

On Possibility of Using the Global Permian Stage Scale in the Tethyan Region

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Abstract—A possibility of using the Permian global chronostratigraphic scale in the Tethyan region is estimated in this work. Permian successions in this region show that the proposed subdivision of the Permian System into the Cisuralian, Guadalupian, and Lopingian series is efficient when it is definitely proved that the lower boundary of the Guadalupian Series corresponds to the base of the Kubergandian Stage of the Tethyan scale. This problem is, however, unsolved so far. The Asselian, Sakmarian, and Artinskian stages of the Cisuralian Series correspond to the Asselian, Sakmarian, and Yakhtashian stages of the Tethyan scale. The correlation between the Kungurian and Bolorian stages can be taken for testified, when the exact position of the lower boundary of the Guadalupian Series is established. The conodont biostratigraphy used to discriminate the Roadian, Wordian, and Capitanian stages of the Guadalupian Series is inappropriate for the Tethyan region. The Wuchapingian and Changhsingian stages of the Lopingian Series correspond to the Dzhulfian (*sensu stricto*) and Dorashamian stages of the Tethyan scale.

Key words: global chronostratigraphic scale, Tethyan scale, correlation, Cisuralian, Guadalupian, and Lopingian series, Asselian, Sakmarian, Artinskian, Kungurian, Roadian, Wordian, Capitanian, Wuchapingian, Changhsingian, Yakhtashian, Bolorian, Kubergandian, Murgabian, and Midian stages.

INTRODUCTION

The recent activity of the International Subcommittee on the Permian Stratigraphy (SPS) resulted in elaboration of the global chronostratigraphic scale of the Permian System (Jin *et al.*, 1997). In the latter, the system is subdivided into three series: Cisuralian, Guadalupian, and Lopingian. The first of them corresponds to the lower series of the traditional European scale, the second one is defined in sequences of the Guadalupe Mountains in western Texas, and the third unit is distinguished in South Chinese sections. The stage subdivision of series is carried out in line with their subdivision in the relevant type regions. In December 1999, the SPS approved by voting the Guadalupian Series and its constituent Roadian, Wordian, and Capitanian stages. This decision was ratified by the International Geological Congress held in Rio de Janeiro in August 2000. The Cisuralian and Lopingian series are next to be officially approved. Thus, in the nearest future, one should expect an official approval of the new stage scale of the entire Permian System. This scale will unavoidably create many problems and difficulties in applying the new criteria for positioning the stage boundaries and their tracing beyond the location areas of the type sections.

This paper is aimed to assess the new scale from the standpoint of its application in the Tethyan region and to consider the relevant problems and possible ways of their solution.

STANDARD AND TETHYAN STAGE SCALES AND PRINCIPLES OF THEIR ELABORATION

Miklukho-Maklay (1958) was the first to propose the initial version of the stage scale for the Caucasian–Sinian biogeographic province. Disclaiming a possibility to apply the East European stage scale for this region, he defined, subdividing the system into two series, four new stages: the Karachatyrian and Darvazian in the lower series, and the Murgabian and Pamirian in the upper one. After subsequent works (Leven, 1963, 1967, 1974, 1975, 1979, 1980a, 1980b, 1981; Rostovtsev and Azaryan, 1974), the scale was significantly modified and detailed. In 1979, the Interdepartmental Stratigraphic Committee (ISC) of the former Soviet Union recommended it for using in the southern (Tethyan) regions of the USSR. The version approved by the ISC was published in 1980 (Leven, 1980a) and, since that time, it was widely used by Russian and foreign geologists as a standard for subdivision and correlation of Permian deposits in various areas of the Tethyan region. In the published version, the Permian System was subdivided, in line with tradition, into two series. It should be mentioned, however, that previously I proposed a three-member scheme for the Permian System respectively subdivided into the Yaikan, Kushan, and Arianian series (Leven, 1974, 1975). A possibility of subdividing the Permian System into four series constituting two superseries was discussed as well (Leven, 1992a, 1992b, 1997; Kotlyar *et al.*, 1994).

All stages of the Tethyan scale, except for two upper ones, were discriminated on the basis of fusulinids. The Asselian and Sakmarian stages were established by means of correlation of their characteristic fusulinid assemblages from the Uralian type sections with the counterparts from the Tethyan successions. Most of remaining stages were recognized on the basis of natural phases in evolution of higher fusulinids. The stage boundaries were placed at the first occurrence levels of taxa of the generic and family ranks in their continuous phylogenetic lineages, beginning from primitive *Pamirina* to highly organized *Yabeina* and *Lepidolina* forms. Changes in the accompanying fusulinid assemblages were also taken into consideration. Such an approach to definition of stages ensured the continuity of their succession and unambiguous understanding of boundaries between them. Along with a wide geographical distribution and frequent occurrence of fusulinids, this enabled a relatively easy recognition of stages in the entire Tethyan region from the Mediterranean to Japan and Indochina. At the end of the Midian Age, most of fusulinids became extinct, and, as a consequence, two upper stages—Dzhulfian and Dorashamian—were established using the ammonoid biostratigraphy, and later were supported by conodont successions.

As was shown in several works (Leven, 1993; Leven *et al.*, 1996), the stages in fusulinid development were related to major abiotic events of trans-Tethyan extent and, first of all, sea-level oscillations. The latter affected the entire biota, and the main turning points in fusulinid development and the relevant boundaries between stages and series were substantiated, to a different extent, with due consideration of other faunal groups, e.g., of ammonoids, brachiopods, and conodonts.

As is mentioned in the introduction, the global chronostratigraphic scale of the Permian System is composite. Its three series are of the natural-historical character, reflecting major stages in the marine biota development. Stages of the series are established by representatives of different geological schools in different periods and in various regions of different biogeographic provinces. In contrast to the Tethyan scale, they are defined, therefore, on the basis of different principles. For instance, the Asselian, Sakmarian, and Artinskian stages established in the Urals correspond to certain stages in ammonoid evolution (Karpinsky, 1874; Ruzhentsev, 1951, 1954, 1956). Boundaries between these stages were specified according to fusulinid biostratigraphy. The Kungurian Stage was originally established as a local lithostratigraphic unit (Schtuckenbergh, 1890), and its biostratigraphic characteristic is incompletely clear even now. The Roadian, Wordian, and Capitanian stages of the Guadalupian Series initially represented the synonymous formations; the stage status was attributed to them later, after elucidation of their paleontological characteristics. In the most clear and logical form, this was done by Furnish (1973). Defining the Roadian Stage as the terminal one in the

Lower Permian, he indicated its characteristic assemblage of ammonoids, most typical among which are *Perrinites hilli* (Smith), *Paraceltites elegans* Girty, *Texoceras texanum* (Girty), *Glassoceras normani* (Miller et Furnish), and some other forms. Furnish correlated the Wordian Stage with the *Waagenoceras* Zone, and the Capitanian Stage with the *Timorites* Zone. In addition, the Amarassian Stage characterizing the first occurrence of *Cyclolobus* forms was defined in the Guadalupian Series. In general, data on fusulinids are consistent with his conclusions, although they did not reveal such a distinct picture. For instance, in the opinion of Ross (1963), the Roadian fusulinid assemblage is almost identical to the Wordian one. The boundary between the Wordian and Capitanian stages is marked by the first occurrence of *Polydiexodina* forms. The fusulinid assemblage from the Lamar Limestones referred by Furnish to the Amarassian Stage also bears characteristic features. However, no ammonoids have been found in the limestones, and their correspondence to the stage under consideration is not unambiguous.

