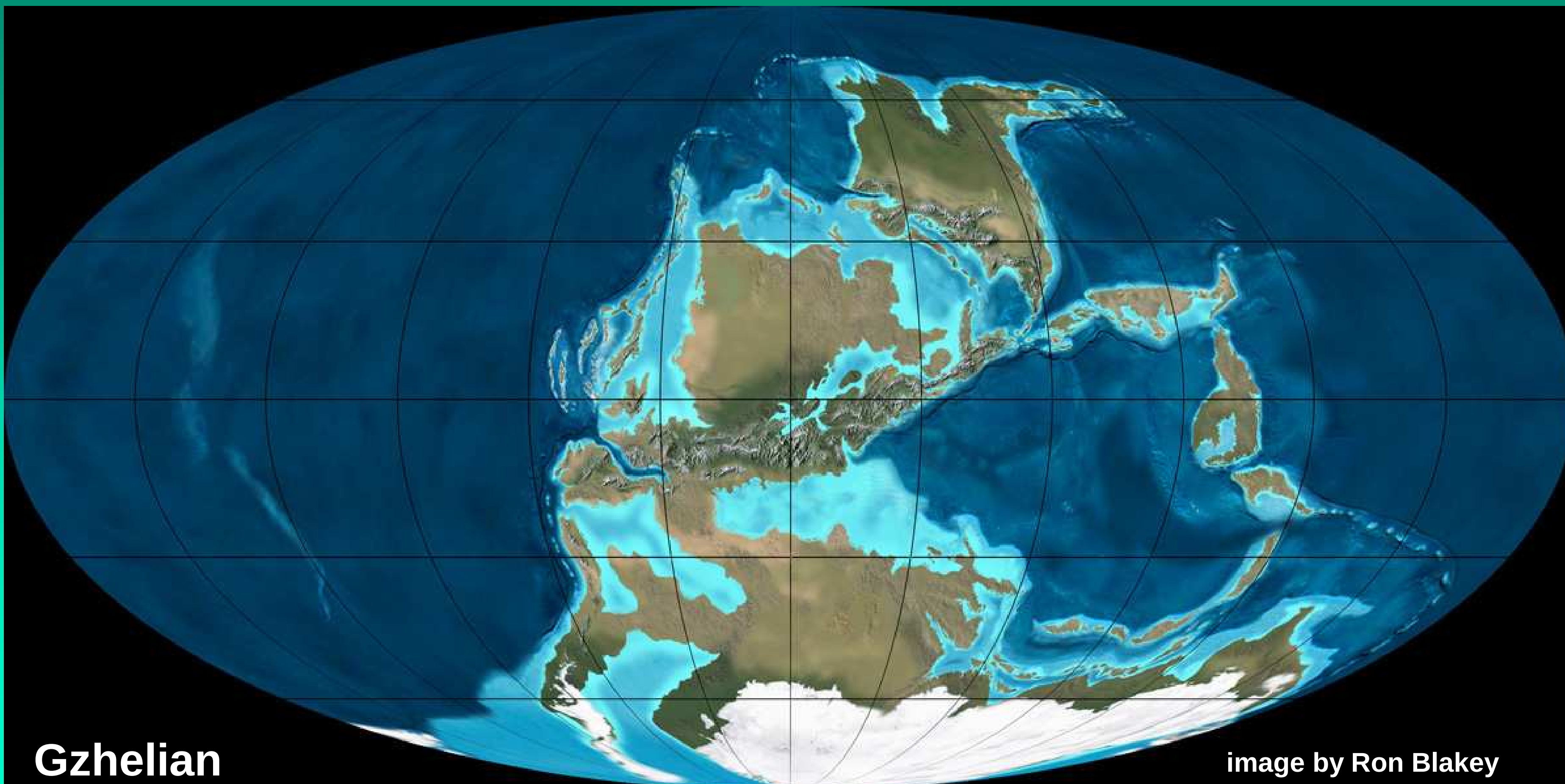
Current Status of the International Carboniferous Time Scale

