

PERMIAN CHRONOSTRATIGRAPHY IN KANSAS

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ABSTRACT

Correlations between the type Permian System of Russia and North American strata have been difficult for decades because of biostratigraphic and nomenclatural confusion. Consequently, a standard Permian section was established in West Texas that is widely accepted throughout North America. Series of the North American standard section are, in ascending order: Wolfcampian, Leonardian, Guadalupian, and Ochoan.

This nomenclature was adopted for usage in Kansas in 1951, but was later abandoned in favor of local terminology. However, direct biostratigraphic correlations between Kansas and the West Texas standard section have now been firmly established, and local chronostratigraphic names, i.e., Big Blue, Lyon, Geary, Cimarron, and Custer, have not been widely accepted. The Kansas Geological Survey has now readopted usage of the Wolfcampian Series for rocks of the Council Grove (restricted) and Chase Groups; the Leonardian Series for the Sumner and Nippewalla Groups; and the Guadalupian Series for rocks of the Whitehorse, Day Creek, and Big Basin Formations.

The Admire Group is reassigned to the latest Virgilian Series (Pennsylvanian).

INTRODUCTION

Correlation of various series and stages of the Permian System has been a worldwide problem since Murchison proposed the term in 1841. The problem stems from inherent nomenclatural inconsistencies and a paucity of diagnostic fossils in key stratigraphic horizons, both in the Russian type section and in North America. Confusion and uncertainty regarding physical correlations of lithostratigraphic units of Permian age has led to equally confusing vacillations in chronostratigraphic terminology in Kansas. Use of chronostratigraphic nomenclature has varied from that generally accepted as the North American standard to the applications of various local names. It is the purpose of this paper to examine the history of Permian chronostratigraphic terminology, to revise the Pennsylvanian-Permian boundary in Kansas, and to report readoption by the Kansas Geological Survey of the widely accepted North American standard nomenclature.

HISTORY OF PERMIAN CHRONOSTRATIGRAPHY

In light of the historical development of Permian nomenclature, it is not surprising that confusion and terminology conflicts have occurred in Kansas. The Permian System has always been, and remains, a maverick chronostratigraphic unit. It was conceived to fill a nomenclatural "void" between the Upper Carboniferous and the Triassic in western Europe. Unfortunately, the Upper Carboniferous of England, as the name implies, consists of non-marine "coal measures," and the lower part of the type Triassic is a redbed sequence. To make matters worse, much of the type Permian System in Russia consists of non-marine redbeds and evaporites. Because of the general lack of marine index fossils in these strata, global correlations have not been closely constrained. Indeed, the boundaries set by the American Association of Petroleum Geologists Stratigraphic Subcommittee on the Permian of the United States (Tomlinson and others, 1940) did not correspond to the recognized Russian type Permian System. Consequently, the Permian boundaries have been in dispute for nearly a century and a half, and international agreement on the boundaries has yet to be reached.

Murchison went to Russia during the summers of 1840 and 1841 at the negotiated invitation of Czar Nicholas I to see if the previously named lower Paleozoic systems were valid on a broad geographic scale (Dunbar, 1940). During the second summer, he travelled across the vast Perm Basin from Moscow to the city of Perm and made seven reconnaissance traverses of the Ural Mountains. That fall he wrote a report to the Czar in which he designated his new Permian System which was to include "...the chief deposits of gypsum of Arzamas, of Kazan, and of the rivers Piana, Kama, and Oufa, and of the environs of Orenbourg; we also place in it the saline sources of Solikamsk and Sergiefsk, and the rock salt of Sletsk and other localities in the government of Orenbourg, as well as the copper mines and the large accumulations of plants and fossil wood of which you (Fischer de Waldheim) have given a list in the 'Bulletin' of your Society (anno 1840). Of the fossils of this system, some undescribed species of Producti might seem to connect the Permian with the Carboniferous aera; and other shells, together with fishes and saurians, link it on more closely to the period of the Zechstein, whilst its peculiar plants appear to constitute a Flora of a type intermediate between the epochs of the new red sandstone or 'trias' and the coal measures. Hence it is that I have ventured to consider this series a 'system'" (Murchison, 1841).

