to reach also agreement in other unsolved problems to become finally a happy family.

CONCLUSIONS

(1) The officially approved lower Triassic boundary is traceable at the base of the Tethyan *Otoceras fissisellatum* and Boreal *Otoceras boreale* zones. Analogues of the *Otoceras concavum* Zone are unknown in the Tethyan realm.

(2) The Induan Stage, which gained a universal admittance during its half-century history, should be kept in the stratigraphic nomenclature of the Triassic System.

(3) The Central Himalayan and Salt Range classical sections are most suitable for the GSSP of the Olenekian lower boundary.

(4) The world-traceable base of the *Eoprotrachyceras curionii* Zone is the most appropriate for the lower boundary of the Ladinian Stage with the GSSP in the Bagolino locality (Lombardian Alps).

(5) The base of the *Daxatina* cf. *canadiensis* Subzone could be accepted for the Carnian lower boundary with the GSSP in Prati-di-Stuores (Italian Dolomites). The two-member division of the Carnian Stage should be retained.

(6) It is necessary to find a candidate for the GSSP of the Norian lower boundary substantiated jointly by conodonts and ammonoids.

(7) Two variants are possible for the Rhaetian Stage: either to correlate it with the *Vandaites stuerzenbaumi* and *Choristoceras marshi* zones or to place its lower boundary slightly lower, at the FO of the genus *Cochloceras*, with the GSSP in the Kleine Zlambachgraben near Bad Goisern in Austria.

