The Importance of Palaeobiogeographical Data for the Solution of the Problem on the Lower Triassic Division

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In the Late Permian and Early Triassic a well-pronounced climatic zonation took place that had an effect on the palaeozoogeographical division of sea basins into districts. Tethys and many seas of the Pacific ocean (Southern Primorye region, Little Khingan, Southern China, and Western USA region) were situated within tropical and subtropical zones (Tethyan Palaeozoogeographical Belt). In the Early Triassic Verkhoyanye region, Kolyma, Arctic Siberia, Spitsbergen, Arctic Canada and a part of Greenland and British Columbia were undoubtedly placed within the limits of the outtropical region of the northern hemisphere (Boreal Belt). Information about the location of the southern hemisphere outtropical region in the Permian and Triassic is very limited and needs more precise definition.

Besides the climatic control there are some other factors which effect peculiarities of sea fauna arrangement, chemical composition of sea basin waters being the most significant (this concerns primarily cephalopods). V. I. Ustrizkij (1970) explains the absence of Djulfian ammonoids in the boreal basin not only by a relatively cold palaeoarctic climate, but also by the change of the boreal basin water salinity which is no longer connected with the Tethys. I. S. Gramberg & N. S. Spiro (1965) who studied chemical composition of the Permian and Mesozoic sediments of Arctic Siberia consider that the greatest change of the sea water composition was at the Permian-Triassic boundary. However, V. N. Sax et al. (1972) call to treat this information with care.

The analysis of the isotopic composition of aragonite ammonoid shells from the Lower Triassic of Arctic Siberia (Zakharov, Naidin & Teiss, in press) permits to draw two conclusions confirming the rightness of Ustrizkij, Gramberg & Spiro's opinions. First of all we found that well-preserved Lower Triassic ammonoid shells have comparatively low contents of O^{18} and some freshening of Lower Triassic boreal sea water might have been responsible for this. Some deviation from the normal salinity of the boreal basin water is emphasized by the presence of conchostracs in the Lower Triassic of Siberia which are sometimes associated with the ammonoids. And, secondly, the temperature

Table I. Temperature of the water of Triassic basins.

Temperature \ Basin	Boreal basin (freshened waters)	Tethyan basin (waters with normal salinity)
T° (from—to)	12.7—25.4[1])	No less than 21.5[2]) (16.5[3]))
T° (average)	14.5[1])	23.0—27.0 (?)

[1]) Zakharov, Naidin & Teiss (in press). Teiss' measurements were made with the allowance of the "water" correction; values δO^{18} in aragonite ammonoid shells are fluctuating from —5.0 to —8.0‰.
[2]) Kaltenegger, 1967 (values δO^{18} are fluctuating from —1.11 to —3.14‰).
[3]) Fabricius et al., 1970 (values δO^{18} are fluctuating from —0.05 to 2.83‰).

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of the Triassic boreal basin water, judging by R. V. TEISS' measurings made with allowance to the "water correction", was markedly lower (T=12.7—25.4° with the average of 14.5°) than the temperature of the Tethys water (table 1). According to the data of KALTENEGGER (1967), the temperature of the Tethys water in the Alpine region was over 21.5° and according to FABRICIUS et al. (1970) no less than 16.5° during the Late Triassic. It follows also from NAIDIN & TEISS' data, who studied isotopic composition of Toarcian belemnitoids, that the freshening of the Triassic boreal sea water was more pronounced than that of Jurassic. It means that the boreal sea water freshening, which probably reached its maximum in the Late Permian, was gradually decreasing in Early and Middle Mesozoic times till it disappeared completely or almost completly.

Peculiarities of ancient continental massif arrangements in the northern and southern hemispheres might have provided sea basin freshening in the North Pole region, but it did not create conditions for the repetition of an analogous phenomenon in the Antarctic.

