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The Roadian Stage of the Permian and Problems of Its Global Correlation

E. Ya. Leven[a] and M. F. Bogoslovskaya[b]

[a]*Geological Institute, Russian Academy of Sciences, Pyzhevskii per. 7, 119117 Moscow, Russia*
[b]*Paleontological Institute, Russian Academy of Sciences, Profsoyuznaya ul. 123, 117647 Moscow, Russia*

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Abstract—Ammonoids, conodonts, and fusulinids from the type sections of the Roadian and contiguous stages in western Texas and adjacent areas are analyzed and partially revised. Four successive Roadian ammonoid assemblages are distinguished and correlated with conodont zones; data on their distribution are presented. Based on the results obtained, the Roadian Stage is identified in the Boreal and Tethyan regions. Boundaries of the Roadian Stage defined accurately in the type sections of Texas are hardly recognizable elsewhere. Recognition of the upper boundary is especially difficult. Occurrence of Roadian fossils means that deposits of this age are present in a sequence, but they cannot be differentiated from underlying and overlying beds. Like in the type area, the stage lower boundary based on conodonts is above the level of significant changes in marine biota within the Boreal and Tethyan realms as well. The upper boundary is not marked by noticeable biotic events either. Correlation of the Roadian deposits is imprecise because their boundaries are formally established using distribution of relatively rare conodonts.

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Key words: Permian, Roadian, ammonoids, conodonts, fusulinids, correlation, Texas, Boreal region, Tethys.

INTRODUCTION

The Permian deposits of western Texas named "Guadalupian" by Girty (1902) more than 100 years ago are considered now as the middle (Guadalupian) series of the Permian System of the Standard Chronostratigraphic Scale (Yugan et al., 1997). The series is divided into three the Roadian, Wordian, and Capitanian stages. Type sections of the former two stages are in the Glass Mountains, and that of the third one, in the Guadalupe Mountains. Since the moment of their identification, initial stratigraphic ranges of the stages are remarkably changed now because of different determination criteria. The stages first established using ammonoids are identified now based on distribution of conodonts. As a result, the conodont-based boundaries turn out to be inside the distribution ranges of ammonoids characterizing the original stages. Recognition of the stages and especially of their boundaries is difficult because of a limited distribution of key conodont species outside the western United States. The priority significance of conodonts for discriminating the stages is authorized in the adopted Permian stratigraphic scale and cannot be disputed therefore. The problem is to correlate as accurately as possible the boundaries in conodont successions with remarkable events in evolution of other fossils, primarily of ammonoids and fusulinids. To some extent, the issue has been considered already (Leven, 2001), and considerations in this article are focused on the Roadian Stage.

Furnish (1973) identified the Roadian Stage as corresponding in range to the first limestone bed of the Upper Permian Word Formation (King, 1931). Cooper and Grant (1964) ranked this bed as the Road Canyon Formation and placed the boundary between the Permian series, or between the Leonardian and Guadalupian groups, at the top but not at the base of the formation. Their decision was based on similarity between the Roadian and late Leonardian (Cathedralian) brachiopod assemblages. Furnish, who studied ammonoids, was of the same opinion. On the contrary, experts in fusulinids believed that the Roadian assemblages of these fossils are closer to the Wordian rather than to the Cathedralian ones.

Thus, controversies concerning the Roadian Stage affiliation with the Permian series originated at the very moment of the stage establishment. The situation became more complicated when conodonts had been chosen as a key group to calibrate boundaries of the Permian stages in the Standard Chronostratigraphic Scale. According to recommendations of the International Commission on Stratigraphy, the unit boundaries must be defined in the so-called Global Stratotype Section and Points (GSSP) chosen in certain sequences of lithologically uniform beds at the levels of natural changes in continuous succession of species. Neither the lower nor the upper boundary of the Roadian Stage in its initial range meets this requirement. After intense study of conodonts from the type sections of western

Table 1. Ammonoid-based correlation of the Roadian Stage between different biogeographic regions

<table>
<tr><th colspan="2" rowspan="2">SCS</th><th colspan="4">Texas</th><th colspan="3" rowspan="2">Wyoming, Idaho</th><th colspan="2" rowspan="2">Tethys</th><th colspan="2">Boreal region</th></tr>
<tr><th colspan="2">Guadalupe Mountains</th><th colspan="2">Glass Mountains</th><th>Canada</th><th>Russia</th></tr>
<tr><td rowspan="6">Guadalupian Series</td><td>Wordian</td><td rowspan="2">Cherry Canyon Formation</td><td>④</td><td rowspan="4">Word Formation</td><td>Apple Beds ④</td><td rowspan="7">Phosphoria Formation</td><td colspan="2">Rex Chert Formation</td><td colspan="2" rowspan="3">Murgabian Stage</td><td>Trold Fiord Formation</td><td>Urzhum Horizon</td></tr>
<tr><td rowspan="5">Roadian</td><td rowspan="3">Gateway Beds ④ ③ Pipeline Beds</td><td rowspan="3">Williams Ranch Beds ③ China Tank Beds</td><td rowspan="6">Meade Peak Formation</td><td rowspan="5">②</td><td rowspan="5">Assistance Formation</td><td rowspan="5">Kazanian Stage</td></tr>
<tr><td rowspan="2">Brushy Canyon Formation</td></tr>
<tr><td rowspan="4">Kubergandian Stage</td><td rowspan="2">Cancellina cutalensis</td></tr>
<tr><td rowspan="3">Cutoff Formation</td><td rowspan="2">Williams Ranch Beds ② El Centro Beds</td><td rowspan="3">Road Canyon Formation</td><td rowspan="2">②</td></tr>
<tr><td rowspan="2">Armenina, Misellina ovalis</td></tr>
<tr><td rowspan="2">Cisuralian Series</td><td rowspan="2">Kungurian</td><td>① Shumard Canyon Beds</td><td>①</td><td>① “Goniatites” Beds</td><td>Sabine Bay Formation</td><td>Ufimian Stage</td></tr>
<tr><td colspan="2">Bone Spring Limestones</td><td colspan="2">Cathedral Mountains</td><td colspan="3">Grandeur Formation</td><td colspan="2">Bolorian Stage</td><td></td><td>Kungurian Stage</td></tr>
</table>