Reviewer A.G. Konstantinov

REFERENCES

1. D. V. Ager, "A Defense of the Rhaetian Stage," Albertiana, No. 6, 4–13 (1987).

2. M. Balini, "The proposals for the GSSP of the Ladinian Stage: Pros and Cons of a Complex Choice," Albertiana, No. 28, 48–53 (2003).
3. M. Balini, L. Krystyn, and A. Nicora, "Ladinian–Carnian Boundary Sections in Spiti (Tethys Himalayas, India)," Albertiana, No. 31, 6–7 (2004).
4. Y. Bando, "On the Otoceratidae and Ophiceratidae," Sci. Rep. Tohoku Univ. Ser. 2 *Spec. 6*, 337–351 (1973).
5. P. Brack and H. Rieber, "Towards a Better Definition of the Anisian–Ladinian Boundary: New Biostratigraphic Data and Correlations of Boundary Sections from the Southern Alps," Eclog. Geol. Helv. **86**, 415–527 (1993).
6. P. Brack, H. Rieber, and R. Mundel, "The Anisian–Ladinian Boundary Interval at Bagolino (Southern Alps, Italy): 1. Summary and New Results on Ammonoid Horizons and Radiometric Age Dating," Albertiana, No. 15, 45–56 (1995).
7. P. Brack, H. Rieber, and A. Nicora, "The Global Stratigraphic Section and Point (GSSP) of the Ladinian Stage (Middle Triassic): A Proposal for the GSSP at the Base of the *curionii* Zone in the Bagolino Section (Southern Alps, Northern Italy)," Albertiana, No. 28, 13–25 (2003).
8. C. Broglio Loriga, S. Cirilli, V. De Zanche, et al., "The Prati di Stuores/Stuores Wiesen Section (Dolomites, Italy): A Candidate Global Stratotype Section and Point for the Base of the Carnian Stage," Riv. Ital. Paleontol. Stratigr. **105** (1), 37–78 (1999).
9. H. Bucher, "Lower Anisian Ammonoids from the Northern Humboldt Range (Northwestern Nevada, USA) and Their Bearing upon the Lower–Middle Triassic Boundary," Eclog. Geol. Helv. **82**, 945–1002 (1989).
10. E. S. Carter and M. J. Orchard, "A Norian–Rhaetian Boundary at Kennecott Point (Queen Charlotte Islands, Canada) Defined by Radiolarians and Conodonts," Albertiana, No. 31, 7 (2004).
11. J. E. T. Channel, H. W. Kozur, T. Sievers, et al., "Carnian–Norian Biomagnetostratigraphy at Silická Brezová (Slovakia): Correlation to Other Tethyan Sections and to the Newark Basin," Palaeogeogr. Palaeoclimatol. Palaeoecol. **191**, 391–402 (2003).
12. A. S. Dagys, "The Lower–Middle Triassic Boundary in Boreal and Tethyan Regions and Correlation of Anisian Sediments," Geol. Geofiz., No. 11, 3–9 (1988).
13. A. S. Dagys, "Zonal Scheme of the Boreal Lower Triassic and the Induan–Olenekian Stage Boundary," Tikhookean. Geol. **16** (4), 36–40 (1997).
14. A. Dagys, "Evolution of the Family Sibiritidae and Detailed Biostratigraphy of the Siberian Upper Olenekian (Triassic)," in *Advancing Research on Living and Fossil Cephalopods* (Kluwer Acad.-Plenum, New York, 1999), pp. 109–123.
15. A. S. Dagys and A. A. Dagys, "Biostratigraphy of the Lowermost Triassic and the Boundary between Paleozoic and Mesozoic," Mem. Soc. geol. ital. **34**, 313–320 (1988).
16. A. S. Dagys and A. A. Dagys, "A Global Correlation of the Terminal Triassic," Mem. Geol. (Lausanne), No. 22, 25–34 (1994).