This first description of the Permian System led Dunbar (1940) and Russian geologists to believe that the originally defined system included only the now recognized Kungurian, Kazanian, and Tatarian series, or Middle and Late Permian (fig. 1). The lower boundary is still in dispute. Much of the confusion involves nomenclatural inconsistencies of fusulinid generic names between European and American paleontologists. The European genus Schwagerina is called Pseudoschwagerina in America, and the American Schwagerina is synonymous with the European Pseudofusulina (Ross, 1963; Wilde, 1985). "... The present confusion must constitute one of the most glaring examples of a breakdown in Linnean nomenclature to ever bedevil biologic taxonomy." (Waterhouse, 1978, p. 309)

After much debate among Russian stratigraphers, a symposium was held in Moscow and a standard section of the Russian Permian was proposed by Likharev and others (1966), (fig. 1, column 1). Smith and others (1974) used that standard section for their correlations of the Permian of the British Isles, but stated that: "The standard section of the Russian Permian has severe limitations which prevent it from being used as an international standard. The position of its base remains controversial despite the deliberations of Likharev et al. (1966), and would be taken at different levels in the sequence on the evidence afforded by different faunal groups.

Furthermore, a hiatus of unknown duration separates Lower from Upper Permian sediments, even in the Urals foredeep, and the Upper Permian marine fauna evolved in a restricted and saline shelf sea and is of limited value as an index of Permian faunal evolution as a whole. Finally, as in much of America and Europe, the uppermost strata referred to the Permian are continental, and contain a limited and highly specialized fauna and flora."

Most Permian stratigraphers have settled on the base of the Asselian of Ruzhencev (1954) as the base of the Permian as adopted by Likharev and others (1966). This definition places the boundary at the top of the fusulinid Zone of Triticites (Late Pennsylvanian) and at the bottom of the Pseudoschwagerina Zone (Zone of Schwagerina in the European sense), coinciding with the base of the Wolfcampian Series in the Glass Mountains of West Texas (fig. 1). This boundary was followed by the Permian Working Group of the Geological Society of London (Smith and others, 1974) and by Waterhouse (1978) in his "Chronostratigraphy of the World Permian."

Work on the faunas and stratigraphic relationships of the Permian System continued. Waterhouse (1978) followed the Likharev classification rather closely for the interval Asselian through Kazanian, but chose to replace the Tatarian

Stage with three stages whose type sections are best developed in the Salt Range of Pakistan and in southern Soviet Armenia where marine fossil assemblages are rather complete (column 2, fig. 1). The classification has not as yet been accepted by international agreement, but it serves for comparative purposes with the standard North American section (Baars, 1979).

PERMIAN SYSTEM OF THE UNITED STATES

Relating strata of apparently Permian age in the United States to the Russian system was difficult and frustrating in the 1930s. The lack of agreement as to the boundaries on the part of Russian geologists and the incomplete faunal information available from the classical section made it almost impossible for American stratigraphers to make realistic comparisons. In 1937 prior to the 17th International Geological Congress, a field conference on the Permian System was conducted by Russian geologists. Several American geologists attended the conference and viewed the typical Permian strata first hand. "They differed among themselves in opinion as to the probable position of the base of the Permian. They still differ. In a manner delightfully human, each of the seven is inclined to feel not only that a majority

of Russian geologists now agrees with him, but that the Russian whose opinion deserves greatest respect is one of those who so agrees" (Tomlinson and others, 1940). Some of the participants joined with others in defining a standard Permian section of North America in the Delaware basin and adjacent uplifts of West Texas (Adams and others, 1939), based partly on what they had seen on the Russian Platform and Ural Mountains. The following year the Subcommittee on the Permian of the American Association of Petroleum Geologists' Committee on Geologic Names and Correlations formally proposed acceptance of the West Texas time-stratigraphic sequence as a North American standard (Tomlinson and others, 1940). The terminology was adopted for Kansas by Moore and others (1951) and for the U.S. Geological Survey by Cohee (1960).