Note: Encircled figures ①–④ denote ammonoid assemblages; SCS – the Standard Chronostratigraphic Scale.

Texas, it was decided to relate the stage boundaries of the Guadalupian Series with succession of conodont species *Mesogondolella idahoensis* ⟶ *M. nankingensis* ⟶ *M. aserrata* ⟶ *M. postserrata.* This approach displaced the lower stage boundaries upward, inside the ammonoid-based stages of Furnish. The stage names have not been changed. Consequently, correlations of the Roadian, Wordian and Capitanian stages, which were previously based mainly on ammonoids, have to be revised. This article considers this problem with particular attention to the Roadian Stage. The problem solution is evidently dependent on accuracy of correlation between ammonoid and conodont zonations in the Roadian stratotype area that includes western Texas and New Mexico; sections of Idaho and Wyoming are also of great significance.

STRATOTYPE AREA OF THE ROADIAN STAGE

In the western United States, the stratigraphic interval under consideration is well characterized by *ammonoids.* More than 40 genera and 70 species are described here in detail with indicated positions in the sections (Miller and Cline, 1934; Miller and Furnish, 1940; Miller, 1944; Spinosa et al., 1975; Taralson, 1984; Mikesh et al., 1988; Spinosa and Nassichuk, 1944; and other works). Furnish, Glenister, and Leonova restudied them using some new materials from sections of Texas (Furnish and Glenister, 1977; Wardlaw, 1996) and New Mexico (Wardlaw et al., 1979). Four successive assemblages confined to local stratigraphic units are distinguished based on stratigraphic distribution of ammonoids in the stratotype and adjacent areas (Table 1). Correlation of these units, especially the lower ones characterized by the first ammonoid assemblage, is consistent with correlation suggested recently and based on other fossils, the conodonts included (Harris et al., 2000; Lambert et al., 2000; Wardlaw et al., 2000).

The first assemblage (*1* in Table 1) comprises ammonoid genera of the uppermost beds underlying the Roadian Stage in its range established based on conodonts. The beds belong to local formations, four of which are well characterized by ammonoids. These are (1) a lower part of the Road Canyon Formation (Glass Mountains) correlative in age with Blaine Formation (north of Central Texas), (2) the so-called “*Goniatites* Beds” in the lower part of the Meade Peak Beds of the Phosphoria Formation (Idaho and Wyoming), (3) the Las Sardinas Beds and *Perrinites* Shale (New Mexico), and (4) the Shumard Canyon Beds in the lower part of the Cutoff Formation, which correspond to the gray Bone Spring Limestone (Guadalupe Mountains).

The assemblage consists of 10 to 12 genera and 13 to 16 species. It is easily distinguishable from the preceding assemblage of the Cathedral Mountain Formation because of newly appeared genera *Daubichites* (one of the earliest genera from family Pseudogastrioceratidae), *Glassoceras* (ancestral genus of family Glassoceratinae), *Metacrimites* (family Adrianitidae), probably *Paraceltites* (ancestral genus of order Ceratitida), and *Peritrochia.* All the genera are known from higher strata as well. Most characteristic of the assemblage are species of earlier widespread genera *Bamyaniceras* (*B. knighti*), *Pseudovidrioceras* (*Ps. girtyi*), *Perrinites* (P. *hilli* s.s.), *Eumedlicottia* (*E. whitneyi*), and *Stacheoceras (S. rothi).* The former two genera become extinct being unknown stratigraphically higher. Ammonoids occur in association with conodonts of the *Neostreptognathodus sulcoplicatus–Penicularis bassi* Zone.