Because of a wide distribution of ammonoids and quite distinct differences between their assemblages, the stage scale suggested by Furnish for the Guadalupian Series was accepted worldwide. However, when this series and its stages were proposed to be the international standard units, it appeared that ammonoids are unsuitable for defining the Global Stratotype Sections and Points (GSSP) because they occur only episodically in the type sections. It was impossible also to use fusulinids and brachiopods for this purpose because of their distinct endemism. As a result, conodonts turned out to be the only group appropriate for substantiation of the Guadalupian stages and their boundaries. In the study of conodonts, the main attention was paid to the search of their continuous phylogenetic lineages, which would allow to trace species succession and, thus, to tie the GSSP to the particular moments of their evolutionary changes without the necessary analysis of this faunal group evolution. The procedure of discriminating the stages was formalized and eventually reduced to hammering the "gold spikes" without the proper consideration of successive geological events and general development of biota. In this new interpretation, substantially different time-ranges were attributed to the stages named in accordance with the nomenclature by Furnish, and his criteria lost their significance to a considerable extent. In that new interpretation, stages correspond to the of conodont *Jinogondolella nankingensis* (Roadian Stage), *J. aserrata* (Wordian Stage), and *J. postserrata* (Capitanian Stage) phylogenetic zones distinguished in the sequence. Boundaries between stages are placed at the first occurrence levels of zonal species, which are recorded approximately in the middle of synonymous formations and above the levels marked by renewals in ammonoid and fusulinid assemblages (Fig. 1).

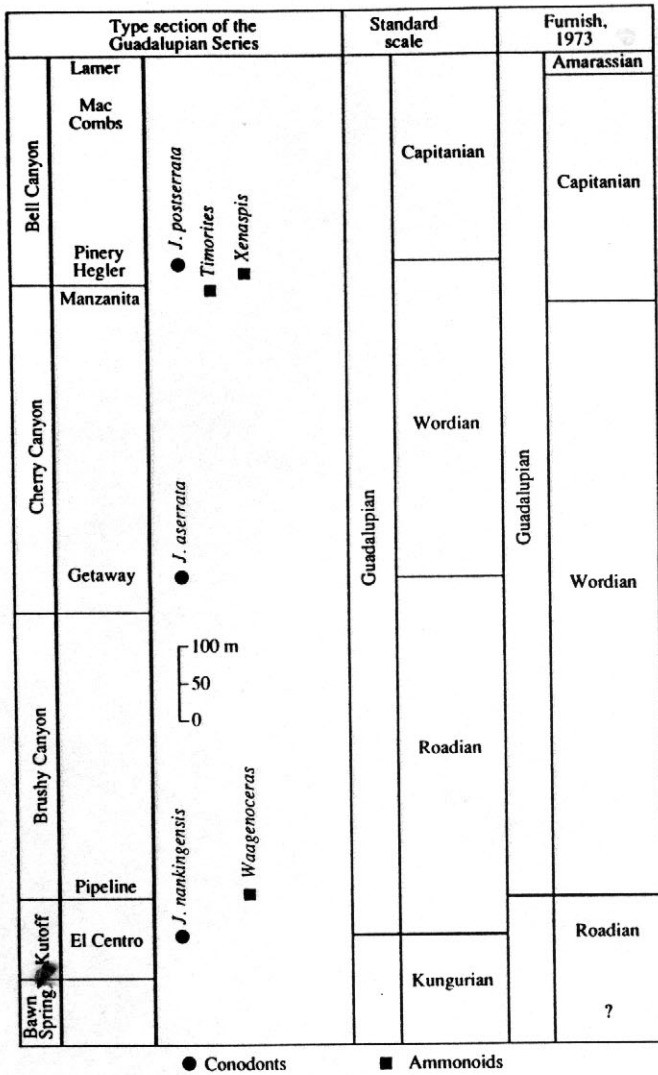


Fig. 1. Type section of the Guadalupian Series and variants of its subdivision into stages separated by the first occurrence levels of conodonts (standard scale) and ammonoids (scheme by Furnish).

Such an exclusive attention to conodonts, when the comprehensive definition of stages and their boundaries was actually discarded, limited the possibility of tracing these subdivisions and, consequently, of using them as global standards. The declared cosmopolitanism of conodonts is obviously overestimated. They are rare in the Boreal and Notal provinces, and less common than fusulinids in the Tethyan region. Similarly to other faunal groups, distribution of conodonts depends on environments and facies (Kozur, 1995, 1998). All this does not allow me to share optimism of those who think that the Guadalupian stages can be used beyond the Midcontinent and should be included into the global scale.

Subdivisions of the Lopingian Series of the standard scale, i.e., the Wuchapingian and Changhsingian stages, are established in the South Chinese sequences.

Their paleontological characteristics are good and versatile (ammonoids, fusulinids, conodonts), and their boundaries are defined on the basis of different indicators. All these indicators are workable, however, in the Tethyan region only, and both stages can hardly be recognized in other biogeographic provinces in the nearest future.

All the aforesaid shows that the proposed version of a new global chronostratigraphic scale is inappropriate for solving any of the problems of the Permian stratigraphy and, to the contrary, it complicates them sometimes. First of all, this is a consequence of inadequate substantiation of the Guadalupian stages and their boundaries, which can be hardly recognized beyond the stratotype region. A possibility of using the new Permian global scale in the Tethyan region is evaluated below.

BOUNDARIES OF THE PERMIAN SYSTEM

The lower Permian boundary in the global chronostratigraphic scale is established in the Aidaralash section in accordance with the conodont biostratigraphy (Davydov *et al.*, 1995). Its position is also compatible with distribution patterns of ammonoids and fusulinids, and the boundary is easily recognizable in many sections throughout the Tethyan region owing to the successive fusulinid assemblages of the *Ultradaixina bosbytauensis* and *Sphaeroschwagerina vulgaris*-*Sphaeroschwagerina fusiformis* zones (Leven and Davydov, 1979; Watanabe, 1991; Leven, 1992b; Davydov, 1995; Krainer and Davydov, 1998).

The upper boundary of the Permian System is not officially approved so far. In the global scale, it is placed at the base of the conodont *Hindeodus parvus* Zone, as it was recommended by the SPS Working Group on the Permian-Triassic boundary (Yin, 1997; *Vote on...*, 1999). Inasmuch as these recommendations are based on biostratigraphic investigations in South China, we have no problem with tracing this level throughout the Tethyan region. The boundary is also recognizable in some Boreal sections, where its position is established within the upper part of the *Otoceras boreale* Zone of the ammonoid scale (Kozur, 1998).

SERIES OF THE PERMIAN SYSTEM

In the global scale, the Permian System includes three series. In principle, this is quite acceptable for the Tethys, because many experts on the Permian stratigraphy in this region used the three-member scale for a long time. Indeed, the Middle Permian begins from the level corresponding to a large-scale Kubergandian transgression that was responsible for a significant reorganization of the entire marine biota (Leven, 1993; Leven *et al.*, 1996). For a long time, Chinese geologists correlated the Carboniferous-Permian boundary with this level. The Middle-Late Permian boundary marks the catastrophic extinction of most groups of marine

organisms. This event was probably related to a rapid regression and signified the commencement of the Great Late Permian extinction (Leven, 1993; Leven and Korchagin, in press; Jin, 1993; Jin *et al.*, 1994). Thus, the idea of three-member subdivision of the Permian System is not new and sufficiently consistent with natural events in the Permian history. Therefore, the Guadalupian Series incorporation into the global scale should be welcomed. It should be emphasized, however, that the first occurrence level of the conodont species *Jinogondolella nankingensis* used to define the lower boundary of the series in the type sections of the North American Delaware basin cannot be effectively applied for recognizing this boundary in the Tethyan region, where the species in question is extremely rare. This question is discussed in the next section, where the correlation of stages and their boundaries is under consideration.