Wolfcampian Series

The lowermost, or oldest, of the West Texas standard section is the Wolfcampian Series, named for the Wolfcamp Formation of the Glass Mountains, that lies with angular unconformity on beds of undisputed Pennsylvanian and older age. The base of the Permian was here defined on the basis of the unconformity, although the Wolfcampian fusulinids Schwagerina (in the American sense), Pseudoschwagerina, and

Paraschwagerina were then considered to be Upper Carboniferous by the Russians. It is now generally accepted throughout the world (Ross, 1963; Waterhouse, 1978; Wilde, 1985; Ross and Ross, 1987; Chuvashov, 1989) that the zone of Pseudoschwagerina is Early Permian in age, and occurs in the Asselian of Likharev and of Waterhouse. These fusulinids, along with the brachiopod and ammonoid faunas, make the Wolfcampian time-stratigraphically equivalent to the Asselian and Sakmarian Stages of the Russian standard section (column 4, fig. 1).

Pennsylvanian-Permian Boundary

It has now become clear that the problem regarding the Pennsylvanian-Wolfcampian boundary in North America is not the same as that of the Carboniferous-Permian boundary in Russia. Ross (1963, 1985), Wilde (1985), and Kozur (1985) have demonstrated that the top of the Pennsylvanian (Virgilian) is older than the top of the Carboniferous (Orenburgian/Gzhelian) (fig. 2). Rocks of the lower Wolfcampian (zone of Triticites-Schwagerina) are probably age-equivalent to rocks of the upper Orenburgian/Gzhelian and basal Asselian (Carboniferous), but younger than Virgilian. By definition, these strata are post-Pennsylvanian and pre-Permian, a time-stratigraphic "black hole." By traditional usage, however, this faunal zone, found

in the Bursum and Pueblo Formations of Texas, the Elephant Canyon Formation of eastern Utah, and the Admire Group of Kansas, have been considered to be lowermost Wolfcampian (Ross, 1963).

To resolve this issue and to bring the basal Permian boundary of North America into conformity with international usage, the Virgilian Series has been redefined in the typical section along the Verdegris River in Kansas (Baars, Ritter, Maples, and Ross, in preparation, 1990). The Virgilian Series now includes all rock units from the base of the Stranger Formation up to the base of the Neva Limestone (fig.3). The Admire Group, as now redefined, includes strata from the base of the Onaga Shale up to the base of the Neva Limestone, and contains the faunas that are equivalent to the Bursum and Pueblo faunas. As the Neva Limestone contains fusulinids of the Pseudoschwagerina biozone (Paraschwagerina kansasensis), and the conodont genera Streptognathodus barskovi and Sweetognathus expansus (Ritter, 1989), it is faunally equivalent to the base of the type Wolfcampian Series of west Texas, as originally defined, and the base of the Russian type Permian System (Chuvashov, 1989). Thus, the upper Pennsylvanian System is age-equivalent to the Upper Carboniferous of Europe.

Leonardian Series

The next younger American series is the Leonardian, named for the Leonard Formation in the Glass Mountains. This series unconformably overlies the Wolfcamp and underlies the Word Formation with questionable conformity. The series contains primitive species of the fusuline Parafusulina, as well as a distinctive brachiopod and ammonoid fauna of Baigendzinian age (fig. 1) (Ross, 1963).

Guadalupian Series

The next overlying series is the Guadalupian, named for a fossiliferous marine sequence in the Guadalupe Mountains that included a lower Word Formation and an upper Capitan Limestone. The lower Guadalupian, or Wordian of some authors, contains advanced species of Parafusulina and the ammonoid Waagenoceras, suggesting a correlation with the Russian Kungurian and Kazanian Stages (fig. 1). The upper Guadalupian, or Capitan, contains the fusuline Polydiexodina and the ammonoid Timorites to establish a correlation with the Punjabian and lower Djulfian Stages of Waterhouse (1978), the lower Tatarian Stage of Likharev and others (1966) (fig. 1).

