

Cyclothem ["digital"] correlation and biostratigraphy across the global Moscovian-Kasimovian-Gzhelian stage boundary interval (Middle-Upper Pennsylvanian) in North America and eastern Europe

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ABSTRACT

The long-standing difficulty of correlating Pennsylvanian strata among provincial faunal regions is resolved by effecting "digital" correlation of major glacial-eustatic cyclothem units that represent highstands when certain species achieved more global distribution than usual. In the late Moscovian-early Gzhelian (late Desmoinesian-early Virgilian) succession in the midcontinent United States, several major cyclothem units are correlated, by both conodont species in common and cyclothem scale, with cyclothem units in Russia (Moscow Basin) and Ukraine (Donets Basin), and the remaining cyclothem units fit into the framework by position and scale. In this way the suggested event marker for the global Kasimovian-Gzhelian stage boundary (first appearance of *Idiognathodus simulator*) is supported, while possible event markers for the Moscovian-Kasimovian boundary await further evaluation.

Keywords: Pennsylvanian, cyclothem, correlation, biostratigraphy.

INTRODUCTION

To establish global chronostratigraphic boundaries, Remane et al. (1996) emphasized that correlation of strata encompassing a global boundary must precede the global stratotype section and point (GSSP) definition of the boundary. The long-recognized difficulty of global correlation of Pennsylvanian rocks among biotically distinct regions led to three different regional systems of chronostratigraphic names. The western European stages are largely terrestrial, the marine Russian stage names have been adopted for global terminology, and the midcontinent U.S. stages contain the disconformity-bounded stratigraphic sequences termed cyclothem units, which are products of glacial eustasy (Heckel, 1994). The Middle to Late Pennsylvanian midcontinent succession of cyclothem units has been correlated across much of the U.S., using the distinctive succession of conodont faunas (Barrick et al., 2004) in what Ritter et al. (2002) termed sequence biostratigraphy. Recognizing global control of glacial eustasy, Russian stratigraphers have identified exposure surfaces separating cyclothem units and have begun correlating them across the Russian Platform (Kabanov, 2003). Cyclothem units are also recognized in the Donets Basin of Ukraine, where marine carbonate and shale alternate with terrestrial clastics and coal. Recent progress on conodont faunas in the U.S. and eastern Europe shows that while provincialism exists, there are levels where distinctive taxa are found among the regions. Given that the major marine units were deposited during highest sea-level stands in all places where glacial-eustatic cyclothem units are separated by lowstand terrestrial units or exposure surfaces, each major marine unit in a succession must correlate as a unit,

that is, in a "digital" fashion, with a major marine unit in other successions, rather than with lowstand units. Therefore, we have correlated the major glacial-eustatic cyclothem units across stage boundary intervals among the regions where they are recognized, as a first step in selecting the event markers that will define global boundaries.

GUIDING ASSUMPTIONS

To establish the most reasonable correlation, the following assumptions are made. (1) The scale of each glacial-eustatic cyclothem, i.e., its relative lateral extent and water depth attained, should be similar globally compared to that of adjacent cyclothem units. This assumes that local differential tectonism acted too slowly (1–2 m.y.; Heckel, 1994) to mask the pattern in the more frequent sea-level fluctuations (20–400 k.y.) that resulted in the particular succession of major, intermediate, and minor cyclothem units of the midcontinent and Texas (Boardman and Heckel, 1989) and the Illinois and Appalachian Basins (Heckel, 1994). (2) Major cyclothem units with the greatest lateral extent of marine facies plus the deepest-water facies on the shelves should be the most readily correlated, because they contain a greater depth range of fossils in a setting that allowed the greatest interchange of species across inundated shelves. (3) Largely pelagic conodonts and ammonoids are the primary fossils used for correlation, while benthic, more provincial fusulines are secondary aids. (4) Major cyclothem units are recognized in the midcontinent by their conodont-rich dark phosphatic shale facies, which resulted from water deep enough and far enough from shoreline to reduce detrital dilution. Major cyclothem units also are recognized in the Moscow and Donets Basins by greatest conodont abundance, reflecting decreased sediment dilution in the deepest-water facies. In the Moscow Basin these facies are often shaly limestones, in contrast to the adjacent purer, shallower-water limestones (Kabanov et al., 2006). In the Donets Basin, these facies are usually nonalgal limestone beds, which are least diluted by detrital influx or carbonate mud production.