The second assemblage (*2* in Table 1) is characteristic of the lower half of the Roadian Stage being interrelated with the first one. Taxa of the assemblage (15 genera and 20 species) occur higher in the same sections, i.e., in the larger upper half of the Road Canyon Formation of the Glass Mountains and concurrent strata: the upper Williams Ranch Beds of the Cutoff Formation in Guadalupe Mountains and the upper half of the Meade Peak Beds in Wyoming. The lower distribution limit of the second assemblage, which can be regarded as marking the Roadian lower boundary, is defined by the first occurrence of several taxa. These are genera *Texoceras* (phylogenetic relations are unknown) and *Epithalassoceras* (descendant of Early Permian *Thalassoceras*) and five species: *Glassoceras normani* (descendant of *G. bransonorum* occurring in the first assemblage), *Eumedlicottia burckardti* (allied to older *E. whitneyi*), *Perrinites vidriensis* (succeeding *P. hilli* in evolution), and abundant *Paraceltites elegans.* Appearing above the lower boundary, probably at different levels, are genera *Spirolegoceras* (presumable descendant of *Gobioceras*) and *Demarezites* (an earliest taxon of highly advanced Cyclolobidae). The earliest representatives of *Waagenoceras* are also reported from this interval (Lambert et al., 2000), but they have not been described and their presence at this stratigraphic level is doubtful.

Thus, the second assemblage differs from the first one in presence of four or five new genera. The Roadian lower boundary is defined certainly by the first occurrence of *Texoceras* and probably of *Epithalassoceras.* In principle, the boundary marks appearance of new species. The assemblage is most complete in the upper parts of the Road Canyon and Cutoff formations (Williams Ranch Beds). Roadian *Spirolegoceras fisheri* and *Demarezites furnishi* from the upper part of the Meade Peak Beds of the Phosphoria Formation have no known ancestors and are of uncertain stratigraphic position. In the above beds, they are associated with typical Roadian conodonts, *Mesogondolella nankingensis* included (Miller et al., 1957; Spinosa and Nassichuk, 1994). The species are unknown in the stratotype sections.

The third assemblage (*3* in Table 1) is most abundant and widespread. It consists of 18 genera and nearly 25 species, most of which are known from the Wordian Stage in understanding of Furnish (1973), i.e., from the second (China Tank Beds) and third (Williams Ranch Beds) limestone members of the Word Formation distinguished by King (1931). The assemblage is most widespread in the Glass Mountains and New Mexico. The first occurring *Altudoceras, Tauroceras* (China Tank Beds), *Mexicoceras, Pseudagathiceras*, and *Waagenoceras* (Williams Ranch Beds) are abundant at this stratigraphic level and higher. Within the range of the China Tank Beds, *Atsabites* appears and become extinct along with the Early Roadian *Demarezites* and *Epithalassoceras* forms.

The third assemblage is most diverse in taxonomic aspect. In addition to appearance of five new genera, it is noticeably distinct from the second one by a sharp increase in abundance of taxa with multicomponent, complicatedly dissected lobe. Taxa of this kind are characteristic of the fourth assemblage from the lower part of the Wordian Stage in its recent interpretation. There are no data sufficient for accurate determination of the upper distribution limit of third assemblage.

The fourth assemblage (*4* in Table 1) from the lower part of the Wordian Stage in its recent interpretation differs a little from the third assemblage in generic composition. Genera characteristic of the lower part of the "new" Wordian (*Neogeoceras, Aricoceras, Pseudagathiceras*) are known also from uppermost beds of the Roadian (Gateway Limestone), which contain ammonoids of the third assemblage and conodont *M. nankingensis.*

Conodonts, the priority fossils in Permian stratigraphy, have been intensively studied in recent time. Conodonts from type sections of the Guadalupian Series, including those of the Roadian Stage, were carefully examined as well.

In the Glass Mountains, conodont zones of the stratigraphic interval under consideration are as follows (Wardlaw, 2000; Wardlaw et al., 2000):

(1) ***Transition Zone*** is characterized by forms transitional from *Mesogondolella idahoensis* to *M. nankingensis.* The zone lower boundary is approximately at the base of the Road Canyon Formation. The zone contains the first ammonoid assemblage.

(2) ***Zone "A"*** is defined above the first occurrence level of true *M. nankingensis*, and its base coincides with the lower boundary of the Roadian Stage, which is therefore inside the lower third of the Road Canyon Formation. The zone is characterized by the second ammonoid assemblage.

(3) ***Zone "B"*** spans interval from the base of the China Tank Beds of the Word Formation to the Williams Ranch Beds inclusive, i.e., up to the upper distribution limit of *M. nankingensis.* The zone is characterized by the third ammonoid assemblage.

(4) ***The Mesogondolella aserrata Zone*** is basal one in the Wordian Stage. The stage lower boundary corresponds to the first occurrence level of the zonal index species. In the Wordian stratotype section (Guadalupe Mountains) this boundary is slightly below the top of the Gateway Beds of the Cherry Canyon Formation.

The lower part of the zone contains the fourth ammonoid assemblage.

In the Guadalupe Mountains, the Roadian lower boundary marks the appearance level of the *M. idahoensis* transitional to *M. nankingensis*, which is established in the middle part of the El Centro Beds of the Cutoff Formation (Wardlaw, 2000). Therefore this boundary seems to be somewhat lower here than in the Glass Mountains. The Shumard Canyon Beds at the base of the Cutoff Formation yield only *M. idahoensis* in association with ammonoids of the first assemblage. The upper El Centro Beds and the Williams Ranch Beds of the Cutoff Formation include the second ammonoid assemblage and typical Roadian conodonts, the most characteristic of which is *M. nankingensis.* This species is transit, occurring in the Brushy Canyon Formation and lowest interval of the Cherry Canyon Formation (a lower part of the Gateway Beds), where conodonts are associated with ammonoids of the third assemblage. The *M. aserrata* Zone now equivalent in range to the Wordian Stage spans the larger part of the Cherry Canyon Formation. Sporadic ammonoids occurring in the zone can be referred to the fourth assemblage only conventionally.