Ochoan Series

The youngest of the West Texas Permian series is the Ochoan, which includes all post-Guadalupian, pre-Triassic strata. Although this uppermost series consists almost entirely of evaporites and contains only rare pelecypods, it is correlated with the upper Djulfian and Dorashamian Epochs of Waterhouse (1978). The series was previously related to evaporites of the Kazanian and Tatarian by Smith and others (1974) (fig. 1). In the absence of diagnostic faunas, correlation of the Ochoan with the Russian Permian is a matter of faith (Baars, 1979).

In hindsight, the Permian standard section of West Texas was an excellent choice and has withstood the test of time. The base of the Pseudoschwagerina Zone that occurs in the Neal Ranch Formation of the type Wolfcamp section has been widely adopted as the "traditional" base of the Permian. The West Texas terms have become thoroughly entrenched in North American literature and are approved by most state and federal geological surveys. It is the post-Virgilian, pre-Permian time interval that has been troublesome in North America; with the redefinition of the Virgilian Series, this problem is mitigated.

SERIES OF THE PERMIAN

Russian geologists divided the Permian System into Upper and Lower Series, the boundary falling between the Kungurian and Ufimian Stages, according to Likharev and others (1966). Cohee (1960, p. 1579) reported that the U.S. Geological Survey had accepted the two-fold subdivision of the long-standing Russian terminology, indicating that the boundary was placed between the Cherry Canyon and Bell Canyon Formations (Word and Capitan equivalents) of West Texas. From a search of the confusing stratigraphic and paleontologic literature, this would appear to be too high in the Russian section, at least in present usage, falling above the Kazanian Stage. He also reported the approval by the federal geological survey of the Wolfcampian, Leonardian, Guadalupian, and Ochoan provincial series "...according to current usage," in fact approving two different standard series designations. O'Connor (1963) changed the former tripartite subdivision of the Permian of Kansas to a similar two-fold system, placing the boundary between the Nippewalla Group (top of the Dog Creek Formation) and the Whitehorse Formation. This would appear to be correlative with the base of the Word, rather than the top of the Word (fig. 1), the boundary recommended by Cohee (1960), comprising still another definition of Upper-Lower Series boundaries. To further complicate the matter, Waterhouse

(1978) recommended a three-fold subdivision of the World Permian, using entirely different boundaries for his Lower, Middle, and Upper Series (fig. 1).

The North American Stratigraphic Code (1983) states that it is proper to designate series by Lower, Middle, and/or Upper terms, however, it further suggests that "...a geographic name is preferable because it may be related to a type area." Also, "Use of internationally accepted (mainly European) stage [series] names is preferable to the proliferation of others." (North American Commission on Stratigraphic Nomenclature, 1983, p. 869, Article 77, remarks b).

In the case of the Permian System, a global correlation of the Russian typical series is only approximate at best. Indeed, Cohee (1960) appears to have miscorrelated the boundary by two Russian stages, and others in North America have apparently miscorrelated with Cohee's designation (O'Connor, 1963). The units and their rock equivalents contain several hundreds or thousands of feet of sedimentary strata. An error of a stage or two involves a lot of rocks and Earth history. Anyway, which of the four Upper/Lower boundaries is correct?

It is recommended that the terms "lower" and "upper" series

be considered as generalized subdivisions with informal status in the case of the Permian System. More detailed designations (i.e., Wolfcampian, Leonardian, Guadalupian, and Ochoan) are far more meaningful and useful, at least in North America. In fact, even more detailed subdivisions (e.g., "lower Wolfcampian" and "upper Wolfcampian," etc.) were used to relate the Permian rocks of western Kansas to the Rocky Mountains (Rascoe and Baars, 1972). Elimination of the "lower" and "upper" Permian terminology in formal usage simplifies the levels of stratigraphic classification and eliminates a category of unnecessary correlation inaccuracies. As formally approved by the U.S. Geological Survey and Kansas Geological Survey, Upper and Lower Series designations duplicate internationally accepted terms and, being apparently inaccurate correlations, use identical terms for different intervals of Earth history. Furthermore, the approved terminology (Cohee, 1960) is nomenclaturally incorrect. If the term Lower Permian Series is used, then the Wolfcampian would necessarily become a stage name, when in fact it is approved as a series name. This problem was corrected by the Kansas Geological Survey (O'Connor, 1963; O'Connor and others, 1968).