17. A. S. Dagys and S. P. Ermakova, "A Detailed Biostratigraphic Scheme of the Boreal Lower Triassic," Stratigr. Geol. Korrelyatsiya **1** (2), 26–36 (1993) [Stratigr. Geol. Correlation **1**, 154–164 (1993)].
18. A. S. Dagys and S. P. Ermakova, "Induan (Triassic) Ammonoids from Northeastern Asia," Rev. Paleobiol. **15**, 401–447 (1996).
19. A. S. Dagys and A. G. Konstantinov, "Upper Anisian Infrazonal Scale of Northern Siberia," in *Mesozoic Biostratigraphy of Siberia and the Far East* (Nauka, Novosibirsk, 1986), pp. 48–56 [in Russian].
20. A. S. Dagys and A. G. Konstantinov, "New Zonation Scheme of the Ladinian Stage for Northeastern Asia," Stratigr. Geol. Korrelyatsiya **3** (3), 121–127 (1995) [Stratigr. Geol. Correlation **3**, 314–320 (1995)].
21. A. S. Dagys, A. G. Konstantinov, and E. S. Sobolev, "Materials to the Biostratigraphic Scheme of the Ladinian Stage for Boreal Regions," in *Triassic Biostratigraphy and Paleontology* (Nauka, Novosibirsk, 1991), pp. 74–96 [in Russian].
22. A. S. Dagys and E. S. Sobolev, "Parastratotype of the Olenekian Stage (Lower Triassic)," Albertiana, No. 16, 8–16 (1995).
23. S. P. Ermakova, "The Problem of the Global Induan–Olenekian Boundary Stratotype," Tikhookean. Geol. **23** (1), 65–68 (2004).
24. M. Gaetani, "From the Chairman," Albertiana, No. 24, 4 (2000).
25. Y. Gallet, J. Besse, L. Krystyn, et al., "Magnetostratigraphy of the Kavalaani Section (South-western Turkey): Consequence for the Origin of the Antalya Calcareous Nappes (Turkey) and for the Norian (Late Triassic) Magnetic Polarity Timescale," Geophys. Res. Lett. **27**, 2033–2036 (2000).
26. R. Golebiowski, "The Alpine Kössen Formation, a Key for European Topmost Triassic Correlation," Albertiana, No. 8, 25–35 (1990).
27. E. Gradinaru, "Introduction, Geological Setting and General Stratigraphy of the Desli Caira Section," in *Workshop on the Lower–Middle Triassic (Olenekian–Anisian) Boundary, 7–10 June, Tulcea, Romania* (Bucharest, 2000), pp. 77–79.
28. E. Gradinaru, M. Orchard, A. Nicora, et al., "Conodont Succession Across the Olenekian–Anisian Boundary in Desli Caira, Romania," in *STS-IGCP 467 Field Meeting, Veszprem, Hungary, 5–8 September, 2002* (Budapest, 2002), pp. 11–13.
29. K. Grasmück and R. Trümpy, "Triassic Stratigraphy and General Geology of the Country around Fleming Fiord (East Greenland)," Medd. Grønl. **168** (2), 6–71 (1969).
30. J. Guex, A. Hungerbühler, J. Jenks, et al., "Dix-huit nouveaux genres d'ammonites du Spathien (Trias inférieur) de l'Quest américan) Idaho, Nevada, Utah et Californie): note préliminaire," Bull. Géol. Lausanne, No. 362, 1–31 (2005a); No. 363, 1–25 (2005b).
31. C. W. Cümbel, "Über die Gleichstellung der Gestainmassen in den nordöstlichen Alpen mit ausseralpinen Flötzschichten," Vehr. Gesellsch. Deutsch, Naturf. Arzte, **34**, 80–88 (1859).
32. Y. Jin, Sh. Shen, Z. Zhu, et al., "The Selong Section, Candidate of the Global Stratotype Section and Point of the Permian–Triassic Boundary," in *Paleozoic–Mesozoic Boundary: Candidates of the Global Stratotype Section and Point of the Permian–Triassic Boundary* (China Univ. Geosci. Press, Wuban, 1996), pp. 127–137.