The upper boundary of the middle series that is established in sections of South China at the top of the Maokou Limestones (Jin, 1999) corresponds to the top of the Capitan Formation in the Delaware basin, where this level is well recognizable on the basis of conodont zonation (Mei *et al.*, 1998).

STAGES OF THE PERMIAN SYSTEM

Asselian Stage. All stages included into the lower Cisuralian Series of the Permian System were established in the Urals. The possibility of practicing them in the Tethyan region was repeatedly discussed (Leven, 1967, 1979, 1980b; Leven and Shcherbovich, 1978; Leven and Davydov, 1991; Leven *et al.*, 1992; Movshovich *et al.*, 1979; and others). It became clear after the discussion that recognition of the Uralian stages in the Tethyan region is not an easy task because of isolation of the East European basin that commenced in the Sakmarian Age. This general conclusion remains valid until present. The free water exchange that existed between the Uralian and Tethyan basins in the earliest Permian time favored the faunal interchange, and, correspondingly, the Asselian Stage is easily recognizable on the basis fusulinid biostratigraphy throughout the entire Tethyan region. Similarly to the South Uralian stratotype region, the Asselian fusulinid assemblage from the Tethys includes subspherical forms with a freely coiled spire, which belong to genera *Sphaeroschwagerina*, *Pseudoschwagerina*, *Paraschwagerina*, *Zellia* and coexist with abundant *Rugosofusulina*, *Dutkevitchia*, and *Pseudofusulina* species. Particularly close to the South Uralian faunas are fusulinid assemblages from adjacent areas of the Tethyan region, e.g., from the Fergana and Darvaz. Accordingly, the Asselian Stage in these areas can be subdivided into three fusulinid zones recognized in the Urals (Bensh, 1972; Leven and Shcherbovich, 1978; Leven and Davydov, 1991). The Asselian fusulinids are missing, however, from the southern peri-Gondwanan areas of the Tethys (southern Afghanistan, southern Pamirs, Karakorum,

Himalayas, and southern Tibet), and it is impossible so far to recognize the Asselian Stage there. All attempts to distinguish this unit on the basis of other faunal groups seem doubtful, because they usually operate with indirect data instead of direct correlation with the type sections of the stratotype region.

Sakmarian Stage. Like the Asselian Stage, the Sakmarian one is also included into the Tethyan scale, although its recognition in the region under consideration meets more difficulties than in the previous case. Two reasons are responsible for this: the definition of the stage boundaries in the stratotype region is inexact, and the isolation of East European basins from the Tethys commenced at that time.

When establishing the Sakmarian Stage and characterizing ammonoid assemblages of the stage as a whole and of the constituent *Tastuba* and *Sterlitamak* horizons, V.E. Ruzhentsev put aside the problem of its lower boundary, because sections displaying the succession of these assemblages are unknown. Placing this boundary at the top of the Kurmaya Formation in the Kondurovka section of the Orenburg region of the Urals, he paid main attention to fusulinids, but not to ammonoids. According to Rauser-Chernousova (1965), the boundary in question marks the major reorganization in fusulinid communities. The Asselian assemblage with characteristic *Sphaeroschwagerina*, *Pseudoschwagerina*, *Rugososchwagerina*, and *Dutkevitchia* forms is replaced here by the impoverished assemblage mainly consisting of *Pseudofusulina* species. Most remarkable among the latter is *Pseudofusulina moelleri* (Schellwien) from the lower zone of the Sakmarian Stage. Characteristic of this zone are also paraschwagerins, for instance, *Paraschwagerina mira* Rauser.

In the Tethyan sequences, the Sakmarian Stage is recognized on the basis of fusulinids despite a substantial difference between their assemblage from this and stratotype regions. For instance, the Sakmarian Stage hosts here almost all genera and many species characteristic of the Asselian Stage. Accordingly, the boundary between these stages is obscure in the Tethyan region. Nonetheless, the appearance of abundant paraschwagerins, such as *P. mira*, and of pseudofusulins from the *P. moelleri* group elucidates more or less confidently the boundary position (Bensh, 1972; Leven and Shcherbovich, 1980). In sections of the Darvaz, Japan, and Carnic Alps, this boundary corresponds to the first occurrence level of the *Robustoschwagerina* and *Zellia* forms, e.g., of *R. schwellwieni* (Hanzawa), *R. geyeri* (F. et G. Kahler), *Z. heritschi* F. et G. Kahler, and also of *Darvasites* species (Leven and Shcherbovich, 1978, 1980; Watanabe, 1991; Forke, 1995). Beds yielding all mentioned fusulinid genera and species in association with abundant representatives of *Pseudofusulina* and *Rugosofusulina* genera are considered as corresponding to the *Robustoschwagerina*-*Paraschwagerina* Genus-zone referred to the Sakmarian Stage, although one cannot be completely sure that boundaries of this

zone (particularly the upper one) exactly coincide with those of the stage.

The inclusion of the *Robustoschwagerina-Paraschwagerina* Zone into the Sakmarian Stage appears to be correct also from data on distribution of ammonoids and conodonts. For instance, in the Darvaz sections, the fusulinid assemblage of this zone occurs together with ammonoids, among which several species of the *Boesites*, *Synartinskia*, *Medlicottia*, and *Paragastrioceras* genera are similar to the species from Sakmarian deposits of the Uralian region. In opinion of Leonova, this assemblage shows that enclosing rocks are correlative with the Sakmarian Stage (Leven *et al.*, 1992). In the Carnic Alps, similar fusulinids are found together with conodonts *Mesogondolella cf. bisselli* (Clark et Behnken), *Sweetognathus inornatus* Ritter, and *S. aff. whitei* (Rhodes) characteristic of the uppermost Sakmarian and lowermost Artinskian stages (Forke, 1995). Similar fossils are recorded in sections of Japan and China.

Artinskian Stage. In the Tethyan scale, the Artinskian Stage corresponds to the Yakhtashian one. According to fusulinid biostratigraphy, the latter is equivalent to the *Pamirina-Chalaroschwagerina* Genus-zone. Its lower boundary coincides with the first occurrence level of representatives of these genera, and the upper one is marked by the first occurrence of the genus *Misellina* represented by the subgenus *Brevaxina*. In contrast to the Sakmarian fusulinid assemblage from the Tethyan and East European basins, which show some similarity, the coeval Artinskian and Yakhtashian assemblages are different absolutely and cannot be used for the direct correlation of the stages. The correlation is possible only on the basis of ammonoids and conodonts.

For instance, the upper part of the Yakhtashian Stage stratotype yields a diverse ammonoid assemblage associated with characteristic fusulinids *Pamirina darvasica* Leven, *Chalaroschwagerina vulgaris* (Schwellwien et Dyhrenfurth), *Darvasites ordinatus* (Chen), *Pseudofusulina krafftii* (Schwellwien et Dyhrenfurth). According to Leonova, the ammonoid assemblage includes species of the *Daraelites*, *Propinacoceras*, *Thalassoceras*, *Metalegoceras*, *Eothinites*, *Kargalites*, *Almites*, *Cardiella*, *Crimites*, and *Neocrimites* genera, which are "... close to the Uralian late Artinskian species of the corresponding genera" in the development level. This suggests that "... the upper part of the Yakhtashian Stage can be correlated with the upper half of the Artinskian Stage of the Urals" (Leven *et al.*, 1992). Conodonts found together with ammonoids are represented by *Mesogondolella bisselli* (Clarke et Behnken) and *Sweetognathus inornatus* Ritter, all occurring in the uppermost Sakmarian and Artinskian stages of the Uralian sections. Similar data are known from the South China, where the *Pamirina darvasica* Beds (Longyin Formation or Longyinian Stage) yield also the Artinskian ammonoids *Propinacoceras simile*

Haniel, *Popanoceras kueichowense* (Chao), *Daraelites cf. elegans* Tchernow, *Eothinites* sp., and others, as well as conodonts *Sweetognathus whitei* (Rhodes) (Zhou, 1988, 1989a, 1989b; Sheng and Jin, 1994).