Although it might be desirable to use the Russian stage names as formal series terms on an international basis, North

American stratigraphers are too stubborn and provincial to adopt "unpronounceable" Russian names. Anyway, as already demonstrated, detailed correlations with the Russian section are difficult to impossible. Ross (1963, p. 45-46) noted that: "The early Permian fusulinid faunas of Russia do not closely resemble either fauna of the western hemisphere. The Ural region was probably isolated from the North American region for most of the time from about the beginning of the Asselian until the early Artinskian." Without species-level taxonomic overlap, accurate correlations currently are not possible.

PERMIAN SYSTEM OF KANSAS

Wolfcampian

The term Wolfcampian Series was proposed by Adams and others (1939) for the lowermost chronostratigraphic unit in the Permian System of North America. Tomlinson and others (1940) formally proposed that the West Texas terminology be accepted for usage in North America. Moore and others (1951) followed suit by abandoning the former term "Big Blue series" in favor of the accepted term Wolfcampian for the 785 feet of strata in Kansas of older Permian age. Branson (1960) declared that the term Wolfcampian should not be used in Kansas,

Oklahoma, and Nebraska, and proposed the alternate term Lyon Series (Lyonian Epoch). O'Connor (1963) agreed that the name Wolfcampian was inappropriate for Kansas, because depositional environments in West Texas differed from those in Kansas and the rocks could not be related "with any degree of certainty." He (O'Connor, 1963) ignored the formerly proposed term Lyon Series of Branson (1960), and proposed yet another term "Gearyan Stage" of the "Lower Permian Series" for rocks of the Admire, Council Grove, and Chase Groups of Kansas. This terminology was followed by O'Connor and others (1968).

As proposed, the term "Gearyan stage" of O'Connor (1963) is a lithostratigraphic unit, because the rocks of Texas and Kansas were being compared, not the time of deposition of the strata nor their fossil content that would establish time-correlative relationships. In the same year, Ross (1963) compared the fusulinid faunas of the Wolfcampian type section with those from specific formations in Kansas and elsewhere (fig. 2). He (Ross, 1963, p. 45) concluded that: "Similar fusulinid faunas of the early Permian occur in the western hemisphere from Kansas through Texas and probably through Central America into South America." He correlated fusulinids from the Admire Group in Kansas with those from the Pueblo Formation (then considered to be lower Wolfcampian) of north-central Texas; fusulinids from the Red Eagle Limestone through

the Beatie Limestone (middle Council Grove Group in Kansas) with the Neal Ranch Formation (lower Wolfcampian as originally defined and used here); and fusulinids from the Florence Limestone of the Chase Group in Kansas with those from the Lennox Hills and Hueco Formations (upper Wolfcampian) of West Texas (Ross, 1963, p. 48) (fig. 2). Thus, the "Gearyan Stage" of O'Connor (1963) was established as directly correlative in age with the Bursum section and Wolfcampian Series. Rascoe and Baars (1972) concurred, and assigned the Admire and Council Grove Groups to the lower Wolfcampian and the Chase Group to the upper Wolfcampian. Baars, Ritter, Maples, and Ross (in preparation, 1990) have redefined the Admire Group to include those rocks up to the base of the Neva Limestone, and assigned the Admire to the upper Virgilian Series (fig. 3).

Because of the problems cited and the established correlations with the West Texas standard section, the Kansas Geological Survey has abandoned the terms "Lower Permian Series," "Big Blue Series," "Lyon Series," and "Gearyan Series" in Kansas. The Council Grove (restricted) and Chase Groups, formerly included in those units, are reassigned to the Wolfcampian Series. Thus, stratigraphers and others in Kansas can maintain nomenclatural consistency with widely accepted North American terminology, and be in conformity with global correlations. The name "Geary" could be retained for a

lithostratigraphic unit, such as a supergroup, if that should prove to be a useful designation.