33. H. M. Kapoor, "The Guryul Ravine Section, Candidate of the Global Stratotype Section and Point of the Permo-Triassic Boundary," in *Paleozoic–Mesozoic Boundary: Candidates of the Global Stratotype Section and Point of the Permian–Triassic Boundary* (China Univ. Geosci. Press, Wuban, 1996), pp. 99–110.
34. V. B. Karaulov and V. R. Lozovskii, "Different Approaches to Perfection of the General Stratigraphic Scale," Stratigr. Geol. Korrelyatsiya **10** (6), 3–19 (2002) [Stratigr. Geol. Correlation **10**, 531–546 (2002)].
35. L. D. Kiparisova and Yu. N. Popov, "Division of the Lower Triassic into Stages," Dokl. Akad. Nauk SSSR **109**, 842–845 (1956).
36. A. G. Konstantinov, "Upper Anisian Biostratigraphy and Ammonoids of Northern Siberia" (Nauka, Novosibirsk, 1991) [in Russian].
37. A. G. Konstantinov, "Correlated Ammonoid Zonation in Ladinian Deposits of the Boreal Realm," Stratigr. Geol. Korrelyatsiya **8** (4), 40–48 (2002) [Stratigr. Geol. Correlation **8**, 353–361 (2000)].
38. A. G. Konstantinov and E. S. Sobolev, "Carnian and Lower Norian Biostratigraphy of Northeastern Russia. Article 1. Description of Sections and Stratigraphic Distribution of Cephalopods," Tikhookean. geol. **18** (1), 3–17 (1999a).
39. A. G. Konstantinov and E. S. Sobolev, "Carnian and Lower Norian Biostratigraphy of Northeastern Russia. Article 2. New Zonations and Correlation," Tikhookean. Geol. **18** (4), 48–60 (1999b).
40. H. W. Kozur, "Some Aspects of the Permian-Triassic Boundary and of the Possible Causes of the Biotic Crisis around This Boundary," Palaeogeogr., Palaeoclimatol., Palaeoecol. **143** (4), 227–272 (1998).
41. H. W. Kozur, "Integrated Ammonoid, Conodont and Radiolarian Zonation of the Triassic," Hallesch. Jahrb. Geowiss. B, No. 25, 49–79 (2003).
42. L. Krystyn, "Problem der biostratigraphischen Gliederung der alpin-meditrranen Obertrias," in *Die Stratigraphie der alpin-mediterranen Trias* (Springer, Wien, 1974), pp. 137–144.
43. L. Krystyn, "Eine neue Zonengliederung im alpin-mediterranen Unternkarn," in *Beiträge zur Biostratigraphie der Tethys-Trias* (Springer, Wien, 1978), pp. 37–75.
44. L. Krystyn, "Rhaetian Stage—Chronostratigraphy, Subdivisions and Their International Correlation," Albertiana, No. 8, 15–24 (1990).
45. L. Krystyn, M. Balini, and A. Nicora, "Lower and Middle Triassic Stage and Substage Boundaries in Spiti," Albertiana, No. 30, 40–53 (2004).
46. L. Krystyn, Y. Gallet, L. Besse, and L. Marcoux, "Integrated Upper Carnian to Lower Norian Biochronology and Implication for the Upper Triassic Magnetic Polarity Time Scale," Earth Planet. Sci. Lett. **203**, 343–351 (2002).
47. L. Krystyn and W.M. Kürschner, "The Norian–Rhaetian Boundary—New Data from a Tethyan Key Section in Austria," Albertiana, No. 31, 13 (2004).
48. L. Krystyn and M. J. Orchard, "Lowermost Triassic Ammonoid and Conodont Biostratigraphy of Spiti, India," Albertiana, No. 17, 10–21 (1996).
49. L. Krystyn, B. Plöchinger, and H. Lobitzer, "Triassic Conodont Localities of Salzkammergut Region (Northern Calcareous Alps)," Abh. Geol. Bundesanst. Wien, 61–98 (1980).
50. A. Mastandrea, E. Perri, F. Russo, et al., "A Potential Candidate Section for the Definition of the Carnian–Norian Boundary: The Pignola Section in the Lagonegro Basin (Basilicata, Italy)," Albertiana, No. 31, 14–15 (2004).
51. P. Mietto, P. Gianolla, S. Manfrin, and N. Preto, "Refined Ammonoid Biochronology of the Bagolino Section (Lombardian Alps, Italy), GSSP Candidate for the Base of the Ladinian Stage," Riv. Ital. Paleontol. Stratigr. **109**, 449–462 (2003a).
52. P. Mietto and S. Manfrin, "A High Resolution Middle Triassic Ammonoid Standard Scale in the Tethys Realm: A Preliminary Report," Bull. Soc. géol. France **166**, 539–563 (1995).
53. P. Mietto, S. Manfrin, N. Preto, et al., "Proposal of the Global Stratigraphic Section and Point (GSSP) for the Base of the Ladinian Stage (Middle Triassic): GSSP at the Base of the *avisianum* Subzone (FAD of *Aplococeras avisianum* in the Bagolino Section (Southern Alps, Italy)," Albertiana, No. 28, 26–34 (2003b).
54. E. Mojsisovics, W. Waagen, and C. Diener, "Entwurf einer Gliederung der pelagischen Sedimente des Triassystems," Sitzungber. Akad. Wiss. Wien. Math.–Naturw. Kl. **104** (1), 1–32 (1895).
55. G. Muttoni, D. V. Kent, P. Di Stefano, et al., "Magnetostratigraphy and Biostratigraphy of the Carnian–Norian Boundary Interval from the Pizzo Mondello Section (Sicanti Mountains, Sicily), Palaeogeogr. Palaeoclimatol. Palaeoecol. **166**, 383–399 (2001).
56. K. Nakazawa, "Stratigraphy of the Permian–Triassic Transition and Paleozoic–Mesozoic Boundary," Bull. Geol. Survey Jpn **44**, 425–445 (1993).
57. K. Nakazawa, H. M. Kapoor, K. Ishi, et al., "The Upper Permian and the Lower Triassic in Kashmir, India," Mem. Fac. Sci. Kyoto Univ. Ser. Geol. Mineral. **42** (1), 1–106 (1975).
58. M. J. Orchard, "Upper Triassic Conodont Biochronology and New Index Species from the Canadian Cordillera," Bull. Geol. Survey Can., No. 417, 299–335 (1991).
59. M. J. Orchard, "Executive from the Chair," Albertiana, No. 25, 3 (2001).
60. M. J. Orchard, "A New Conodont Zonation for the Carnian–Norian Boundary at the Black Bear Ridge, NE British Columbia," Albertiana, No. 31, 17–18 (2004).
61. M. J. Orchard and L. Krystyn, "Conodonts of Lowermost Triassic of Spiti: A New Zonation Based on *Neogondonella* Succession," Riv. Ital. Paleontol. Stratigr. **104**, 341–368 (1998).
62. M. J. Orchard and E. T. Tozer, "Triassic Conodont Biochronology, Its Calibration with the Ammonoid Standard, and a Biostratigraphic Summary for the Western Canada Sedimentary Basin," Bull. Can. Petrol. Geol. **45**, 675–692 (1997).
63. M. J. Orchard, J. P. Zonneveld, M. J. Johns, et al., "Fossil Succession and Sequence Stratigraphy of the Upper Triassic of Black Bear Ridge, Northeast British Columbia, a GSSP Prospect for the Carnian–Norian Boundary," Albertiana, No. 25, 10–22 (2001).
64. A. A. Shevyrev, *Triassic Ammonoids* (Nauka, Moscow, 1986) [in Russian].