Barry C. Richards



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ABSTRACT

The Carboniferous comprises the Mississippian and Pennsylvanian subsystems and Tournaisian, Viséan, Serpukhovian, Bashkirian, Moscovian, Kasimovian and Gzhelian stages in ascending order. GSSPs define the base (358.9 Ma; co-incident with Mississippian-Devonian boundary) and top of the Carboniferous (298.9 Ma; co-incident with Pennsylvanian-Permian boundary). Bases of the Tournaisian, Viséan (346.7 Ma) and Bashkirian (323.2 Ma; co-incident with base of Pennsylvanian) are fixed by GSSPs, but the Devonian-Tournaisian boundary (defined by FAD of conodont *Siphonodella sulcata* in slope carbonates at La Serre, France) is being contested. The FAD of foraminifer *Eoparastaffella simplex* defines the Tournaisian/Viséan boundary GSSP in the Chinese Pengchong section (carbonate turbidites). The basal Pennsylvanian GSSP, defined by the FAD of conodont *Declinognathodus noduliferus* s.l., lies in neritic carbonates at Arrow Canyon, Nevada, U.S.A. The FAD of conodont *Streptognathodus isolatus* defines the Gzhelian/Permian boundary GSSP in Aidaralash section (shallow-shelf deposits), Kazakhstan. Definitions have been proposed for bases of the Serpukhovian (330.9 Ma; FAD of conodont *Lochriea ziegleri*) and Gzhelian (ca. 303.7 Ma; FAD of conodont *Idiognathodus simulator* s.s.); carbonate basin and slope successions in China and the Urals contain their GSSP candidate sections. Several conodonts and fusulinids have been recently proposed as indices for the basal Moscovian GSSP (315.2 Ma) but only FADs of *Diplognathodus ellesmerensis,* and *Declinognathodus donetzianus* have received substantial support from SCCS task-group members. The FADs of the conodonts *Idiognathodus turbatus* and *Idiognathodus sagittalis* are considered to have the best potential for fixing the basal Kasimovian GSSP.

INTRODUCTION

This slide deck is based on an oral presentation given by the SCCS Chairman at the May 20 - 22, 2013 Carboniferous-Permian Transition meeting in Albuquerque, New Mexico U.S.A. Text and text slides (abstract, and references) have been added to make the presentation more suitable for this website. The slide deck is designed to accompany the paper by Richards (2013) "CURRENT STATUS OF THE INTERNATIONAL CARBONIFEROUS TIME SCALE", which has been posted on this website under the heading of Timescale. The paper gives background information about the boundaries and stratotype sections illustrated herein. An outline for the slide deck is given below.

OUTLINE FOR SLIDE DECK

1. Overview of major and minor divisions of the Carboniferous System
- present situation, recent past, and future
2. Boundaries in sequential order starting with base of Carboniferous
   A- boundaries defined by GSSPs (bases Tournaisian, Viséan, Bashkirian, and Permian)
      - stratotype sections and criteria used for boundary definition and Global correlation
   B - boundaries not defined by GSSPs (bases of Serpukhovian, Moscovian, Kasimovian, Gzhelian)
      - progress and work plans
3. Stages
- overview of selected stratotype sections (Serpukhovian, Bashkirian, Moscovian, Kasimovian, and Gzhelian)