This is likely to be one of the reasons of the peculiar fact that Late Palaeozoic and Early-Middle Mesozoic ammonoids of high south hemisphere latitudes show relationship with the Tethyan fauna, while the boreal fauna seems to be far more endemic and more poor in generic composition. The newest finding of *Pleuromeia sporangium* in Arctic Siberia (V. A. KRASILOV's determination) appears to be a confirmation of this point of view. It shows that mangrove floras of the palaeoarctic sea coasts in Early Triassic did not significantly differ from mangroves of the Tethys and Pacific ocean coasts. Endemism of boreal cephalopods caused by the climatic zonation presence in Early Triassic might have been strengthened due to the peculiarity of the boreal sea water salt composition.

Palaeozoogeographical data must undoubtedly be used in the designing of the general (International) Stratigraphical Scale and in selection of stratotypes (though some investigators [SCHINDEWOLF, 1970] consider this operation unnecessary). The author of this paper, like the majority of investigators, agrees with the necessity of stratotype establishment. Due to such approach, the name of a stage is completely dependent on the geographical position of a stratotype. To avoid the complications, noted by O. SCHINDEWOLF (1970), only stage subdivisions of the International Stratigraphical Scale must, apparently, be typified. Consideration in the capacity of the zone standards of the entire section series in a stratotype locality including, wherever necessary, even more distant areas (leading sections) will enable us to make all the necessary corrections when new facts are accumulated. The zones established immediately in the stratotypes of the corresponding stages must serve only as the basis of zone subdivisions of the International Scale.

The stage and zonal division of the Lower Triassic is known to be based on the study of ammonoid complexes. When making the Late Palaeozoic and Early Mesozoic International Scale, it is necessary to remember that at the end of the Palaeozoic to the beginning of the Mesozoic periods only Tethyan Belt regions were always populated with ammonoids (boreal ammonoids in Djulfian stage are unknown), and that Tethyan ammonoid fauna, unlike that of the Boreal, is much more various, if judge by the number of generic taxons met (table 2). Thus, taking into account arrangement peculiarities of Early Triassic fauna, stratotypes of the Lower Triassic stages are very important to be chosen within the Tethyan Belt. It is convenient also because the Djulfian stratotype is already outlined within this zoochoria and classic sections of the Middle and Upper Alpine Triassic are situated within the Tethyan Belt as well. Accordingly, the establishment of one of the Lower Triassic stratotypes (Induan stage) in Hindustan is thought to be a great success. For the same reasons the choice of stratotype sections in the north-east of the USSR (KIPARISOVA & POPOV, 1958, 1964; VAVILOV & LAZOVSKI, 1971) and in Arctic Canada (TOZER, 1965) should not be considered successful.

Table 2. Indices of faunal distinction of ammonoid fauna of adjacent Permian and Triassic stages (obtained by PRESTON's [1962] method): N=real quantity of taxa in two compared units; N_1=quantity of taxa in the first stage; N_2=quantity of taxa in the second stage; Z=index of faunal distinction.

$$\left(\frac{N_1}{N}\right)^{\frac{1}{Z}} + \left(\frac{N_2}{N}\right)^{\frac{1}{Z}} = 1$$

Tethyan Belt

Anisian	Russian	Ussurian	Induan	Djulfian	Guada-lupian	Stage
*83**)	0.92	0.97	1.00	1.00[1])	—	Anisian
	81	0.82	1.00	1.00[1])	—	Russian
		66	0.82	0.99[1])	—	Ussurian
			22	0.94[1])	—	Induan
				31	—	Djulfian
					52	Guadalupian

Boreal Belt

Anisian	Russian	Ussurian	Induan	Djulfian	Guada-lupian	Stage
*36**)	0.97	1.00	1.00	1.00[1])	—	Anisian
	27	0.94	0.96	1.00	—	Russian
		27	0.84	1.00	—	Ussurian
			14	1.00	—	Induan
				0	—	Djulfian
					6	Guadalupian

*) *Quantity of genera*
[1]) Index of faunal distinction (Z).
(The units are perfectly distincted when Z=1.00, they are homogeneous when $Z \leq 0{,}27$.)