65. A. A. Shevyrev, *Triassic Ammonoids and Chronostratigraphy* (Nauka, Moscow, 1990) [in Russian].

66. A. A. Shevyrev, *Triassic Ammonoids of the Northeastern Caucasus* (Nauka, Moscow, 1995) [in Russian].

67. A. A. Shevyrev, "The Lower Boundary of the Triassic and Its Correlation in Marine Sediments: Paper 1. Boundary Sections of the Tethys," Stratigr. Geol. Korrelyatsiya **7** (2), 11–27 (1999) [Stratigr. Geol. Correlation **7**, 116–129 (1999)].

68. A. A. Shevyrev, "The Lower Boundary of the Triassic and Its Correlation in Marine Sediments: Paper 2. Boreal Sections of the Basal Triassic and Their Correlation with the Permian-Triassic Boundary Deposits of the Tethys," Stratigr. Geol. Korrelyatsiya **8** (1), 55–65 (2000) [Stratigr. Geol. Correlation **8**, 43–53 (2000)].

69. A. A. Shevyrev, "Ammonoid Zones of the Olenekian Stage (Lower Triassic) and Their Correlation," Stratigr. Geol. Korrelyatsiya **10** (5), 59–69 (2002) [Stratigr. Geol. Correlation **10**, 476–487 (2002)].

70. A. A. Shevyrev, "In Searching for Global Stratotype Sections and Points of the Triassic Stage Boundaries," Stratigr. Geol. Korrelyatsiya **11** (6), 136–142 (2003) [Stratigr. Geol. Correlation **11**, 653–658 (2003)].

71. N. J. Silberling and K. M. Nichols, "Middle Triassic Molluscan Fossils of Biostratigraphic Significance from the Humboldt Range, Northwestern Nevada," U.S. Geol. Surv. Prof. Pap., No. 1207, 1–150 (1982).

72. N. J. Silberling and E. T. Tozer, "Biostratigraphic Classification of the Marine Triassic in North America," Spec. Pap. Geol. Soc. Am., No. 110, 1–63 (1968).

73. C. Teichert and B. Kummel, "Permian–Triassic Boundary in the Kap Stosch Area," Medd. Grønland **197** (5), 3–54 (1976).

74. A. Tollmann, *Geologie von Österreich* (Deuticke, Wien, 1985).

75. J. Tong, H. J. Hansen, L. Zhao, and J. Zuo, "High-Resolution Induan–Olenekian Boundary Sequence in Chaohu, Anhui Province," Sci. China. Ser. D **48**, 291–297 (2005).

76. J. Tong, Y. D. Zakharov, and M. J. Orchard, "A Candidate of the Induan–Olenekian Boundary Stratotype in the Tethyan Region," Sci. China. Ser. D **46**, 1182–1200 (2003).

77. J. Tong, Y. D. Zakharov, and Sh. Wu, "Early Triassic Ammonoid Succession in Chahou, Anhui Province," Acta Paleontol. Sin. **43**, 192–204 (2004).

78. E. T. Tozer, "Upper Triassic Ammonoid Zones of the Peace River Foothills, British Columbia, and Their Bearing on the Classification of the Norian Stage," Can. J. Earth Sci. **2**, 216–226 (1965).

79. E. T. Tozer, "A Standard for the Triassic Time," Bull. Geol. Surv. Canada, No. 156, 1–103 (1967).

80. E. T. Tozer, "Latest Triassic (Upper Norian) Ammonoid and *Monotis* Faunas and Correlation," Riv. Ital. Paleontol. Stratigr. **85**, 843–875 (1980).