MAIN DIVISIONS OF CARBONIFEROUS SYSTEM

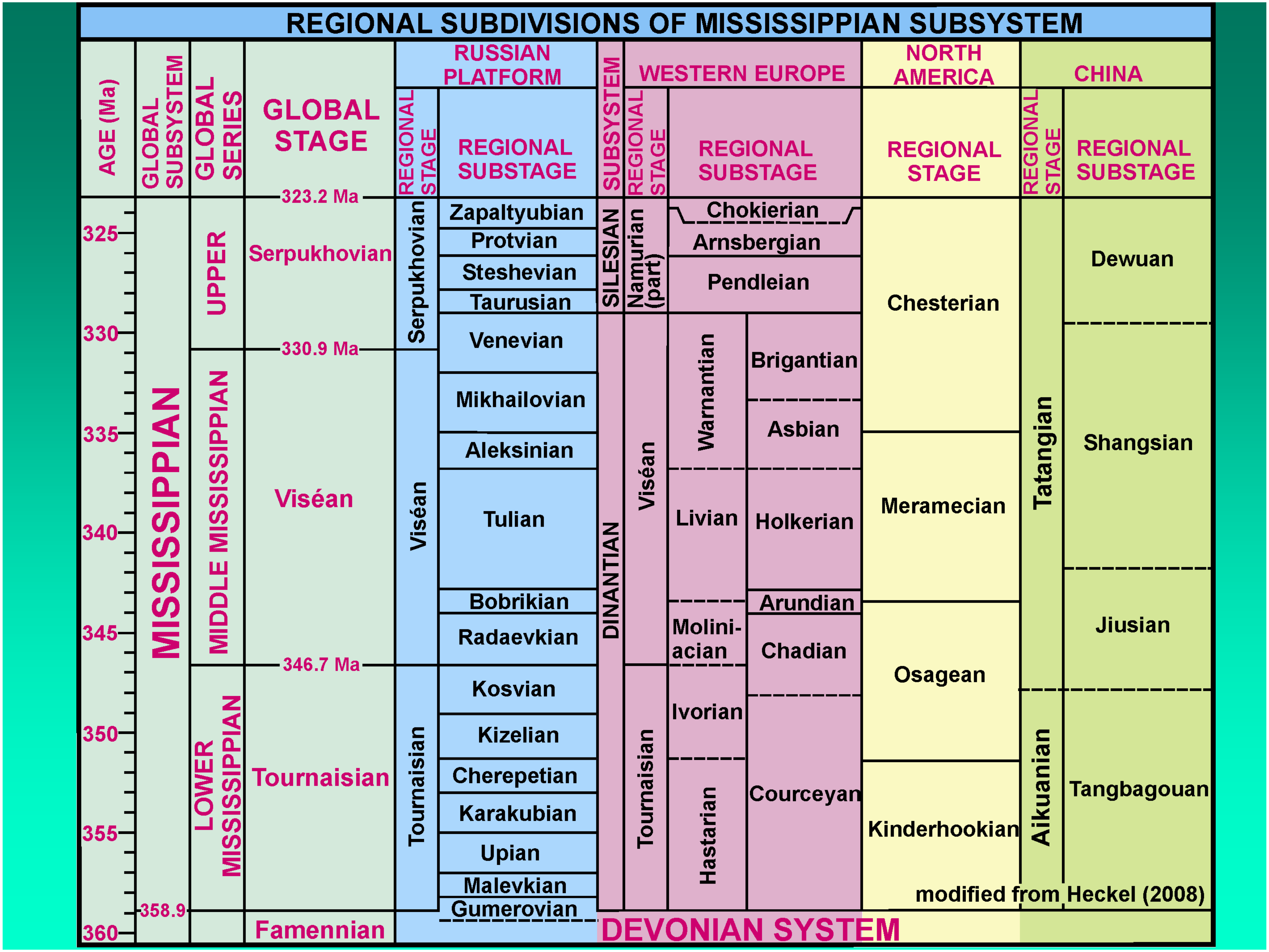
SYSTEM	SUBSYSTEM	SERIES	STAGE	AGE Ma
			GSSP	298.9 ± 0.2
CARBONIFEROUS	PENNSYLVANIAN	UPPER	Gzhelian 4.8 Myr	303.7 ± 0.1
			Kasimovian 3.3 Myr	307.0 ± 0.2
		MIDDLE	Moscovian 8.2 Myr	315.2 ± 0.2
	24.3 Myr	LOWER	Bashkirian 8 MYr	323.2 ± 0.4
			GSSP	
	MISSISSIPPIAN	UPPER	Serpukhovian 7.7 Myr	330.9 ± 0.3
		MIDDLE	Viséan 15.8 Myr	346.7 ± 0.4
			GSSP	
	35.7 Myr	LOWER	Tournaisian 12.2 Myr	358.9 ± 0.4