Joint occurrence of conodonts and ammonoids is known in the Meade Peak Beds of the Phosphoria Formation of Wyoming and Idaho. The basal part of the beds, which is lacking *M. nankingensis*, is referred to the *Neostreptognathodus sulcoplicatus–Pennicularis bassi* Zone (Wardlaw and Collinson, 1986). Ammonoids from this level (*Goniatites* Beds) belong to the first assemblage. The larger upper part of the Meade Peak Beds corresponds to the *Neogondolella serrata–Neostreptognathodus newelli–Pennicularis bassi* Zone (Wardlaw and Collinson, 1986). The most characteristic species is *Mesogondolella nankingensis (=Neogondolella serrata*). The zone includes rare ammonoids (*Demarezites, Spirolegoceras*) of the second assemblage (Spinosa and Nassichuk, 1994).

The next *Neogondolella phosphoriensis–Thamnosia depressa* Zone comprising the uppermost Meade Peak and overlying Rex Chert beds (Wardlaw and Collinson, 1984, 1986) contains no ammonoids.

Summarizing data on distribution and joint occurrence of ammonoids and conodonts in the Roadian stratotype areas, it is possible to state the following:

(1) The lower boundary of the Roadian Stage defined by first occurrence of *N. nankingensis* corresponds approximately to the level of transition from the first by the second ammonoid assemblage in the lower third of the Road Canyon Formation and concurrent sequences.

(2) According to distribution of ammonoids, this boundary is less distinct and significant than that marking appearance of the first ammonoid assemblage and coinciding with the lower boundary of the Road Canyon Formation.

(3) The upper boundary of the Roadian Stage defined by the first occurrence of *M. aserrata* is indistinct in the ammonoid succession. One can suspect only that it approximately corresponds to the level of transition from the third to fourth ammonoid assemblages.

Thus, the events in ammonoid evolution are correlative more or less with stages of conodont evolution. It is more difficult however to interrelate events in evolution of fusulinids and conodonts. Beginning from the Cathedralian (Kungurian) Stage, fusulinids are mostly represented by *Parafusulina* forms of a rather uniform morphology that is getting complicated gradually up to the top of the Wordian. Distinct stages in evolution of this genus are difficult to outline. The existing local zonations (Wilde, 1990, 2000; Yang and Yancey, 2000) based on endemic slightly differing *Parafusulina* species are unsuitable for distant correlations. The only significant event is appearance of the earliest multiapertural genera *Skinnerina* (Wilde, 2000), *Yangchienia* and *Rauserella* in the lower third of the Road Canyon Formation, which are typical of the Late Permian in Tethyan realm. However, an unambiguous stratigraphic conclusions is impossible because of sporadic occurrence of these three genera. Their position in relation to the Roadian lower boundary is differently interpreted. For instance, *Skinnerina* and *Rauserella* are thought to appear either at this boundary (Wilde, 2000) or somewhat below it (Yang and Yancey, 2000).

Having analyzed the distribution of Roadian ammonoids, conodonts, and fusulinids in the type sections, let us turn to the Boreal and Tethyan realms.

BOREAL REALM

In deposits of Boreal realm, fusulinids of the stage under consideration are unknown. The Roadian Stage can be recognized and correlated here based on ammonoids and conodonts.

In Arctic Canada, the Roadian zonal species *Mesogondolella nankingensis* appears in the Assistance Formation, where ammonoid genera *Daubichites* (one species), *Sverdrupites* (two species), and *Biarmiceras* (?) sp. are found at different levels (Nassichuk, 1970; Kozur and Nassichuk, 1977). *Sverdrupites* is represented by two successive species (*S. harkeri* ⟶ *S. amundseni*,), the first of which is found at the base and in the middle of the formation; the second one, slightly below its top. Stratigraphic ranges of *M. nankingensis* and *Sverdrupites* forms are restricted most likely by the Assistance Formation. In this case, the formation corresponds to the Roadian Stage, because the overlying Trold Fiord Formation lacks conodonts but contains ammonoid *Neogeoceras* (*N. macnairi*) widespread above the Roadian deposits (Nassichuk et al., 1965; Nassichuk, 1995). The Sabine Bay Formation underlying the Assistance Formation contains conodont species *M. idahoensis* (Kozur and Nassichuk, 1977) and an ancestral form of *Sverdrupites* described by Nassichuk (1970) as *Sverdrupites* sp. and by Bogoslovskaya as *Epijuresanites* sp. This form was found in debris at the base of the Assistance Formation and in autochthonous position in the middle part of the Sabine Bay Formation. At present, there are no reasons to refer the latter formation to the Roadian Stage (Nassichuk, 1995). In Texas, it is likely correlative with lower beds of the Road Canyon Formation and concurrent deposits containing the first ammonoid assemblage.