The cited data indicate that the Yakhtashian Stage corresponds approximately to the Artinskian one. Nonetheless, only more exact correlation of their boundaries, position of which should be specified with the help of additional sampling of ammonoids and conodonts in the Uralian and Tethyan sections, may prove the complete correspondence of these units. In addition, the improved correlation of the conodont, ammonoid, and fusulinid zonal scales is necessary.

Kungurian Stage. This unit is considered as equivalent to the Bolorian Stage of the Tethyan scale, because the latter occurs above the Yakhtashian Stage, which is, in turn, correlated with the Artinskian one. The direct correlation of the Bolorian and Kungurian stages is hardly possible due to the poor paleontological characteristics of the latter in the Urals, where its characteristic fossils are mostly endemics. Extremely rare fusulinids of the Kungurian Stage are represented by *Parafusulina* species similar to those from the uppermost Artinskian deposits and missing from the Tethyan sections. Ammonoids from the lower part of the stage (the Sarana Horizon) are similar to those from the uppermost Artinskian Stage. Upward in the section, their assemblage becomes impoverished and, already in the middle part of the stage, ammonoids are almost exclusively represented by endemic species of the *Uraloceras* genus inherited from the Artinskian Stage. The diverse Buztera ammonoid assemblage is recorded in sections of southeastern Pamirs within beds with typical Bolorian fusulinids. In opinion of Leonova (Leonova and Dmitriev, 1989), its constituting forms are "... slightly younger as compared with species of the Baigendzha (upper Artinskian) assemblage from the Urals, and the corresponding Bolorian deposits occupy position in the global stratigraphic scale above the Artinskian Stage and correspond to the Kungurian level." Analyzing distribution of conodonts, Kozur arrived at a similar conclusion (Kozur, 1995, 1998; Kozur *et al.*, 1994). In the southeastern Pamirs, he distinguished two conodont assemblages characterizing the considered interval of the Permian sequence: *Mesogondolella shindyensis-M. intermedia* and *Neostreptognathodus idahoensis-N. leonovae*. The first of them includes *Neostreptognathodus exculptus* Igo, a species that appears in association with *N. pnevi* Kozur et Movshovich in the western areas of North America. The latter is, in turn, characteristic of basal layers of the Sarana Horizon in the Uralian sections (Sylva Reefs and Shurtan Beds), and its first occurrence level is now accepted for the lower boundary of the Kungurian Stage (Kozur, 1995, 1996, 1998; Jin *et al.*, 1997; Chuvashov *et al.*, 1999). *N. idahoensis* (Youngquist, Hawley et Miller) from the second assemblage is a species occurring worldwide in the Kungurian and coeval deposits.

Thus, the cited data suggest an approximate correlation of the Kungurian and Bolorian stages, although, as in the case with the Sakmarian and Artinskian stages, the exact correlation between boundaries of these units should be verified. Indeed, there is no evidence indicating that the first appearance of *Misellina* forms marking the base of the Bolorian Stage was synchronous to first occurrence of *N. exculptus* and *N. pnevi* at the lower boundary of the Kungurian Stage. The degree of correspondence between upper boundaries of these stages will be discussed below.

Roadian Stage. As was mentioned, this unit was established by Furnish (1973) on the basis of ammonoids. The stage assemblage includes first representatives of the Ceratitida order (genus *Paracelmites*), new *Glassoceras* and *Texoceras* genera, and new species of the *Perrinites*, *Eumedlicottia*, and *Peritrochia* genera discovered in the Road Canyon Formation of the Glass Mountains in Texas. A similar assemblage is also recorded in the Kutoff Formation of the Guadalupe Mountains and in Meade Peak Beds of the Phosphoria Formation in Idaho. The assemblage from the latter locality includes also the *Daubichites* genus widespread in many sections of the Boreal province, South China and, even, in Australia. This fact seems to be opportune for the global recognition of the Roadian Stage, but it is not, as is shown below.

Furnish did not define the exact boundaries of the Roadian Stage and its stratotype. His data and materials of other specialists on ammonoids, who accept the Roadian Stage as valid, do not answer the question how quickly the Cathedral (Artinskian, according to Furnish, and Kungurian, according to the modern view) assemblage was replaced by the Roadian one, and to what extent concurrent are the appearance levels of its genera and species. Nothing exact was also said about the upper boundary of the stage, although one can understand that it was correlated with the first occurrence level of the *Waagenoceras* genus, which is now universally accepted for that boundary.

In the global stage scale under discussion, the problem concerning the stratigraphic range and boundaries of the Roadian Stage is solved with the help of conodonts (Glenister *et al.*, 1999). The time-range of the stage is correlated with that of the *Jinogondolella nankingensis* conodont zone. Its lower boundary is placed at the first occurrence level of the zonal species representing a descendant of *Mesogondolella idahoensis idahoensis* (Youngquist, Hawley et Miller). In the Guadalupe Mountains of Texas, this event is recorded in the upper part of the El Centro Bed, 43 m above the base of the Kutoff Formation (Fig. 1). The GSSP of the lower boundary of the stage and, correspondingly, of the entire Guadalupian Group is fixed precisely at this level. In the Glass Mountains, the replacement of *M. idahoensis idahoensis* (Youngquist, Hawley et Miller) by *J. nankingensis* (Ching) occurs in the lower third of the Road Formation (Wardlaw and Grant, 1987). The

Roadian–Wordian boundary is placed at the first occurrence level of *Jinogondolella aserrata* (Clark et Behnken), the descendant of *J. nankingensis*. The boundary GSSP is located within the Getaway Limestones of the Cherry Canyon Formation of the Guadalupe Mountains. In the Glass Mountains, the boundary is drawn between the Willis Ranch and Appel Ranch beds of the Word Formation, if we consider classical definition of the latter. In both cases, it occupies a substantially higher position than the first occurrence level of the ammonoid genus *Waagenoceras*. Correspondingly, the time-range of the Roadian Stage in the new (conodont-based) interpretation exceeds that proposed by Furnish on the basis of ammonoids.

Fusulinid assemblages of the Roadian Stage are uniform, mainly represented by species of the *Parafusulina* genus. Boundaries of the stage inferable from fusulinid biostratigraphy are very ambiguous. The endemic species composition of Roadian parafusulins is unfavorable for distant correlations, with the Tethyan sections in particular. In the last case, conodonts and ammonoids are of the prime significance. As is shown below, the Roadian Stage is now traced from the stratotype region (the Delaware basin of North America) to the Tethys. In the Tethyan sections, the ammonoid assemblage comparable with the Roadian one is discovered in the southeastern Pamirs, Afghanistan, presumably, in the Crimea, and also in some sections of South China.