81. E. T. Tozer, "Triassic Ammonoidea: Geographic and Stratigraphic Distribution," in *The Ammonoidea* (Acad. Press, N.Y., 1981), pp. 397–431.

82. E. T. Tozer, "The Trias and Its Ammonoids: The Evolution of a Time Scale," Geol. Surv. Can. Miscell. Rep., No. 35, 1–171 (1984).

83. E. T. Tozer, "Rhaetian: A Substage not a Stage," Albertiana, No. 7, 9–15 (1988).

84. E. T. Tozer, "How Many Rhaetians?," Albertiana, No. 8, 10–13 (1990).

85. E. T. Tozer, "Canadian Triassic Ammonoid Faunas," Bull. Geol. Surv. Can., No. 467, 1–663 (1994a).

86. E. T. Tozer, "Age and Correlation of the *Otoceras* Beds at the Permian–Triassic Boundary," Albertiana, No. 14, 31–37 (1994b).

87. E. T. Tozer, "Interpretation of the Boreal *Otoceras* Beds: Permian or Triassic?," Albertiana, No. 28, 90–91 (2003).

88. R. Trümpy, "Lower Triassic ammonites from Jameson Land (East Greenland), Medd. Grönland **168** (2), 77–116 (1969).

89. M. Ulrichs, "*Trachyceras* Laube 1869 (Ammonoidea) aus dem Unterkarn Obertrias) der Dolomiten (Italian)," Stuttgart. Beitr. Naturk. Ser. B, No. 217, 1–55 (1994).

90. H. Visscher, "The New STS Triassic Stage Nomenclature," Albertiana, No. 10, 1 (1992).

91. A. Vörös, T. Budai, J. Haas, et al., "GSSP (Global Boundary Stratotype Section and Point) Proposal for the Base of Ladinian (Triassic): A Proposal for the Base of the *reitzi* Zone (sensu stricto) at Bed 105 in the Felsöörs Section, Balaton Highland, Hungary," Albertiana, No. 28, 35–47 (2003).

92. Y. Wang, "Earliest Triassic Ammonoid Fauna from Jiangsu and Zhejiang and Their Bearing on the Definition of the Permo-Triassic Boundary," Acta Paleontol. Sin. **23**, 257–269 (1984).

93. H. Yin, W. C. Sweet, B. F. Glenister, et al., "Recommendations of the Meishan Section As Global Stratotype Section and Point for Basal Boundary of Triassic System," Newslett. Stratigr. **34** (2), 81–108 (1996).

94. H. Yin, K. Zhang, J. Tong, et al., "The Global Stratotype Section and Point (GSSP) of the Permian–Triassic Boundary," Episodes **24** (2), 102–114 (2001).

95. Yu. D. Zakharov, "Stratotype of the Induan–Olenekian Boundary (Lower Triassic)," Tikhookean. Geol. **13** (4), 33–44 (1994).

96. Yu. D. Zakharov, "The Global Stratigraphic Section and Point 2 (GSSP) of the Base of the Olenekian Stage (Lower Triassic)," Albertiana, No. 29, 38–40 (2004).

97. Yu. D. Zakharov, A. M. Popov, and G. I. Buryi, "Triassic Ammonoid Succession in South Primorye. 3. Late Olenekian–Early Anisian Zones," Albertiana, No. 31, 54–64 (2004).

98. Yu. D. Zakharov, Ya. Shigeta, A. M. Popov, A. N. Sokarev, G. I. Buryii, and V.V. Golozubov, "Candidate for a Global Stratotype of the Induan–Olenekian Boundary (Lower Triassic) in Southern Primor'e," Stratigr. Geol. Korrelyatsiya **10** (6), 50–61 (2002) [Stratigr. Geol. Correlation **10**, 575–585 (2002)].

99. L. Zhao, M. J. Orchard, and J. Tong, "Lower Triassic Conodont Biostratigraphy and Speciation of *Neospathodus waageni* around the Induan–Olenekian Boundary of Chahou, Anhui Province, China," Albertiana, No. 29, 41–43 (2004).