CORRELATION OF CYCLOTHEMS

Using these assumptions, the following correlations of major cyclothem units are made from late Moscovian to early Gzhelian across the two boundary intervals (Fig. 1): the midcontinent major Lost Branch cyclothem unit is correlated with the Russian Voskresensk Formation and Donets Limestone N₃, on the basis of the youngest abundant occurrence of the short-ranging distinctive troughed conodont genus *Swadelina* in major cycles. Although different species dominate in different places, *Sw. nodocarinata*, named from the Lost Branch, occurs in both other regions. *Idiognathodus expansus* and *Gondolella magna* occur in both Lost Branch and N₃. This correlates the next older midcontinent major Altamont cyclothem with the

N. AMERICAN MIDCONTINENT cyclothems [MAJOR (core shale), Intermediate, Minor]	MOSCOW BASIN, Afanasievo Quarry; cores [MAJOR CYCLE; Lesser cycle]	DONETS BASIN, esp. Kalinovo [MAJOR CYCLE; Lesser cycle]
LECOMPTON (Queen Hill) / NECESSITY [Tx]: <i>I. tersus</i> <i>S. pawhuskaensis</i> , <i>S. ruzhencevi</i> , <i>S. vitali</i>	AMEREVO: <i>S. ruzhencevi</i> , <i>S. vitali</i> ; <i>I. simulator</i> fus. abundant <i>Rauserites stuckenbergi</i>	O7 [?]: <i>I. tersus</i> , <i>I. cf. simulator</i> fus. <i>Rauserites rossicus</i>
Spring Branch or Clay Creek: <i>S. pawhuskaensis</i> ; <i>I. tersus</i> , <i>I. lobulatus</i>	[not identified]	O6/1 [?]: <i>S. firmus</i> , <i>I. toretzianus</i>
OREAD (Heebner) / FINIS [Texas]: <i>S. pawhuskaensis</i> first <i>I. simulator</i> , <i>I. tersus</i> [types in Ks]; <i>S. firmus</i> amm. <i>Vidrioceras uddeni</i> ; first global <i>Shumardites</i> [Tx]	UPPER RUSAVKINO: <i>S. pawhuskaensis</i> first <i>I. simulator</i> [s.s.]; <i>I. tersus</i> , <i>S. firmus</i> fus. cotype <i>R. rossicus</i> [best base Gzhelian]	O6: <i>S. firmus</i> , <i>I. toretzianus</i> first <i>I. simulator</i> [s.s.] fus. <i>Triticites</i> sp.
CASS (Little Pawnee)/LR COLONY CK [Tx]: <i>S. firmus</i> <i>S. zethus</i> , <i>S. pawhuskaensis</i> , <i>I. aff. simulator</i> [transit.] amm. <i>Vidrioceras conlini</i> , <i>Pseudaktubites stainbrooki</i>	MIDDLE RUSAVKINO: <i>S. pawhuskaensis</i> <i>S. zethus</i> , <i>S. firmus</i> ; <i>I. aff. simulator</i> [transit.] fus. rare, poorly known	O5: type <i>S. firmus</i> dominant <i>S. pawhuskaensis</i> fus. primitive <i>Rauserites rossicus</i>
Iatan: <i>S. pawhuskaensis</i> , <i>S. firmus</i>	Lower Rusavkino: <i>S. firmus</i> ; <i>I. toretzianus</i>	[not identified]
South Bend (Gretna): <i>S. pawhuskaensis</i> <i>S. firmus</i> , <i>I. aff. simulator</i> [transitional?]	Basal Rusavkino: <i>I. aff. toretzianus</i>	[not identified]
STANTON (Eudora) / UPR WINCHELL [Tx]: 'type' <i>I. aff. simulator</i> ; <i>S. firmus</i> in top, <i>S. gracilis</i> gp. in base amm. <i>Pseudaktubites newelli</i> [Midcontinent]	TROSHKOVO: <i>I. aff. simulator</i> ; <i>I. toretzianus</i> ; <i>Gondolella</i> fus. rare <i>Rauserites quasiarcticus</i>	O4/6: <i>S. firmus</i> dom.; <i>S. isakovae</i> <i>I. toretzianus</i> , <i>I. bachmuticus</i>
Plattsburg (Hickory Creek): <i>S. gracilis</i> group	Myasnit'skaya: type <i>S. isakovae</i> ; flat forms	O4/5: [poorly known]
Wyandotte (Quindaro): <i>S. gracilis</i> group	Sadovaya: troughed and flat forms	O4/4: [poorly known]
IOLA (Muncie Creek) / LR WOLF MOUNTAIN [Texas]: <i>S. gracilis</i> group [type <i>S. elegantulus</i> , <i>S. excelsus</i> in Tx]	Presnya: <i>S. isakovae</i> , <i>I. toretzianus</i>	O4/3: <i>S. firmus</i> , <i>S. isakovae</i> [type <i>S. kalitvensis</i> ; <i>S. cf. excelsus</i>]
DEWEY (Quivira) / MID-POSIDEON [Texas]: <i>S. gracilis</i> group; <i>I. magnificus</i> [types in Texas]	MESTSHERINO: <i>Gondolella</i> <i>S. isakovae</i> , type <i>I. mestsherensis</i>	O4/1: first <i>S. firmus</i> ; <i>S. isakovae</i> [type <i>I. toretzianus</i> , <i>I. bachmuticus</i>]
Cherryvale (Wea): <i>S. gracilis</i> group	Perkhurovo: <i>S. neverovensis</i> ; flat forms	O4: mostly troughed forms