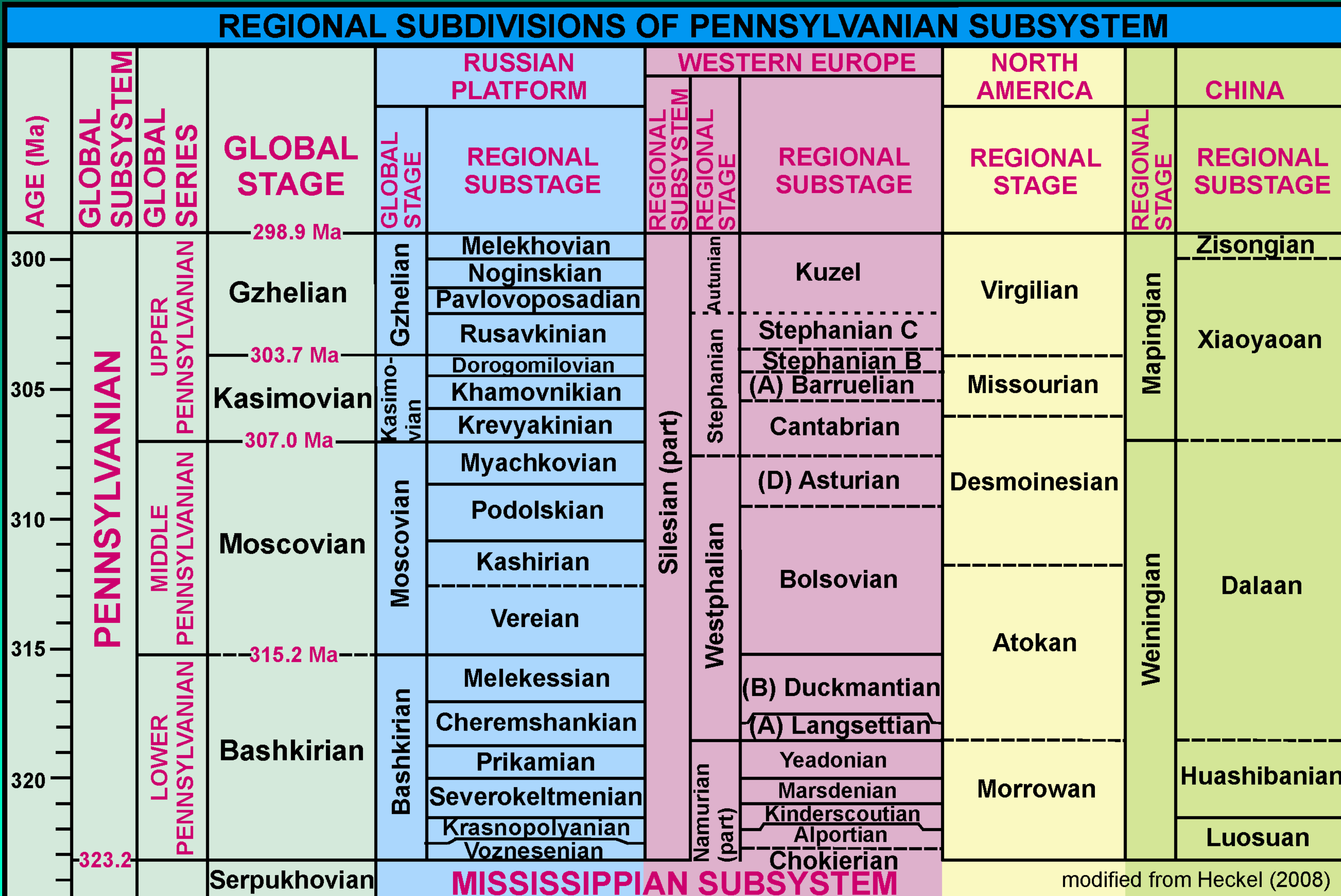
GLOBAL CARBONIFEROUS DIVISIONS

from Heckel (2004) and Heckel and Clayton (2006)