In northeastern Russia no conodonts have been found, but Roadian ammonoids *Daubichites goochi* and two *Sverdrupites* species (in the same succession as in the Assistance Formation of Arctic Canada) were discovered in the lower Delenzha Subhorizon of the Verkhoyansk region and in the Omolon Horizon of the Kolyma–Omolon province (Andrianov, 1985; Kutygin et al., 2002, 2004). Occurrence of these taxa means that the mentioned units can be correlated with the Assistance Formation and the Roadian Stage. Their lower boundaries defined by the first occurrence of *Sverdrupites harkeri* coincide very likely with the Roadian base, but there is no reliable evidence for position of upper boundaries. Thus, leaving aside the exact positioning of the Roadian upper boundary, we can correlate the Roadian Stage with the lower Delenzha Subhorizon. The suggested correlation is consistent with data on occurrence of *Epijuresanites* (an ancestral form of *Sverdrupites*) in the underlying upper Tumara Subhorizon. As noted above, highly advanced *Epijuresanites* sp. (=*Sverdrupites* sp., Nassichuk, 1970) was found in the Sabine Bay Formation of Arctic Canada.

In European Russia, the Roadian Stage approximately corresponds to the Kazanian Stage and its age analogs (the Kocherga and Gerke formations of the Novaya Zemlya). All of these units are characterized by ammonoid genera and species known from Arctic Canada and northeastern Russia (Bogoslovskaya et al., 1982; Leonova et al., 2002, 2005; Leonova and Shilovskii, 2004). In the Novaya Zemlya, ammonoids are divisible in two assemblages: the lower one including *Sverdrupites harkeri* and *Daubichites butakovensis* (Kocherga Formation) and the upper assemblage containing *D. butakovensis, S. amundseni*, and *A. boreum* (Gerke Formation). Coexistence of *S. amundseni* and *A. boreum* (genus *Altudoceras* appears at the level of the China Tank Beds) indicates the late Roadian age of the Gerke Formation, while the Kocherga Formation lacking the late Roadian forms is evidently the early Roadian in age. In the Kazanian Stage stratotype (Kirov area), ammonoids were found in a single outcrop, at two closely spaced levels near the boundary between the Prikazanskie and Pechishchi beds of the upper Kazanian Substage (Leonova et al., 2002). However, according to Kotlyar et al. (2004), the *Goniatites* Beds are correlative with the Baitugansk and Kamyshlin beds of the lower Kazanian Substage. In general, the Kazanian assemblage consists of 10 ammonoid species (a half determined in open nomenclature) and 6 genera (a half questionable). In majority, the species belong to two genera: the strictly Roadian *Sverdrupites* represented by widespread *S. harkeri* and *S. amundseni* and the new genus *Biarmiceras*, which occasionally occurs below the Roadian deposits. The last genus is represented in the assemblage by three abundant species (Leonova et al., 2005). A peculiar feature of the assemblage is presence of two *Sverdrupites* species. Commonly *S. harkeri* occurs only in lower beds of the Roadian Stage (lower part of the Assistance Formation and the Delenzhi Horizon), whereas *S. amundseni* is confined to the upper part of the stage. This is consistent with morphological complication of septum in the phylogenetic succession *Epijuresanites* ⟶ *Sverdrupites.* Presence of two interrelated *Sverdrupites* species suggests the middle Roadian age of the Kazanian assemblage, which is located between two assemblages from the Novaya Zemlya. Thus, if the above ammonoids are confined to the mid-Kazanian level, the Roadian Stage most likely corresponds to the entire Kazanian Stage rather than to its lower substage as assumed by Kotlyar et al. (2004). It is quite evident besides that the available data on ammonoid cannot be used for a reliable correlation of boundaries of the original Kazanian and Roadian stages.

Nevertheless, there are enough criteria for recognizing the Roadian Stage in Boreal regions. The main evidence is the ammonoid phylogenetic succession *Epijuresanites* (*E. primaris* ⟶ *E. musalitini* ⟶ *E. vaigachensis* ⟶ *E.* sp.) ⟶ *Sverdrupites* (*S. harkeri* ⟶ *S. amundseni* ⟶ *S.* aff. *amundseni*). In this succession, genus *Sverdrupites,* whose upper distribution limit should be determined more precisely, is likely indicative of the Roadian Stage, while *Epijuresanites* is index taxon of the Ufimian Stage. The Roadian lower boundary at the level of transition from *Epijuresanites* to *Sverdrupites* forms is documented in the boundary beds between the Sabine Bay and Assistance formations of Arctic Canada. There are no doubts that this interval and the upper distribution limit of *Sverdrupites* species need to be studied further.