Hogshooter: forms transitional to <i>S. gracilis</i> group	[not identified]	O3: flat plus troughed forms
DENNIS (Stark): many forms, flat and troughed, incl. type <i>S. confragus</i> fus. <i>Triticites</i> [not most primitive]	UPPER NEVEROVO: many forms, including <i>I. sagittalis</i> , <i>S. neverovensis</i> , <i>S. cf. cancellosus</i> fus. <i>Montiparus subcrassulus</i>	O2: mostly flat forms, but including <i>S. cf. confragus</i> fus. <i>Triticites</i> ; advanced <i>Montiparus</i>
Mound Valley: first <i>S. confragus</i>	[not identified]	O1/2: <i>S. cf. confragus</i>
SWOPE (Hushpuckney): many forms, including type <i>S. cancellosus</i> , <i>I. sulciferus</i> ; rare <i>I. sagittalis</i> fus. <i>Eowaeringella ultimata</i>	MID-NEVEROVO: flat + troughed forms, incl. <i>S. cf. cancellosus</i> , <i>I. cf. sulciferus</i> , <i>I. sagittalis</i> fus. typical-advanced <i>Montiparus</i>	O1: flat and troughed forms <i>I. cf. sulciferus</i> ; type <i>I. sagittalis</i> fus. adv. protrit.; prim. trit., <i>Montiparus</i>
HERTHA (Mound City): nodose <i>Idiognathodus</i> , including <i>I. eccentricus</i> , rare <i>I. sagittalis</i> [no fusulines]	Lower Neverovo: type <i>S. neverovensis</i> ; some flat forms [no fusulines]	N5/1: <i>Idiognathodus</i> , many nodose, <i>I. sagittalis</i> ; <i>I. cf. eccentricus</i> [no fus.]
Exline: flat forms, incl. <i>I. sagittalis</i> ; first <i>I. eccentricus</i> [no fusulines]	Basal Neverovo: <i>S. neverovensis</i> ; flat forms, incl. <i>I. cf. eccentricus</i> [fus. prim. <i>Montiparus</i>]	N5: [poorly known]
Checkerboard-S. Mound: flat, incl. <i>I. sagittalis</i> [no fus.]	[not identified]	[not identified]
Glenpool [upper Lost Branch]: last <i>Neognathodus</i> ; <i>Sw. nodocarinata</i> ; <i>I. n. sp. of B. & R.</i> [no fusulines]	Ratmirovo: flat forms; several in base, including <i>I. cf. trigonolobatus</i> , <i>Sw. makhlinae</i>	N4: [poorly known] [last <i>Neognathodus</i> reported]
LOST BRANCH (Nuyaka Creek): <i>I. expansus</i> ; <i>G. magna</i> type <i>Swadelina nodocarinata</i> ; <i>I. n. sp. of B. & R.</i> fus. <i>Beedeina eximia</i>	VOSKRESENSK: <i>I. trigonolobatus</i> , <i>I. fischeri</i> ; type <i>Swadelina makhlinae</i> ; <i>Sw. nodocarinata</i> fus. typical protrititids	N3/3: <i>I. expansus</i> ; <i>Gondolella magna</i> <i>Sw. neoshoensis</i> ; <i>Sw. nodocarinata</i> fus. typical protrititids
Norfleet: mostly <i>Neognathodus</i> ; <i>Sw. nodocarinata</i> , <i>I. n. sp. of Barrick & Rosscoe</i> [transit.]; <i>S. subexcelsus</i>	Upper Suvorovo [Sharsha]: <i>S. subexcelsus</i> ; type <i>I. fischeri</i>	N3/2: several, incl. <i>Sw. neoshoensis</i> [no fusulines known]
ALTAMONT (Lake Neosho): broad <i>I.</i> in upper part; type <i>Swadelina neoshoensis</i> fus. <i>Beedeina megista</i> , <i>B. acme</i> , etc.	MID-SUVOROVO [Garnasha]: type <i>S. subexcelsus</i> ; <i>I. fischeri</i> fus. typical protrititids	N3/1: forms incl. <i>S. subexcelsus</i> , <i>I. trigonolobatus</i> ; <i>Swadelina</i> ? [no fusulines known]
Farlington: first <i>Swadelina neoshoensis</i> fus. present, but unidentified	Lower Suvorovo: first <i>S. subexcelsus</i> fus. incl. rare typical protrititids [current base of Kasimovian Stage]	N3: first <i>S. subexcelsus</i> and <i>Sw. neoshoensis</i> ; <i>Sw. nodocarinata</i> ? fus. primitive protrititids, like Peski
Coal City (Joe): flat forms including type <i>Idiognathodus delicatus</i> , <i>I. claviformis</i> fus. <i>Beedeina</i> [primitive protrititid level in W. U.S.]	Upper Peski [Volodarsky]: last <i>Neognathodus</i> ; flat forms, including <i>I. delicatus</i> fus. primitive protrititids, <i>Fusulina</i> , <i>Fusulinella</i>	N2/1: [poorly known]
LOWER PAWNEE (Anna): all flat forms including <i>I. delicatus</i> ; type <i>I. fustiformis</i> fus. <i>Beedeina</i> [primitive protrititid level in W. U.S.]	Middle Peski [Lower + Upper Titovo]: flat forms, including <i>I. delicatus</i> fus. primitive protrititids; <i>Fusulina</i> , <i>Fusiella</i>	N2: flat forms, incl. <i>I. cf. delicatus</i> fus. <i>Fusulina</i> , <i>Taitzeoella</i>