Leonardian

Rocks above the Chase Group in Kansas have undergone a similar history of chronostratigraphic terminology changes as the Wolfcampian Series. Adams and others (1939) proposed that the Leonard Formation of the Glass Mountains of West Texas constitute the type section for the Leonardian Series. They correlated the Leonard with rocks above the Herington Limestone to the top of the Dog Creek Shale in Kansas (Sumner and Nippewalla Groups), and proposed that these rocks, formerly included in the Cimarron Series, be reassigned to the Leonardian. Moore and others (1951) agreed that the Sumner and Nippewalla Groups were of Leonardian age, and they were shown as such on the graphic column of Jewett (1959). Condra and Reed (1959) correlated the Cimarron Series from Oklahoma across Kansas into Nebraska. O'Connor (1963) then reassigned the Sumner and Nippewalla Groups to the Cimarron Stage of the Lower Permian Series in preference to provincial terminology in Kansas; O'Connor and others (1968) further established that nomenclature. Meanwhile, Ross (1963, p. 43, fig. 11) did not document detailed fusulinid comparisons of Leonardian species with those from Kansas, but correlated the Sumner Group with

the Leonardian of West Texas. Rascoe and Baars (1972) assigned the Sumner Group to the lower Leonardian Series, and the Nippewalla Group to the upper Leonardian. Because of the presence of a regional unconformity at the base of the Stone Corral Formation, and Runnymede Sandstone where present, these units are now included at the base of the Nippewalla Group, rather than the top of the Sumner Group (Rascoe, 1988).

The term Leonardian Series, like the Wolfcampian, is widely accepted in the North American standard Permian section, and has been used synonymously with the "Cimarron Series" which is not recognized by the U.S. Geological Survey as a valid chronostratigraphic term. The Kansas Geological Survey has again abandoned the term Cimarron as a chronostratigraphic unit, and rocks of the Sumner and Nippewalla Groups are reassigned to the Leonardian Series. Although the age of the upper beds of the series in Kansas is not constrained by fossils, Kansas nomenclature will be in compliance with widely accepted terminology of the Permian System of North America.

Guadalupian

Rocks of the upper Nippewalla Group and overlying rocks in Kansas believed to be of Permian age are relatively unfossiliferous and contain no diagnostic species to compare

with any chronostratigraphic sequence. Thus, the Leonardian-Guadalupian boundary was placed arbitrarily at the base of the Whitehorse Formation (Adams and others, 1939). Rocks of Permian age above the base of the Whitehorse were included in the Custer Series in Oklahoma (Fay, 1965). The Whitehorse, Day Creek, and Big Basin Formations in Kansas were included in the Custer Stage of the Upper Permian Series by O'Connor and others (1968). This section is probably, but not conclusively, of Guadalupian age. Rascoe and Baars (1972) assigned the three formations to the Guadalupian Series.

The term Custer Series (or Stage) has not been adopted for use by others as a chronostratigraphic term, and it is certainly predated by the term Guadalupian. The Kansas Geological Survey has therefore abandoned the term Custer Series in Kansas, and the equivalent time-stratigraphic interval is being called Guadalupian in accordance with North American standard terminology. May Custer now rest in peace.

Ochoan

No known rocks of latest Permian, or Ochoan, age are present in Kansas. Therefore, no deviation from standard North American terminology has been published in Kansas. However, some unfossiliferous redbeds may be of Ochoan age.

CONCLUSIONS

- 1) International correlation of chronostratigraphic units of the Permian System are difficult if not impossible. To avoid erroneous "corkscrew" correlations, attempts to utilize Russian terminology in Kansas are presently discouraged.

- 2) The terms "Lower Series" and "Upper Series" of the Permian System are too general to be of value, and have been misused and miscorrelated with the standard Russian section in Kansas and North America. Such terms create cumbersome classifications and should be used only informally.

- 3) The West Texas standard chronostratigraphic terminology for the Permian System has been formally proposed and widely accepted throughout North America. These terms, i.e., Wolfcampian, Leonardian, Guadalupian, and Ochoan, were originally adopted by the Kansas Geological Survey, and later abandoned for various, sometimes unorthodox, reasons in favor of local names.

- 4) Direct chronostratigraphic correlations between Kansas and the West Texas standard section have been firmly established.