Correspondence of the Kazanian Stage with the Roadian Stage can be also inferred from conodonts occurring in lower (*Kamagnathus khaliambadzhae, Stepanovites aliensis*) and upper (*Kamagnathus volgensis, Stepanovites meyeni*) Kazanian substages (Chernykh et al., 2001; Chernykh and Silant'ev, 2004). However, the conodont-based correlation does not seem to be fully correct. *Stepanovites* forms have not been found in the Roadian type sections of the western United States. In addition, their distribution is not limited by this stage. Par example, *S. aliensis* is described from the Shurtan Beds in the Perm region of the Cis-Urals, i.e., from the basal Kungurian level (Chuvashov et al., 1999). *S. meyeni* is known from the Wordian deposits (Kozur, 1995). The lowest (Baitugansk) beds of the Kazanian Stage are correlated with basal Roadian beds of the western United States based on similarity between Pa elements of *Kamagnathus* and some of Pa elements of *Sweetina triticum* from the Dry Bread

Hollow site in Utah (Chernykh and Silant'ev, 2004). However, according to Wardlaw and Collinson (1986, fig. 2, table 1), *S. triticum* is confined in this locality to the Franson Beds above the Grandeur Beds with *Mesogondolella nankingensis.* Because the Roadian lower boundary is defined by the first occurrence of the last species, it appears to be below the beds with *S. triticum.* Consequently, in the East European sections this boundary can also be not at the base of but below the beds with earliest *Kamagnathus* forms comparable with *S. triticum* from Utah. This conclusion shows that decision to abandon the Ufimian Stage and to include relevant deposits into the Kungurian Stage (*Resolutions…*, 2004) is hasty and insufficiently substantiated. The necessary criteria must be more reasonable.

All the data considered above show that in the East European sections the Kazanian Stage approximately corresponds to the Roadian one. However, it would be untimely to assert the full coincidence of stages, because correspondence of their boundaries, especially of upper ones, has not been proved so far.

TETHYAN REALM

Problems of using the standard stages of the Guadalupian Series in the Tethyan realm have been discussed already (Leven, 2001). As is shown, it is difficult to recognize here the stage boundaries including those of the Roadian Stage. Stages correlated previously based mainly on ammonoids were those suggested by Furnish (1973). Now we should take into account new positions of their boundaries. Earlier, Bogoslovskaya reasonably correlated the ammonoid-defined lower boundary of the Roadian Stage with the base of the Kubergandian Stage (Chediya et al., 1986). Now this correlation must be corrected, however, because the Roadian base is displaced higher.

Revision of data on *ammonoids* from the Roadian and Kubergandian type sections leads to the conclusion that the Roadian lower boundary in its current interpretation does not coincide with the Kubergandian base in the Tethyan scale, as supposed earlier, but is at a higher level, probably in the upper part of the *Armenina–Miselina ovalis* Zone of fusulinid scale. In the stratotype section (Kubergandy River in the southeastern Pamirs), the ammonoid assemblage from the lower part of the zone (9 genera and 10 species) includes, beside Late Permian *Paraceltites* and *Epiglyphioceras*, representatives of many Early Permian genera. These are latest *Bamyaniceras*, transit *Eothinites, Popanoceras, Neocrimites*, and other forms widespread in the Lower Permian in and outside the Tethyan realm (Tumanskaya, 1935; Chediya et al., 1986). According to joint occurrence of many older and newly appeared genera, which diversified later on, this assemblage is comparable with the first ammonoid assemblage from North American sections. In addition, both assemblages contain genera in common: *Bamyaniceras* (unknown stratigraphically higher), *Paraceltites* (newcomer), and *Neocrimites* (transit).

Ammonoids characteristic of the upper Kubergandian *Cancellina cutalensis* Zone were found at two closely spaced levels in the Tezak section of southern Afghanistan (Termier et al., 1972). Their assemblage consists of 12 species representing 10 genera. These are predominantly the Early Permian genera, which are represented however by species similar to the Wordian ones from Sicily. Only two genera (*Tauroceras* and *Paraceltites*) are of Late Permian age. The Wordian species *Neogeoceras troutscholdi* described from this section is most likely a new species of the genus *Medlicottia* known from the Lower Permian of the Tethyan realm. In general, the assemblage is undoubtedly of the Roadian age. Among highly advanced species of long-existed genera, which are similar to those from Sicily, there are older forms, e.g., *Stacheoceras rothi* (the latest one is known from the Road Canyon Formation of the Glass Mountains) and *Eothinites* sp. nov. The assemblage is most probably transitional between the second and third ammonoid assemblages of North America. Regretfully, Termier et al. (1972) published the general list of ammonoids from two different levels. Only *Stacheoceras rothi* was mentioned to occur at the lower level. This is an additional evidence for the middle Roadian age of the assemblage.

An assemblage from the Kichkhi-Burnu section at the Marta River of the Crimea is comparable with the third ammonoid assemblage from the Roadian type sections. O.G. Tumanskaya described 31 species of 12 genera from this section. A similar set of genera (Exposure 110/1) was reported by Kotlyar et al. (1999). The assemblage is dominated by Early Permian genera, but their species are either of Sicilian aspect or new forms close to the latter, suggesting coeval origin. The most abundant and diversified genera are *Agathiceras, Propinacocers, Stacheoceras*, and *Prostacheoceras.* Species of the former two genera are most similar to forms from Sicily. The latter two genera (most plentiful) consist mostly of new species. The *Stacheoceras* forms are less advanced than species from Sicily, while the genus *Prostacheoceras* is missed from the Sicilian assemblage. The Late Permian species of genera *Paraceltites* and *Tauroceras* are close to Sicilian counterparts. Despite similarity of ammonoids from the Marta River section of the Crimea with the Wordian forms of Sicily, the older (late Roadian) age of the former is beyond doubts. The Crimean and third North American assemblages have only three genera in common (*Stacheoceras, Paraceltites*, and *Tauroceras*) represented by different but equally advanced species. Nevertheless, the data presented above suggest that these assemblages can be regarded as age analogs.