Figure 1. Correlation of disconformity-bounded cyclothems of various magnitudes (specified by type font) across Moscovian-Kasimovian and Kasimovian-Gzhelian stage boundary intervals in North America and eastern Europe. Even though many cyclothems contain endemic faunas in different regions, enough of them contain taxa in common, especially first appearances (indicated by gray shading), to construct framework that correlates nearly all major cyclothems and most lesser cyclothems with cyclothems of similar scale in other regions, in "digital" fashion. Data are from authors' information, references in text, and following sources: midcontinent North America (Heckel, 2002); Moscow Basin of Russian Platform (Alekseev et al., 2004; Kabanov and Baranova, 2007); Donets Basin of Ukraine (Aizenverg et al., 1975; Nemyrovska and Kozitska, 1999; brackets show data reported from sections other than Kalinovo, which may not be precisely correlated by bed number). Lesser midcontinent cycles with undiagnostic faunas and unidentified equivalents elsewhere are omitted from chart. For regional North American stages, Desmoinesian-Missourian boundary is at base of Exline cyclothem, and Missourian-Virgilian boundary is just above base of Cass cyclothem. Abbreviations: adv., advanced; amm., ammonoids; dom., dominant; fus., fusulines; *G.*, *Gondolella*; *I.*, *Idiognathodus*; prim., primitive; protrit., protrititids; *R.*, *Rauserites*; *S.*, *Streptognathodus*; *Sw.*, *Swadelina*; transit., transitional; trit., trititids.