In the first region, this is the so-called “Kubergandian assemblage” described by Tumanskaya (1935) who correlated it with the Wordian assemblage of Texas. It should be noted that beds subsequently attributed to the Roadian unit were included at that time into the Word Formation. Bogoslovskaya was first to correlate the Kubergandian assemblage with the Roadian one. In her opinion, “the Kubergandian ammonoids are undoubtedly younger than those of the Artinskian–Kungurian level, because they include species of the *Epiglyphioceras*, *Stacheoceras*, and *Paracelmites* genera that appear first in the Roadian assemblage of North America... Simultaneously, the Kubergandian Ammonoidea are definitely older than their Wordian assemblage, because the *Bamyaniceras* and *Popanoceras* genera unknown above the Roadian are present among them...” (Chediya *et al.*, 1986). In the stratotype section (the Kubergandy River, southeastern Pamirs), ammonoids are confined to the lower *Armenina–Misellina ovalis* Zone of the Kubergandian Stage. Occurring directly lower in the section are deposits of the Bolorian Stage with *Misellina termieri* (Deprat), *M. parvicostata* (Deprat), *Brevaxina otakiensis* (Fujimoto), and others. Associated forms are *Misellina ovalis* (Deprat), *Armenina salgirica* A. M.-Maklay, first *Yangchienia* and *Pseudodoliolina* (Leven, 1981; Chediya *et al.*, 1986).

In the Pamirs, the upper *Cancellina cutalensis* Zone of the Kubergandian Stage is barren of ammonoids, but

the latter are well represented in this interval of the section in the Tezak exposure of Central Afghanistan (Termier *et al.*, 1972; Desparmet *et al.*, 1972). The corresponding ammonoid assemblage is almost identical to the Kubergandian one in the generic and, to a large extent, in the species composition and can be considered, therefore, as correlative with the Roadian assemblage. Ammonoids associate with fusulinids of the *Cancellina cutalensis* Zone (Leven, 1997). Slightly higher in the section, there are fusulinids typical of the lowermost Murgabian strata, such as *Neoschwagerina simplex* Ozawa and *Presumatrina neoschwagerinoides* (Deprat).

Ammonoids coexisting with fusulinids of the lower zone of the Murgabian Stage were also found in Sample 110/1 from the Kichkhi-Burnu outcrop at the Marta River in the Crimea (Kotlyar *et al.*, 1999). At this site, the assemblage includes *Propinacoceras* sp., *Prostaheoceras tauricum* (Toumansky), and *Cardiella* (?) *kussica* (Toumansky). Zakharov who determined these fossils considers the assemblage as the Kubergandian or Roadian in age, but his conclusion is insufficiently substantiated in opinion of Bogoslovskaya (oral communication). In addition to his own materials, Zakharov cited also a large list of taxa described by Tumanskaya (1931) from the Kichkhi-Burnu site (the Marta assemblage). The section exposed at this site consists, however, of several limestone blocks, which yield, along with the early Murgabian species, also fusulinids from higher zones of this stage (Miklukho-Maklay, 1957). Accordingly, it is not inconceivable that ammonoids were sampled by Tumanskaya precisely from these blocks and should be younger in age. Tumanskaya correlated them with the Sicilian (i.e., Wordian) forms, and Bogoslovskaya (1984) supported this conclusion.

In South China, the ammonoid assemblage from the Kufeng Formation that includes the *Kufengoceras*, *Altudoceras*, *Paraceltites*, *Daubichites*, and *Cibolites* genera is usually correlated with the Roadian one (Zhou, 1986, 1989a; Sheng and Jin, 1994). The listed ammonoids do not associate with fusulinids, and their exact position in the Tethyan scale is unclear. It is inferred from the fact that the Kufeng Formation overlies the Chihhsia Formation and replaces the Maokou Formation or some its beds along the strike. In recent works, Chinese stratigraphers defined in the Kufeng Stage two *Neoschwagerina craticulifera* and *Neoschwagerina margaritae* fusulinid zones corresponding to the upper half of the Murgabian Stage, or three *Altudoceras-Paraceltites*, *Kufengoceras*, and *Waagenoceras* cephalopod zones (Sheng and Jin, 1994). Ammonoids from two lower zones are correlated with the Roadian assemblage.

Summarizing these data on distribution of ammonoids of the Roadian type in the Tethyan sections, one can find out that they occur from the base of the Kubergandian Stage (the *Armenina-Misellina ova-*

lis Zone) to the middle part of the Murgabian Stage (the *Neoschwagerina craticulifera*) at least. According to ammonoid biostratigraphy, the lower boundary of the Roadian Stage and, correspondingly, of the Guadalupian Series, corresponds to the base of the Kubergandian Stage. In the Tethyan sections, this level is marked by significant changes in composition of fusulinid and cephalopod communities and, thus, it is most suitable for placing here the boundary between series of the Permian System (Leven *et al.*, 1996). As for the upper boundary of the Roadian Stage in the Tethyan sections, it is not determined using ammonoids because of two reasons. First, as was mentioned, this level is uncertain even in the Texas type sections, because most characteristic representatives of the Wordian assemblage (genus *Waagenoceras*) appear inside the Roadian Stage (in its current understanding). Second, the first occurrence of the assemblage with *Waagenoceras* species in the Tethyan sections is established inexactly. I can only mention that the undoubtedly Wordian ammonoids are unknown below the upper half of the Murgabian Stage.

As for conodonts and their potential for recognition of the Roadian Stage in the Tethyan region, I should note the following.

In the currently accepted version of the global scale, the lower and upper boundaries of the stage are placed at the first occurrence levels of *Jinogondolella nankingensis* and *J. aserrata*, respectively. However, the characteristic genera and species of the stage are not indicated. Inasmuch as the species mentioned above dwelt only in warm water environments, they lack in deposits accumulated in colder climatic zones, or in relatively deeper settings. Consequently, the possibility of recognizing the stage in question remains ambiguous without versatile characteristics of conodonts typical of the stage. In the full measure, this is evident from variable interpretations of the Roadian Stage boundaries in the Tethyan sections, which have been suggested by experts on the conodont biostratigraphy.

The index species of the *Jinogondolella nankingensis* conodont zone that presumably corresponds to the Roadian Stage is known in the Tethyan region only from few sections of South China, and thus, it is of a limited significance for the correlation purpose. To solve the problem, we should define the exact position of the above conodont zone relative to the fusulinid zonation easily applicable for correlation of the Tethyan sections. Such an attempt is exemplified by the subdivision scheme of the Luodian section in the Guizhou Province of South China (*Excursion Guidebook*, 1994; Zhu and Zhang, 1994; Jin, 1998a, 1998b; Henderson *et al.*, 1999). In this section (Fig. 2), *J. nankingensis* is noted first in Bed 46, i.e., 150 m above the first occurrence level of the index species (*Neoschwagerina simplex*, Bed 28) of the lower zone of the Murgabian Stage and only 25 m below the first occurrence of the genus *Yabeina* (Bed 49) characteristic of the Midian Stage. The overlying Bed 50 yields first speci-

mens of *J. aserrata* representing the index species of the Wordian Stage according to the new definition of the latter (*Excursion Guidebook*, 1994). In addition to conodonts, Bed 46 yields fusulinids *Sumatrina annae* Volz., *Afghanella megasphaerica* Leven, *Pseudodoliolina pseudolepida* (Deprat), and others species characteristic of the upper half of the Murgabian Stage.

Using these data and formally following the Roadian Stage definition on the basis of conodonts, Mei Shilong and Ch.M. Henderson (Mei *et al.*, 1999; Henderson *et al.*, 1999) argued that the Roadian Stage in the considered section should include Beds 46–49 that are 78 m thick in total. In the Tethyan scale, this interval corresponds to the uppermost part of the Murgabian Stage that yields the highly evolved *Neoschwagerina*, *Afghanella*, and *Sumatrina* species and to the lowermost Midian beds with *Yabeina* forms. In this case, the greater part of the Murgabian Stage and the entire Kubergandian Stage are referred to the Kungurian Stage of the Lower Permian, and the boundary between the Cisuralian and Guadalupian series is placed inside the Murgabian stage. Such a conclusion substantiated only by occurrence of a sole conodont species (*J. nankingensis*) recognized in some sections is absolutely inconsistent with the data on ammonoid distribution mentioned above. In addition, the boundary between Permian series, when it is placed inside the Murgabian Stage, seems doubtful from the standpoint of successive events, because nothing happened in the fusulinid community at this level. Accordingly, this boundary position is artificial and virtually unrecognizable at least in the Tethyan region.