In addition to aforementioned genera and species, Kotlyar et al. (1999) reported also on the genus *Cardiella* widespread in the Sakmarian–Bolorian deposits of the Pamirs and Darvaz but unknown at higher levels.

Table 2. Correlation of Permian fusulinid and conodont zones of the Tethys

Stage	Fusulinid zone	Conodont zone (according to Kozur)	
Midian	*Yabeina*, *Sumatrina*	*Mesogondolella omanensis* *Mesogondolella siciliensis* *Mesogondolella aserrata* *Mesogondolella nankingensis*	
Murgabian	*Neoschwagerina haydeni*, *Afghanella schencki*	*Mesogondolella nankingensis* (reworked ?)	
		- - - - - - - - - - - - - - - - - - - -	1
	Neoschwagerina deprati, *Afghanella tereshkovae*	*Mesogondolella siciliensis*	
	Neoschwagerina simplex, *Presumatrina neoschwagerinoides*	*Mesogondolella siciliensis*	
Kubergandian	*Cancellina cutalensis*	*Mesogondolella siciliensis*	
		- — - — - — - — - — - — -	2
	Armenina, *Misellina ovalis*	*Mesogondolella siciliensis* *Mesogondolella phosphoriensis* *Gullodus cataloni, Hindeodus gulloides* *Mesogondolella saraciniensis*	
		- - — - - — - - — - - — - -	3
Bolorian	*Misellina parvicostata*, *M. termieri*	*Mesogondolella leonovae* *Mesogondolella shindyensis* *Mesogondolella gujioensis*	
	Brevaxina dyhrenfurthi	*Rabeignathus bucuramangus*	

Note: (1–3) position of the Roadian Stage lower boundary as interpreted by (1) Henderson et al., 1999; (2) Leven and Bogoslovskaya (this work); (3) Kozur, 1998; Kozur et al., 2001.

C. kussica also mentioned by Kotlyar et al. was described by Tumanskaya from the Al'ma River exposures of the Crimea, where it was found in association with other strictly Early Permian genera and species. Appearance of this taxon in the list of ammonoids from the Kichkhi-Burnu site seems occasional, having no much importance.

In Exposure 110/1, ammonoids are associated with fusulinids, owing to which the host limestones were attributed to the Kubergandian Stage (Kotlyar et al., 1999). However, the fusulinid assemblage described may be of the early Murgabian age, as one can judge from presence of *Neoschwagerina simplex* (index species of the Murgabian Stage lower zone) and very characteristic *Presumatrina schellwieni.*

There are known some other localities with Roadian ammonoids in the Tethyan realm. However, the occurrence levels of ammonoids have never been correlated there with those of fusulinids and conodonts, and these localities are therefore useless for recognizing the Roadian Stage in the relevant Tethyan sections.

Inferences from jointly occurring ammonoids and fusulinids described above are as follows:

(1) In Tethyan sections, the standard Roadian Stage corresponds approximately to the interval spanning the Kubergandian upper zone and the lower half of the Murgabian Stage of the Tethyan scale. Data on ammonoids outline the Roadian Stage approximately. They do not determine position of its lower and, especially, upper boundary, and the precise scope of the Roadian Stage remains undeterminable hence.

(2) The lower boundary of the standard Roadian Stage is inside the Kubergandy Formation corresponding approximately to the Kubergandian Stage. In this sense, the situation is similar to that in the western United States, where the boundary position is inside the Road Canyon Formation.

(3) Like in the United States, this boundary is not marked by any significant changes in evolution of marine biota, which are recorded instead below, at the bases of the Kubergandian Stage and the Road Canyon Formation.

(4) Position of the Roadian upper boundary is unclear in the Tethyan scale. Most likely, it is inside the Murgabian Stage, probably, closer to its top.

Attempts to determine the lower and upper boundaries of the Roadian Stage in the Tethyan realm based on conodonts are even less successful, because conodonts occur less frequently here, especially in association with fusulinids. Above all, this is typical of shallow- and warm-water serrate gondolellids, which define boundaries of all the Guadalupian stages, the Roadian Stage included. This group includes *Mesogondolella nankingensis* whose first occurrence marks the lower boundary of the Roadian Stage. In the Luodian section of southern China, this species is found in association with the latest Murgabian fusulinids (Leven, 2001). Accordingly, Mei and Henderson (Henderson et al., 1999; Mei and Henderson, 2001) correlated the greater part of the Murgabian and the entire Kubergandian with the Kungurian Stage (Table 2). In opinion of

Kozur and Wardlaw, this species is redeposited (Kozur, 1998; Kozur et al., 2001), because in the neighboring Tianlin section it was found in the middle and upper parts of the Chihsia Formation, i.e., in much older deposits (Clark and Wang, 1988). In the Chihsia type section near Nanking, the formation basal part corresponds to the Bolorian–Kubergandian transitional beds as is evident from presence of characteristic species *Misellina claudiae* (Chen, 1934). The upper part of the formation is referred by Chinese specialists (Sheng and Jin, 1994) to the *Neoschwagerina simplex–Presumatrina neoschwagerinoides* Zone (the Xiangboan Stage), i.e., to the lower zone of the Murgabian Stage of the Tethyan scale. According to this data, the Roadian lower boundary is not above but, probably, below the Murgabian base, in the middle of the Kubergandian Stage. This is consistent with distribution of ammonoids.