major Mid-Suvorovo cycle and Donets Limestone N₃¹. *Sw. neoshoensis* first appears in the next older intermediate Farlington cyclothem, and in Donets Limestone N₃ at the Farlington level. *Streptognathodus subexcelsus* first appears in the Lower Suvorovo cycle and in Donets Limestone N₃. Below these three units correlated by first appearances, the conodonts are all flat forms that include *I. delicatus* in the midcontinent (Lower Pawnee, Coal City), Russia (Peski Formation), and Donets Limestone N₂. The abrupt change in conodont faunas between these two levels coincides with the current base of the Kasimovian Stage in Russia.

Among fusulines, protrititids that are considered typical (*Protrititites* and *Obsoletes*) dominate the Suvorovo and Voskresensk Formations in Russia, but occur only in Limestone N₃¹ in the Donets Basin. Those in Donets Limestone N₃ are considered primitive, like those below the Suvorovo in the middle and upper Peski, which correlate via conodonts with the midcontinent Lower Pawnee and Coal City cyclothem. The latter are dominated by provincial *Beedeina* faunas, but correlate via conodonts (Ritter et al., 2002) with the western U.S. units that contain primitive protrititids reported by Wahlman et al. (1997).

Above the *Swadelina*-bearing Lost Branch cyclothem in the midcontinent, two minor cyclothem (Glenpool, Checkerboard) are followed upward by the intermediate Exline, and major Hertha and Swope cyclothem (Fig. 1). These cyclothem display a radiation of *Idiognathodus* species with coarser transverse ribs and longer adcarinal ridges than similar flat forms in the older units with *Swadelina* (Barrick et al., 1996). A possibly ancestral form in the Altamont-Glenpool interval is being studied by Barrick and S. Rosscoe. Above the Glenpool, first appearances involve *I. eccentricus* in the Exline, several nodose forms in the Hertha, and a greater variety in the Swope, including type *I. sulciferus*, type *I. eccentricus*, and type *S. cancellus*. The basic morphotype of the earlier forms was included in *I. sulciferus* by Barrick et al. (1996), but most specimens have a less prominent inner lobe than the holotype from the Swope, so these basic forms may be an earlier species. Some forms are *I. sagittalis*, named from Limestone O₁ in the Donets Basin. Above the Swope is the minor Mound Valley cycle in which *S. confragus* first appears, overlain by the major Dennis cyclothem, which contains several forms including the holotype of *S. confragus*.