The determination of the number of stage subdivisions within the Lower Triassic is another important point concerning the biostratigraphy of the Lower Triassic. Greatly various points of view are known to exist concerning this question. L. D. KIPARISOVA & Y. N. POPOV (1956, 1964) made a scheme of binominal composition of the Lower Triassic, while M. N. VAVILOV, V. R. LAZOVSKIJ (1970), KOZUR (1972) and Y. D. ZAKHAROV (1968, 1973) consider it to be trinominal. E. T. TOZER (1967) distinguishes four stages in this subdivision. In B. KUMMELS (personal communication) opinion the distinction of subdivisions within the Lower Triassic has not a rank of stage but a rank of zones, and a single (Scythian) stage is the only representative of the Lower Triassic.

The International Commission on Stratigraphy is to choose the best variant proposed. I must only say that the variant of trinominal composition of the Lower Triassic finds the ever growing support among Soviet palaeontologists, judging from the results of the conference held in Novosibirsk in 1972. At present, the admissability of this variant is not denied by Y. N. Popov and L. D. Kiparisova, the authors of the binominal composition scheme. This point of view is especially favoured by M. N. Vavilov and V. R. Lazovskij' works (1970). They showed that in the development of both marine and continental faunas were three distinctly pronounced stages which effected the change of family and generic compositions of some groups.

Our calculations of the distinction degree between the three Lower Triassic subdivisions made by means of Syomkin & Preston's methods (1972 and 1962, respectively) show that they are well suited for the rank of stages, but not for zones, as is considered by B. Kummel. These subdivisions are quite distinct in both family level with the account of the number of genera (lower subdivision within the Tethyan belt differs from the middle one by 68%, and the middle subdivision differs from the upper one by 59%) and in superfamily level with the allowance for the number of families, though the latter difference was naturally less (table 3).

Table 3. Calculation of the distinction degree ($1-K_0$) of the Lower Triassic stages by Syomkin's (1972) method:

$$K_0\,(x_1, \ldots, x_n) = \frac{n\,(T-S)}{(n-1)\,T}$$

when $n = 2$ $K_0\,(x_1, x_2) = \frac{2\,(T-S)}{T} = \frac{2m\,(x_1 \cap x_2)}{m\,(x_1) + m\,(x_2)}$

n = number of the compared units

$T = \sum_{i=1}^{n} m\,(x)$ (total sum of the taxa)

$T-S = m\,(x_1 \cap \ldots \cap x_n)$ (sum of the minimums)

K_0 = resemblance degree.

1. On the superfamily level with the registration of the family quantities

Tethyan Belt			
Russian	Ussurian	Induan	Stage
12	28%	70%	Russian
	10	50%	Ussurian
		7	Induan

Boreal Belt			
Russian	Ussurian	Induan	Stage
8	38%	54%	Russian
	7	27%	Ussurian
		7	Induan

2. On the family level with the registration of the genus quantity

Tethyan Belt			
Russian	Ussurian	Induan	Stage
29	60%	87%	Russian
	23	68%	Ussurian
		9	Induan

Boreal Belt			
Russian	Ussurian	Induan	Stage
12	58%	85%	Russian
	13	64%	Ussurian
		9	Induan

Mutual inclusion measures of adjacent Lower Triassic subdivisions calculated by the SYOMKIN method enable us to clearly express the interrelation between these subdivisions for each of the two palaeozoogeographical belts. Geometrical pictures presented for this purpose in table 4 and the above calculations make it possible to draw two conclusions which agree with the foregoing statements: (1) The three Lower Triassic subdivisions considered are clearly distinguished by ammonoid taxonomic groups of high rank within both Tethyan and Boreal Belts and therefore they must not be regarded in zone but in stage ranks (less probably in the rank of substages). Thus, the variant of trinominal composition seems to be the most acceptable. (2) As the present subdivisions (stages) are characterized by a more representative fauna composition in the Tethyan Belt, it is desirable that their stratotypes are just within this zoochoria. Hence, the establishment of the Induan stage, the stratotype of which has been chosen in Hindustan, should be considered the best. In contrast to the opinions of E. T. TOZER (1967), M. N. VAVILOV & LAZOVSKIJ (1970), it is suggested that stratotypes of the two other Lower Triassic stages, enclosing the middle and upper parts of the Lower Triassic, should also be established within the Tethyan palaeozoogeographical belt. This proceeds from the considerations of palaeozoogeographical nature.