Kozur (1998) who had a possibility to get acquainted with conodont collection from the Luodian section criticized the conclusions of Mei and Henderson. In opinion of Kozur, the lower boundary of the Roadian Stage in that section should be placed at the appearance level of several smooth and more cryophilic (or deeper dwelt) gondolellids rather than at the first occurrence level of *J. nankingensis* that is probably redeposited. Like the latter, these gondolellids are descendants of *Mesogondolella idahoensis*. They appeared at the Kungurian–Roadian boundary and gave rise to two separate lineages: *M. idahoensis*–*M. saracinensis*–*M. siciliensis* and *M. idahoensis*–*M. phosphoriensis*. Using this concept, Kozur revised the age of beds with conodonts in the Luodian section. His stratigraphic scheme almost completely coincides with mine based on distribution of fusulinid taxa listed in publications (Zhu and Zhang, 1994; *Excursion Guidebook*, 1994) and identified by myself in samples collected during the excursion of the International Symposium on Permian Stratigraphy, Guiyang, 1994. Comparison of these fusulinid- and conodont-based schemes is shown in Figure 2. For instance, *Brevaxina* species and primitive *Misellina* forms, such as *B. dyhrenfurthi* (Dutkevich, *M. termieri* (Deprat), and *M. changmoensis* Dong, from beds 18 and 21b unambiguously indicate the Bolorian age of the beds, although the latter

		Leven, this paper	Beds	Henderson <i>et al.</i> , 1999	
Midian	Yabeina, <i>Metadoliolina</i>		50–55	<i>J. aserrata</i>	Wordian
	Yabeina, <i>S. longissima</i>		49	<i>J. nankingensis</i>	Roadian
Murgabian	<i>N. margaritae</i>		46–48	<i>J. nankingensis</i>	Roadian
	<i>S. annae</i> , <i>A. schencki</i>				
	<i>N. simplex</i> , <i>P. neoschwagerinoides</i>		28–45	<i>Swetognathus subsinmetricus</i>	Kungurian
Kubergandian	<i>C. dutkevitchi</i>		25–27	<i>M. siciliensis</i> <i>M. phosphoriensis</i> , <i>M. saracinensis</i> , <i>M. gujioensis</i>	Roadian
	Yangchienia, <i>M. ovalis</i> , <i>Armenina salgirica</i> , <i>Paraf. yunnanica</i>				
Bolorian	<i>M. termieri</i>		22–24	<i>M. saracinensis</i> , <i>H. gulloides</i>	Kungurian
	<i>M. changmoensis</i>		18–21	<i>M. gujioensis</i>	

Fig. 2. Subdivision of the Luodian section in accordance with the Tethyan fusulinid (left) and standard conodont (right) scales. Fusulinids: (S.) *Sumatrina*; (N.) *Neoschwagerina*; (A.) *Afghanella*; (P.) *Presunatrina*; (C) *Cancellina*; (M.) *Misellina*; (Paraf.) *Parafusulina*. Conodonts: (M.) *Mesogondolella*; (H.) *Hindeodus*; (J.) *Jinogondolella*.

also yields first specimens of *Parafusulina yunnanica* widespread in the Kubergandian Stage. The undoubtedly Kubergandian fusulinids (genus *Yangchienia*) appear in Bed 25a. Beds 22–24 lack fusulinids, but they probably belong also to the Kubergandian Stage. In Bed 25b, fusulinids are represented by *Armenina salgirica* A. M.-Maklay, *Misellina megalocula* Wang et Sun, *M. confragaspira* Leven, *Yangchienia* sp., and *Parafusulina yunnanica* Sheng typical of the lower *Armenina*–*Misellina ovalis* Zone of this stage.

Judging from conodonts, namely from presence of *Mesogondolella gujioensis* (Igo), Kozur attributed Bed 18 to the Bolorian Stage. Beds 19–21 are barren of conodonts, but Bed 22 yields *Gullocus catalonoi* (Gullo et Kozur), *Mesogondolella saracinensis* Gullo et Kozur, and *Hindeodus gulloides* Kozur et Mostler. These species are characteristic of the Roadian Stage, but some of them could have been appearing earlier. Accordingly, Kozur attributes Beds 22–24 to the Roadian, although with some reservations. In his opinion, undoubtedly Roadian is Bed 25b yielding *M. saracinensis* Gullo et Kozur, *M. phosphoriensis* (Youngquist, Hawley et Miller), and *M. siciliensis* (Kozur) (in the upper part). As can be seen, the Kungurian–Roadian boundary in the Kozur's scheme almost exactly coincides with its position between the Bolorian and Kubergandian

stages of the Tethyan scale. As for the upper boundary of the Roadian Stage in the Loudian section, Kozur did not discuss the relevant data. In principle, he believes that the idea to consider the first occurrence of *J. aserrata* as marking the boundary in question is unfortunate, because this species populated only surface waters of warm sea basin and, thus, its correlation potential is very low (Kozur, 1998).

Summarizing data on conodonts from the Luodian section, I can state the following.

(1) The lower boundary of the Roadian Stage, when it is placed at the occurrence level of cryophilic (deep-water) smooth gondolellids, coincides with the lower boundary of the Kubergandian Stage of the Tethyan scale. As is shown above, ammonoid assemblages from the Kubergandian Stage stratotype lead to a similar inference.

(2) When this boundary in the Luodian section is defined by the first occurrence level of *J. nankingensis*, it falls into the upper part of the Murgabian Stage. In this case, the Kungurian Stage time-range exorbitantly increases so, as to span, in addition to the Bolorian Stage, the Kubergandian Stage and the greater part of the Murgabian Stage. Since such a correlation is unlikely, one should assume that either *J. nankingensis* is redeposited in the Luodian section, or it appeared in the Tethys later than in the Delaware basin of North America. In the last case, this species is unsuitable at all to represent a marker of the lower boundary of the Roadian Stage, in particular, and Guadalupian Series, as a whole.

Wordian Stage. Similarly to the Roadian Stage, this unit was established by Furnish (1973) on basis of ammonoids as corresponding to the *Waagenoceras* Genus-zone. Glenister *et al.* (1992) who proposed to include the Guadalupian Series with its stages into the global chronostratigraphic scale shared this standpoint. The lower stage boundary was suggested to coincide with the first occurrence of *Waagenoceras* representatives inside the Pipeline Shales at the base of the Brushy Canyon Formation in the Guadalupe Mountains (Fig. 1). In the Glass Mountains, this level corresponds to the base of Willis Ranch Limestones in the middle part of the Word Formation, in traditional understanding of the latter. The boundary between the Wordian and overlying Capitanian stages was proposed to be at the first occurrence of the *Timorites* genus, the descendant of the *Waagenoceras* genus. In the section of the Guadalupian Mountains, first *Timorites* forms are recorded in the uppermost Manzanita Beds of the Cherry Canyon Formation (Furnish, 1973).

The current concept of the Wordian Stage range and boundaries distinguished on the basis of conodonts essentially differs from the original one. The stage is correlated with the *Jinogondolella aserrata* Zone having boundaries inside the Wordian and Capitanian stages of the former ammonoid-based scale. As was mentioned, the GSSP of the lower boundary of the

Wordian Stage is placed slightly below the roof of the Getaway Limestones of the Cherry Canyon Formation in the section of the Guadalupian Mountains, where it coincides with the first occurrence of the index species. In the Glass Mountains, this boundary separates the Willis Ranch and Appel Ranch limestone units of the Word Formation (Glenister *et al.*, 1999).