Above the *Swadelina*-bearing Voskresensk Formation and faunally related Ratmirovo Formation in the Moscow Basin, several cycles have been recognized in the Neverovo Formation (Basal, Lower, Middle, Upper), the upper two of which have conodonts abundant enough to be considered major (Fig. 1). Above *Swadelina*-bearing Limestone N₃¹ in the Donets Basin, two minor cycles are overlain by two major cycles (N₃¹, O₁) and followed by minor cycle O₂¹ and major cycle O₂. In terms of scale, the lower two major cycles correlate with the Hertha and Swope in the midcontinent, and the minor-major sequences at the top (O₂¹-O₂) contain forms that closely resemble *S. confragus*, which occurs in the similar midcontinent minor-major sequence (Mound Valley-Dennis) above the Swope. Both lower major cycles (Hertha, N₃¹) contain nodose *Idiognathodus*. Fitting the Russian succession into this framework places the major Upper Neverovo cycle equivalent to the Dennis and Limestone O₂, the major Mid-Neverovo cycle equivalent to the Swope and Limestone O₁, and the three lower minor cycles equivalent to the lower cycles in the other regions. Thus the Lower Neverovo cycle is correlated with the Hertha and Limestone N₃¹, and the Basal Neverovo cycle is correlated with the Exline. Although most of the conodonts that dominate these Russian cycles are unlike those dominating their positional equivalents elsewhere, some distinctive forms are found at the same levels. The Basal Neverovo contains a grooved form that closely resembles *I. eccentricus*, which first appears in the Exline. The minor Glenpool and Ratmirovo cycles both contain the youngest occurrences of *Swadelina*, and the Glenpool and Limestone N₄ both contain the youngest occurrences of the genus *Neognathodus*. The Middle and Upper Neverovo contain forms resembling *S. cancellus*,

which first appears in the Swope. A large-lobed form closely resembling type *I. sulciferus* in the Swope occurs in the Mid-Neverovo and Limestone O₁. However, *I. Sagittalis* occurs only in the younger major cycles in Russia and Ukraine, whereas it first appears in older lesser cycles in the midcontinent, probably because the southern midcontinent where these cycles are best developed was more basinward, and hence in deeper water, than the equivalent cycles in eastern Europe.

Larger fusulines are absent from several cycles below the Swope-Mid-Neverovo-O₁ cyclothem, except for rare primitive *Montiparus* in the Basal Neverovo. Those in the Swope-Mid-Neverovo-O₁ cyclothem are provincial, with *Eowaeringella* in the Swope, typical *Montiparus* in the Mid-Neverovo, and advanced protrititids in O₁ (Fig. 1). This fusuline provinciality confused conodont correlations in eastern Europe until recent discovery of a primitive trititid and rare primitive *Montiparus* among the dominant protrititids in Limestone O₁, suggesting that protrititids persisted longer in the Donets Basin than in the Moscow Basin. Only in the Dennis-Upper-Neverovo-O₂ cyclothem are the fusuline faunas less provincial, with advanced *Montiparus* in Russia and Ukraine and post-primitive *Trititites* in the midcontinent, which helps strengthen this correlation. The diachroneity of the protrititids in this part of the succession and their earlier diachroneity in stage of evolution at the current base of the Kasimovian argues against using fusulines as marker events to define global stage boundaries.

Near the top of the succession (Fig. 1), the major midcontinent Oread cyclothem and Texas Finis cyclothem are correlated with the major Upper Rusavkino cyclothem of Russia and Donets Basin Limestone O₆, based on first appearance of distinctive *Idiognathodus simulator* (sensu stricto) in all regions. Correlation of the Oread with the Finis is strengthened by the first appearance of the ammonoid *Vidrioceras uddeni* in both (Boardman and Work, 2004). Two major cyclothem below this correlated cyclothem, the midcontinent Stanton and Texas Upper Winchell cyclothem, are correlated with the Russian Troshkovo cyclothem, based on first appearance of the probable ancestor of *I. simulator* (s.s.), termed *I. aff. simulator* and currently being studied by Barrick and others. Between these two correlated major cyclothem, the major Cass cyclothem is correlated with the Lower Colony Creek cyclothem of Texas by the ammonoids *V. conlini* and *Pseudaktubites stainbrookii* in both, and with the Middle Rusavkino cyclothem of Russia by the first appearance of the conodont *S. zethus* in both. The next major cyclothem above the Oread-Upper Rusavkino-O₆ cyclothem, the midcontinent Lecompton, and Texas Necessity cyclothem are correlated by the presence of *I. tersus*, *S. ruzhencevi*, and *S. vitali*, and these cyclothem are correlated with the Amerevo cyclothem of Russia by the appearance of *S. ruzhencevi* and *S. vitali*. Donets Limestone O₇ is less definitely correlated with the Lecompton and Necessity by the abundance of *I. tersus*.