There is opinion (Kozur 1988; Kozur et al., 2001) that serrated gondolellids are inappropriate indicators of the Roadian boundaries in the Tethyan realm, because they inhabited only shallow-water epiplatform basins, which were not characteristic of the Tethys. In opinion of Kozur, the more appropriate forms are abundant smooth gondolellids, *Mesogondolella saraciniensis* and *M. slovenica* from the Bolorian–Kubergandian transitional beds of the Luodian section included, which inhabited open basins (Table 2). These species occur in association with *Gullodus catalonoi* and *Hindeodus gulloides* typical of Roadian deposits in North America (Leven, 2001; Kozur et al., 2001). This points likely to approximate coincidence of the lower boundaries of the Kubergandian and Roadian stages but contradicts to some extent the conclusions based on ammonoids.

Thus, the conodont succession is ambiguous, unsuitable for determination of the Roadian boundaries in the Tethyan scale. If the viewpoint of Mei and Henderson is unacceptable, then the lower (conodont-based) boundary should be within the interval from the uppermost Bolorian to uppermost Kubergandian. The upper boundary is likely inside the Midian Stage as is evident from occurrence of *Mesogondolella aserrata* in the Luodian section slightly above the first occurrence of Midian *Yabeina* forms (*Excursion Guidebook…*, 1994). These species may be redeposited, however, like *M. nankingensis.* In this case, the boundary should be lower.

F u s u l i n i d s represent a group of microfauna that is well studied, abundant, displaying a high rate of evolution in Tethyan regions. These fossils exactly determine the Permian biostratigraphy of these regions. Stages and zones of the Tethyan scale well correlative inside the realm cannot be recognized, regretfully, outside it because of fusulinid endemism. Accordingly, it is virtually impossible to directly correlate the Tethyan and standard subdivisions established in the North American stratotypes. The same can be stated with respect to the Roadian Stage.

As mentioned above, the Roadian fusulinid assemblage consists mainly of *Parafusulina* forms. This genus occurs also in the Tethyan sections, but none of the Roadian species of American origin has been found in the Tethys and vice verse. In general, the Roadian *Parafusulina* forms seem to be more advanced than those of the Kubergandian, as one can judge from a number of whorls, shell size, and septal fluting. It was noted that the Roadian fusulinid assemblage from America is similar to concurrent Tethyan assemblage in presence of newly appeared multiapertural schwagerinids, *Yangchienia* and *Rauserella* forms widespread in Upper Permian deposits of the Tethys. Multiapertural schwagerinids represented by subgenus *Bidiexodina* of the genus *Eopolydiexodina* are known from the upper zone of the Kubergandian Stage (Leven and Grabchak, 1986). Forms of the same type (*Skinnerina*) also occur near the Roadian base in North American sections (Yang and Yancey, 2000), but morphological distinctions between taxa from two regions are so significant that it is impossible to speak of their genetic relations. There is no doubt that they originated independently and had different ancestors (Leven and Grabchak, 1986). It remains unclear, however, whether they are concurrent in origin.

The Genus *Yangchienia* became widespread in Tethyan basins beginning from the Kubergandian time, and its earliest primitive representatives are known from the uppermost Bolorian. Finally, the genus *Rauserella* found at the Roadian base is known from the uppermost Murgabian only, although there are unverified data on its earlier origination.

CONCLUSIONS

(1) Two successive (second and third) assemblages of ammonoids are established in the type sections of the Roadian Stage. The first assemblage characterizes the lower part of the Road Canyon Formation and concurrent subdivisions. According to the adopted position of the Roadian lower boundary, this part should be attributed to the Kungurian Stage although, changes in ammonoid biota are more significant at the base of the Road Canyon Formation than at the base of the Roadian Stage.

(2) The upper boundary of the Roadian Stage cannot be determined in the type sections based on distribution of ammonoids.

(3) The Roadian ammonoid and conodont assemblages are known in some sections of the Boreal realm. Therefore, the Roadian Stage is recognizable here quite confidently. However, its boundaries need to be defined more precisely in order to elucidate presumable correspondence between the Kazanian and Roadian stages.

(4) Presence of Roadian deposits in Tethyan sections is inferable from ammonoid and conodont records. However, positions of the Roadian Stage boundaries are still unclear here.

(5) Because the Roadian Stage boundaries are of ambiguous position in the Boreal and Tethyan regions, we should abstain from replacing the regional stages by stages of the standard scale. This is undesirable further, because the standard boundaries do not coincide with levels of significant biotic events recorded in the Roadian stratotype area and in both above regions.

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