Before discussing the problem of recognition of the Wordian Stage in the Tethyan region, I should note that this is as difficult as in the Roadian Stage case. The Wordian fusulinid assemblage is almost identical to the Roadian one. It is represented by endemics missing beyond the western Texas and, thus, unsuitable for distant correlations. Ammonoids and conodonts are rare in the corresponding interval of the Tethyan sections, and their finds are poorly correlated with fusulinid markers.

The typical Wordian (after Furnish) ammonoid assemblage is well represented in isolated limestone blocks of Sicily and Timor (Gemmellaro, 1887; Gerth, 1950). Some of its representatives are also recorded in the Far East, Tunisia, China, and Japan. The Marta assemblage described from the Kichkhi-Burnu locality of the Crimea (Tumanskaya, 1931) is also of the Wordian age. In the Tethyan region, deposits with Wordian ammonoids were traditionally correlated with the Murgabian Stage defined in the range of the *Neoschwagerina* Genus-zone. Indeed, when Wordian ammonoids associate with the fusulinid assemblage, the latter usually includes this index genus. At the same time, the *Neoschwagerina* stratigraphic range exceeds that of the Murgabian Stage, because representatives of this genus cross the Murgabian-Midian boundary. In sections reliably dated by fusulinids, *Waagenoceras* representatives with sufficiently developed lobe lines coexist with advanced *Neoschwagerina* species that are absent below the upper Murgabian Stage. In Rupe de Passo di Burgio Sosio, the best known locality of Wordian ammonoids in Sicily, fusulinids (*Kahlerina*, *Rausarella*, *Dunbarula*, and *Sumatrina longissima* Deprat) characterize the basal part of the Midian Stage (Leven, 1996; Kozur and Davydov, 1996).

The Midian fusulinids are recorded together with Wordian ammonoids in Tunisia (*Dunbarula*, *Neoschwagerina*, *Yabeina*) and also in the Cache Creek locality of British Columbia, Canada (*Yabeina*) (Miller and Furnish, 1957; Ross, 1971). Thus, the reliably established stratigraphic range of the Wordian (after Furnish) ammonoid assemblage, first of all that of the *Waagenoceras* genus, comprises in the Tethyan region the upper half of the Murgabian Stage and the lowermost portion of the Midian Stage. Taking into consideration the opinion of Bogoslovskaya (1984) that the Marta ammonoid assemblage is similar to the Wordian one, it is not inconceivable that the stage range can be expanded to the base of the Murgabian. This assumption accords with data on diverse fusulinids from the Kichkhi-Burnu section, most of which characterize the lower zone of the Murgabian Stage, although some

Tethyan Scale (Leven, 1980)		Conodonts				Ammonoids	
Stages	Zones	Henderson <i>et al.</i> , 1999		Kozur, 1998		Bogoslovskaya <i>et al.</i> , 1999	
Dzhulfian (s. s.)	<i>Clarkina leveni</i>	Lopingian	Wuchapingian	Lopingian	Dzhulfian (s. l.)	P ₂	Dzhulfian
	<i>Araxoceras</i>						
Midian	<i>Eoaraxoceras</i>		Guadalupian		Capitanian		
	<i>L. kumaensis</i> <i>L. multiseptata</i> , <i>Y. globosa</i>	Wordian		Wordian			
	<i>A. robbinsae</i> , <i>Y. archaica</i>	Roadian		Wordian			
Murgabian	<i>A. schencki</i>	Cisuralian	Kungurian	Guadalupian	Roadian	P ₁	Roadian
	<i>A. tereshkovae</i>						
	<i>P. neoschwagerinoides</i> , <i>N. simplex</i>						
Kubergandian	<i>C. cutalensis</i>	Cisuralian	Kungurian	Guadalupian	Roadian	P ₁	Roadian
	<i>Armenina</i> , <i>M. ovalis</i>						
Bolorian	<i>M. parvicostata</i>	Cisuralian	Kungurian	Guadalupian	Kungurian	P ₁	Kungurian

Fig. 3. Variants of correlation of the standard and Tethyan stages within the Guadalupian Series. Fusulinids: (M.) *Misellina*; (C.) *Cancellina*; (N.) *Neoschwagerina*; (P.) *Presumatrina*; (A.) *Armenina*; (Y.) *Yabeina*; (L.) *Lepidolina*.

samples yield also the middle and upper Murgabian species.

Conodonts *J. aserrata* and *J. postserrata*, which are now considered, respectively, as markers of the lower and upper boundaries of the Wordian Stage, are recorded beyond the United States only in few sections of South China. Therefore, their practical application for the Wordian Stage recognition in the Tethyan region still remains to be substantiated. Judging from fusulinids (*Yabeina*, *Metadoliolina*) occurring together with indicated conodont species in the Luodian section (Fig. 2), the Wordian Stage in its current conodont-based interpretation (Fig. 3) is fully located inside the Midian Stage of the Tethyan scale (*Excursion Guidebook*, 1994; Mei *et al.*, 1998). Nothing significant in fusulinid development is recorded near the stage boundaries in the conodont scale, and fusulinids are, therefore, useless for their recognition.

Inferences from above information are as follows.

(1) In the Texas type sections, Wordian Fusulinids are represented by endemic forms unsuitable for the stage recognition in Tethyan areas.

(2) The ammonoid assemblage of the Wordian Stage, in its new time-range shortened now, remains inexactly characterized, and this unit cannot be recognized, therefore, in the Tethyan sections (as well as in type sections of Texas) with the help of this fossil group. When the Wordian Stage is considered in its traditional range, some elements of its ammonoid assemblage can be found in particular Tethyan sections. Nevertheless, distribution ranges of respective genera and species are unclear. According to available data, they occur in the interval from the upper part of the Murgabian Stage to the lower part of the Midian Stage. It is

likely as well that their lower distribution limit can be lowered down to the base of the Murgabian Stage.

(3) Judging from conodonts, the Wordian Stage corresponds to a part of the Midian Stage. Species marking new boundaries of the Wordian Stage are recorded only in the United States and South China being, thus, unsuitable for broad correlation with the Tethyan sections. The significance of conodonts decreases further, when one takes into consideration the fact that the guide assemblage of the stage is not established so far.

Capitanian Stage was established by Furnish (1973) as corresponding to the ammonoid *Timorites* Zone, though he did not indicate its stratotype and boundaries. Most representative cephalopod assemblages characteristic of this zone and, correspondingly, of the stage are recorded in Timor (the Basleo locality) and Mexico (the Las Delicias locality). In the Guadalupe Mountains, where the recently accepted type section of the stage is situated, the *Timorites* species occur in the Manzanita Beds of the Cherry Canyon Formation and in the Hegler Beds of the Bell Canyon Formation (Fig. 1). Despite the Hegler Beds Position at the very base of the Bell Canyon Formation, the latter is attributed almost entirely, except for the Lamar Limestones crowning it, to the Capitanian Stage. Furnish ascribed these limestones to the Amarassian Stage characterized by cephalopods known from the Timor and Mexico localities. The most peculiar feature of the Amarassian ammonoid assemblage is the first appearance of the genus *Cyclolobus* and xenodiscids. The Lamar Limestones proper are barren of ammonoids and their correlation with the Amarassian Stage is ambiguous to a considerable extent. It should be noted, however, that first xenodiscids (the genus *Xenaspis*) were recently discovered in the Pinery Beds of the Bell Canyon For-

mation, i.e., significantly below the Lamar Limestones (Wardlaw, 1996).