The succession of five intermediate and major cyclothem below the Stanton-Troshkovo cyclothem (Fig. 1) and above the Dennis-Upper Neverovo-O₂ cyclothem in North America correlates well by position with the five cyclothem in Russia, with only the third cyclothem up (lesser Presnya) not at the same relative scale as its positional equivalent (Iola) in North America. The Donets conodont succession below *I. simulator* in Limestone O₆ is less well known than it is from O₂ downward, but so far appears to be dominated by *S. firmus*, which appears abruptly in the midcontinent in the upper Eudora Shale (Stanton cyclothem) by migration, so the Donets units are correlated mainly by position and scale. Below O₆, the four major Donets cycles correlate well with the four major cyclothem in North America, providing a more reasonable distribution of these higher Donets cycles than shown by Heckel et al. (2005), since the more recent discovery of the first *I. simulator* (s.s.) in Donets cycle O₆ rather than O₇. Thus, the overall correlation framework of major Kasimovian and early Gzhelian cyclothem based on cyclothem scale and first conodont and ammonoid appearances provides the most reasonable correlation possible (Fig. 1).

CONCLUSIONS

This correlation is more accurate and biostratigraphically documented than the general sequence-stratigraphic correlation of Izart et al. (2003), and it should satisfy the guideline of Remane et al. (1996) that correlation of beds precedes stage boundary definition. The Moscovian-Kasimovian boundary around Moscow is currently at the base of the Suvorovo Formation, where typical protrititids appear above primitive protrititids in the underlying Peski Formation. While some workers wish to keep the base of the Kasimovian near this level, the difficulty of distinguishing species among protrititids along with their apparently diachronous appearance relative to the conodont correlation between the Moscow and Donets Basins has led most workers to prefer a higher boundary, above the last occurrence of the conodont *Swadelina* and below the first appearance of *I. sagittalis* and the easily identified fusuline *Montiparus* (Villa and Task Group, 2005).

The relative ease of correlation of the Oread–Upper Rusavkino–O₆ cyclothem by means of the first appearance of *I. simulator* (s.s.) in all regions, and above a succession of cyclothem that contains the first appearance of *I. aff. simulator* followed by the first appearance of *S. zethus* in the midcontinent and Russia, and above a succession in which all major cyclothem correlate at similar positions in the midcontinent and Donets Basin, indicates that this appearance would provide a good marker event for defining the base of the Gzhelian Stage. The appearance with *I. simulator* in this cyclothem in Texas of the ammonoid *S. cuyleri*, the earliest species of *Shumardites* (the traditional basal Gzhelian genus), keeps the base of the Gzhelian at its proper position in the classic ammonoid zonation (Boardman and Work, 2004).

The widespread exposure surfaces that help expedite “digital” correlation will make the selection of GSSPs (which require continuous sedimentation) difficult in shelf regions where the cyclothem are well defined. However, correlating sections where cyclothem are not recognized into this cyclothem framework (Heckel et al., 2005) may allow selecting a GSSP in a section of continuous sedimentation that can be correlated more globally, if several conditions are met: (1) cyclothem are not recognized because the section was deposited at water depths below sea-level lowstands; (2) the section contains a succession of the fossils that occur in more shelfward regions where the correlation framework is recognized; and (3) the section is on a slope gentle enough that the continuity is not interrupted by debris flows that eliminated part of the section or mixed biotas of different ages.

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