Sections of the considered Triassic parts of the Alps and the Caucasus (Djulfa) are known to be quite unfit as stratotypes, and also sections of Hindustan and adjacent territories (Afganistan, South China and Japan) are apparently less suitable for this purpose than basic sections of South Primorye which are well exposed and contain well preserved remains of cephalopods, bivalves, gastropods, brachiopods and also fishes and big vertebrates which help to conceive main biocenose elements of Lower Triassic seas.

Stratotypes of the new stages are proposed to be eastablished in the north-eastern and south-eastern parts of the Russian Island surrounded by the Ussurian Gulf (if no suitable sections are found in some other regions of the Tethyan Belt). These geographical names are suggested to use to name the established subdivisions (Ussurian stage, situated immcdiately above the Induan stage and below the further advanced Russian stage).

As the Ussurian stage stratotype I have chosen a section in the north-eastern part of the Russian Island between the Ayax Bay and western part of the Paris Bay. The section is composed of calcareous sandstones.

For the Russian stage a section in the north western coast of the Tchernishev Bay in the Russian Island is suggested, which is composed of clay-aleurite facies. The boundary between the Ussurian and Russian stages is distinctly fixed in the uninterrupted scale precipice of the Schmidt Cape according to the change of sandstones by sand-clay sediments and the appereance of dominants from Columbitidae and Hellenitidae families.

The number of zones in every of the Lower Triassic stages does not exceed two: *Otoceras woodwardi* (or *Ophiceras connectens*) and *Gyronites frequens* in Induan stage, *Hedenstroemia bosphorense* and *Anasibirites nevolini* in the Ussurian stage, *Neocolumbites insignis* (or *Keyserlingites miroshnikovi* and *Subcolumbites multiformis*) in the Russian stage.

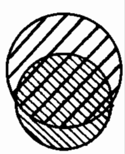
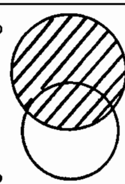
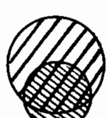
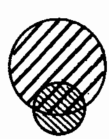
The new Lower Triassic stages are comparatively easily distinguished in sea sediments of the three palaeozoogeographical belts: (1) at Verkhoyan-Kolymian and Canada-Greenlandian provinces of the Boreal Belt, (2) Mediterranean, Induan, West-Pacific and East-Pacific realms of the Tethyan Belt and (3) Australian and New Zealand regions of the Australian Belt.

The continental analogues of the Ussurian and Russian stages can be found actualy only in the European part of the USSR, India, South Africa, Australia and with some conditionality in West Germany and England.

Table 4. Measures of mutual "inclusion" of the adjacent Lower Triassic stages calculated by SYOMKIN's (1972) method.

where $Kx_1 \subset y_1$ = measure of inclusion x_1 in y_1; $Ky_1 \subset x_1$ = measure of inclusion y_1 in x_1; $m(x_1 \cap y_1)$ = sum of the minimums x_1 and y_1; $m(x_1)$ = sum of the x_1 taxa; $m(y_1)$ = sum of the y_1 taxa.

$$Kx_1 \subset y_1 = \frac{m(x_1 \cap y_1)}{m(x_1)} \qquad Ky_1 \subset x_1 = \frac{m(x_1 \cap y_1)}{m(y_1)}$$

Belt	Tethyan belt		Boreal belt	
Stages / Level	On the super-family level with the registration of the family quantities	On the family level with the registration of the genus quantities	On the super-family level with the registration of the family quantities	On the family level with the registration of the genus quantities
Ussurian—Russian	61%  68%	38%  42%	62%  62%	42%  42%
Induan—Ussurian	28%  89%	22%  64%	62%  89%	27%  54%

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