According to the accepted definition of the stage under consideration, its lower boundary (GSSP) is established at the first occurrence level of the *Jinogondolella postserrata* near the top of the Pinery Limestones, i.e., at the appearance level of first xenodiscids above beds yielding first *Timorites* specimens (Fig. 1). The GSSP of the upper stage boundary is defined in South China (Jin *et al.*, 1998a). In the Guadalupe Mountains, its level is close to the roof of the Lamar Limestones, where, like in South China, *Jinogondolella* species are replaced by the *Clarkina* forms (Kozur, 1998; Mei *et al.*, 1998).

Correlating the Capitanian Stage of the new global standard with units of the Tethyan scale, we again meet difficulties related to recognition of the stage boundaries (particularly, of the lower one) because of rare occurrence of conodonts and ammonoids, position of which in the fusulinid zonation remains unclear. Indeed, the Capitanian ammonoids (first of all, *Timorites* species) are recorded only in some Tethyan sections, where they are not accompanied by fusulinids. The best we can do, therefore, is to assume the Midian age of enclosing deposits. In addition, we should keep in mind that the stratigraphic range of *Timorites* genus is wider than the Capitanian Stage range inferred now on the basis of conodont biostratigraphy. As for conodont species *J. postserrata*, whose appearance is proposed to be marker of the lower stage boundary, they are recorded, in addition to sections in Texas, only in several sections of South China, where they occur in the upper half of the Midian Stage, as one can judge from accompanying fusulinids.

Thus, the available data indicate that the Capitanian Stage can be recognized only in some Tethyan sections of South China, where conodonts depict its lower and upper boundaries. In other cases, one can suggest only an approximate correlation of the stage with the uppermost part of the Midian Stage. Fossils, which could substitute conodonts by recognition of the lower stage boundary, are not established so far. As for the upper boundary of the Capitanian Stage, it is more or less coincident with the major biotic crisis resulted in extinction of larger fusulinids, almost all goniatites and corals, and of many other representatives of marine biota (Jin *et al.*, 1994; Leven and Korchagin, in press). Accordingly, this boundary is easily recognizable in the Tethyan region, although some discrepancies, those of the principal character included, exist as well. For instance, the GSSP of this boundary is officially placed at the first appearance level of *Clarkina postbitteri* in one of the South China sections (Jin *et al.*, 1998a, 1998b). Kozur (1998) suggests either to place it slightly below, at the base of the *Clarkina altudaensis* Zone, or, to the contrary, to draw it substantially higher, at the base of the *Clarkina leveni* Zone. In any case, any of the proposed levels can serve as the upper boundary of the

Capitanian Stage and, consequently, the Guadalupian-Lopingian boundary is also well recognizable in the Tethyan region.

The Lopingian Series with its Wuchapingian and Changhsingian stages is included into the global geochronological scale according to the proposal of Chinese stratigraphers; all these units are established in the South Chinese (i.e., Tethyan) sections. Their boundaries are well marked by changes in the conodont, fusulinid, and ammonoid assemblages and, thus, the recognition of the units meets no serious problems in the entire Tethyan realm. Tracing them beyond the Tethyan region, one meets difficulties, but this problem is out of the scope of this work.

CONCLUSION

The estimated correlation potential of the standard chronostratigraphic scale in the Tethyan region leads to the following conclusions.

(1) In principle, it seems reasonable to subdivide the Permian System into three series, because the three-member scale reflects adequately the natural-historical development of the biosphere. At the same time, criteria used to define the lower boundary of the Guadalupian Series need to be specified or revised. The available data show that in case, when this boundary is correlated as proposed, with the first occurrence of thermophilic (shallow-water) *J. nankingensis*, it falls inside the Murgabian Stage of the Tethyan scale, at the level near the stage top, where nothing happened with marine biota. Situation is quite different, when the lower boundary of the Guadalupian Series is placed at the first occurrence level of cold-resistant conodonts and ammonoids. In this case, it coincides with the base of the Kubergandian Stage of the Tethyan scale marked by essential renewals in marine fossil assemblages. Accordingly, the lastly mentioned level can be considered as better corresponding to the boundary between the Cisuralian and Guadalupian series. The noted discrepancies are probably related to the redeposited state of *J. nankingensis* in the South Chinese sections. Additional search for this species in lower layers of these sections are desirable therefore.

(2) Asselian, Sakmarian, Artinskian, and Kungurian stages of the lower Cisuralian Series of the standard scale correspond to the Asselian, Sakmarian, Yakhtashian, and Bolorian stages of the Tethyan scale, respectively. Nevertheless, the inadequate characteristics of conodonts and ammonoids from the Tethyan sections, as well as present-day disagreements concerning the definition criteria of stage boundaries in the standard scale, bring the above statement into challenge. Despite this situation, it is quite possible to practice the indicated stages of the standard scale instead of the Tethyan stages. The sole exception is the Bolorian Stage, since its correspondence to the Kungurian Stage remains uncertain, if we take into consideration the aforemen-

tioned controversial positioning of the lower boundary of the Guadalupian Series. The problem solution needs in additional data that would confirm the boundary position in Tethyan sections at the base of the Kubergandian Stage, but not in the uppermost part of the Murgabian Stage.

(3) None of the stages of the middle Guadalupian Series is recognizable in the Tethyan region. At the first approximation, it can be assumed that the Roadian, Wordian, and Capitanian stages of the standard scale correspond respectively to the Kubergandian, Murgabian, and Midian stages in the Tethyan region, if their correlation would be based on ammonoids according to tradition. Correlation with the help of ammonoids is impossible at present because of their rare occurrence. The current stage boundaries in the standard scale are inferred from the conodont biostratigraphy and substantially differ from those corresponding to biotic events in ammonoid communities. According to the available data, all boundaries between three stages of the standard Guadalupian Series fall in the Midian-uppermost Murgabian interval of the Tethyan scale, when one strictly follows the conodont-based boundary definitions. It is apparent, therefore, that the Roadian, Wordian, and Capitanian stages are absolutely unsuitable for the Tethyan stratigraphy, because their boundaries in current interpretation have no confirmation in fusulinid zonation that is critical for recognition of the Tethyan stages. In addition, the Kungurian Stage time-range, which should correspond in this case to the Bolorian and Kubergandian stages coupled with the greater part of the Murgabian Stage, will be exorbitantly large.

(4) Two stages of the upper Lopingian Series of the Permian System are established in South China. Naturally, there are no problems with their application in the Tethyan region, particularly if we take into consideration that their paleontological characteristics are known much better than those of the Guadalupian stages. Some discrepancies concerning the lower boundary of the series are insignificant and can be eliminated already now by voting. The Wuchapingian Stage time-range in the standard scale would exceed that of the Dzhulfian Stage in the Tethyan scale, if its lower boundary is correlated with the first occurrence level of *Araxoceras* and *Clarkina leveni*. The Changhsingian Stage of the standard scale exactly coincides with the Dorashamian Stage of the Tethyan scale.

(5) The aforesaid indicates that the standard stages of the Cisuralian and Lopingian series of the Permian System can be applied in the Tethyan stratigraphy after some coordination and specifications. Stages of the Guadalupian Series are still inappropriate despite the fact that they are approved by the International Subcommission on Permian Stratigraphy. This is a result of new approach, when, instead of substantiation of the Guadalupian stages on the basis of versatile paleontological characteristics and changes in faunal assem-

blages at their boundaries, the procedure was reduced to formal tracing of the species succession in the sole phylogenetic lineage of conodonts. The formalized recognition of stages and their boundaries on the basis of the single criterion (appearance of successive conodont species) reduces the possibility of distinguishing the same units in other regions.

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