- 5) Terms formerly used for the oldest Permian series in

Kansas, i.e., Big Blue, Lyon, and Geary, have not been widely accepted and are abandoned by the Kansas Geological Survey. Rocks formerly assigned to those units, Council Grove and Chase Groups, are reassigned to the widely accepted West Texas standard term Wolfcampian Series.

6) The Admire Group, as redefined to include rocks up to the base of the Neva Limestone, is reassigned to the upper Virgilian Series.

7) Rocks previously included in the Cimarron Stage of the Lower Permian Series in Kansas, the Sumner and Nippewalla Groups, are reassigned to the Leonardian Series.

8) Rocks of the Whitehorse, Day Creek, and Big Basin Formations, formerly included in the Custer Stage of the Upper Permian Series are reassigned to the North American standard Guadalupian Series.

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FIGURE CAPTIONS

FIGURE 1. Correlation chart of the Permian System of Kansas as
related to the standard section of West Texas and the classic
Permian section of the U.S.S.R. (Modified after Baars, 1979

and Rascoe and Baars, 1972)

FIGURE 2. Correlation of fusulinid zones in Wolfcampian Series with other lower Permian sequences. (From Ross, 1963)

FIGURE 3. Redefinition of the Pennsylvanian-Permian boundary, and related lithostratigraphic units in Kansas as proposed by Baars, Ritter, Maples and Ross (in preparation, 1990).

Age (Ma)	USSR Perm Basin (Likharev, 1959)		World Chronostratigraphy (Waterhouse, 1978)		Fusulinid Zones	Delaware Basin Texas	Kansas (Rascoe and Baars, 1972)	Series Boundary					
	Triassic		Triassic			Triassic	Jurassic						
230 - Baars (1979)	Tatarian		Dorashamian (Late)	Griesbachian	<i>Polydiexodina</i>	Ochoan							
				Ogbinan									
			Vedian										
			Baisalian										
			Urushtenian										
	(Middle) Djulfian	Punjabian	Chhidruan	Kalabaghian		Guadalupian	Capitan		Upper USGS				
	Kazanian	Kazanian	Sosnovian	Kalinovian					Word	Big Basin Fm	Lower		
	Ufimian	Irenian	Kungurian	Irenian		Leonardian	Sumner Group	Day Creek Dol.		Upper USSR			
	250	Kungurian	Filippovian	(Middle) Kungurian				Filippovian	White horse Fm.	Lower Upper KGS			
	PERMIAN	Artinskian	Baigendzinian	(Early) Baigendzinian		Krasnoufimian	<i>Parafusulina</i>	Wolfcampian		Nippewalla Group			
Sarginian													
?				Aktastinian	Sakmarian	Aktastinian					Leonardian	Sumner Group	Chase Group
Sakmarian				Sterlitamakian		Sterlitamakian							
				Tastubian		Tastubian							
Asselian	Kurmaian	Asselian	Kurmaian	<i>Pseudoschwagerina</i>	Wolfcampian		Council Grove Gp.						
	Uskalikian		Uskalikian										
	Surenan		Surenan										
290-300?	Upper Carboniferous (Gzhelian)		Upper Carboniferous (Orenburgian)		<i>Triticites</i>	Penn., - PЄ	Admire Gp.	Virgilian					

Figure 1

Wreford Limestone	Chase Group	Wolfcampian Series	Permian System
Speiser Shale Funston Limestone Blue Rapids Shale Crouse Limestone Easley Creek Shale Bader Limestone Stearns Shale Beattie Limestone Eskridge Shale Neva Limestone	Council Grove Group		
Grenola Limestone Roca Shale Red Eagle Limestone Johnson Shale Foraker Limestone Janesville Shale Falls City Limestone Onaga Shale	Admire Group	Virgilian Series	Pennsylvanian System
Wood Siding Formation Severy Shale	Wabaunsee Group		
Topeka Limestone	Shawnee Group		
Oread Limestone			
Lawrence Formation Stranger Formation	Douglas Group		
Stanton Limestone	Lansing Group	Missourian Series	

Figure 3