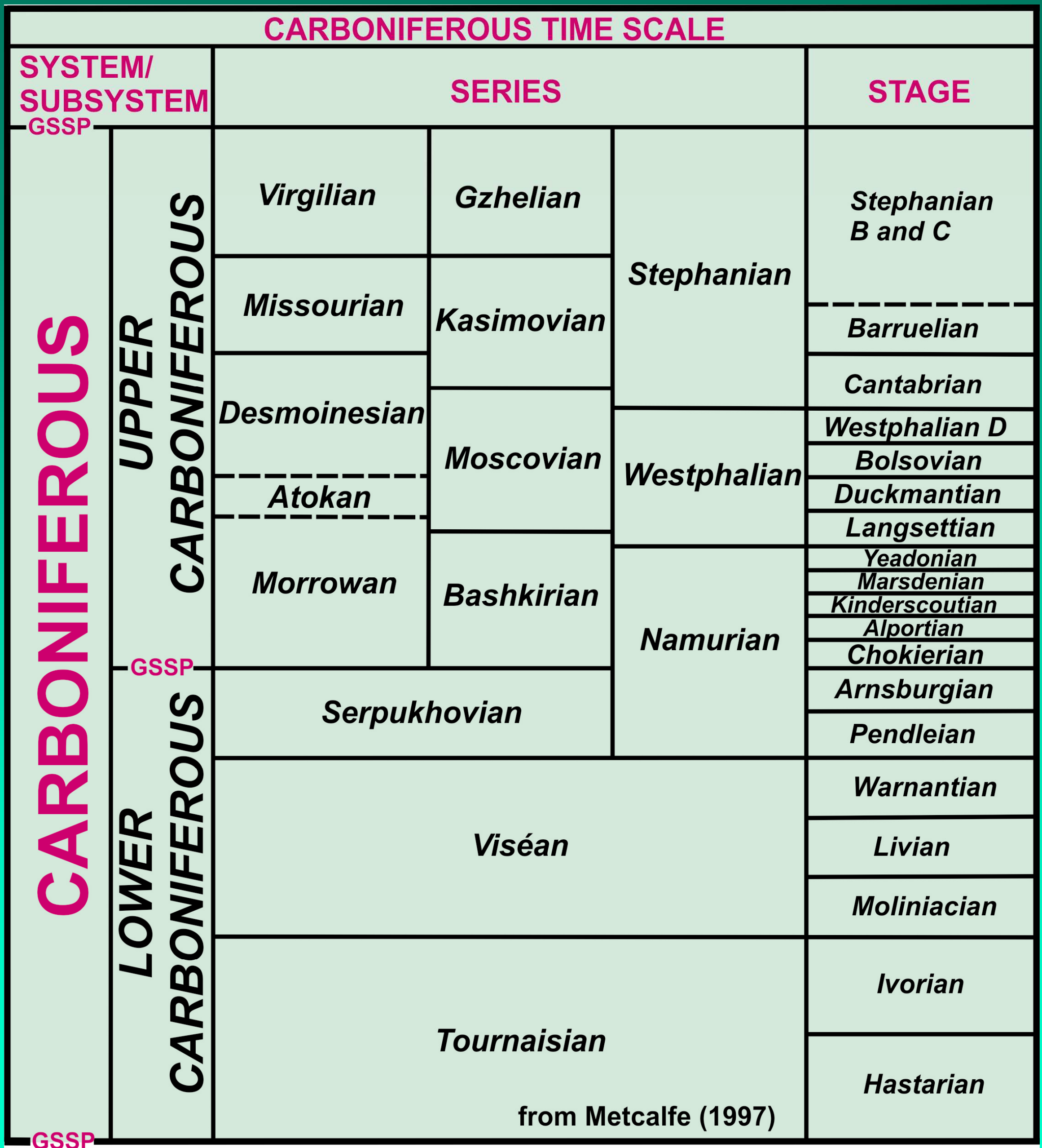
Divisions are the result of ballots taken by SCCS in 2003 and ratified by ICS and IUGS in 2004; ages from GTS 2012 and ICS chart developed for 34th IGC

Slide shows main divisions of Carboniferous System in current use. Next two slides show regional subdivisions (stages and substages) for Mississippian and Pennsylvanian.


REGIONAL SUBDIVISIONS OF MISSISSIPPIAN SUBSYSTEM
AGE (Ma)
GLOBAL SUBSYSTEM
GLOBAL SERIES
GLOBAL STAGE
RUSSIAN PLATFORM
REGIONAL STAGE
REGIONAL SUBSTAGE
SUBSYSTEM
WESTERN EUROPE
REGIONAL STAGE
REGIONAL SUBSTAGE
NORTH AMERICA
REGIONAL STAGE
CHINA
REGIONAL STAGE
REGIONAL SUBSTAGE
325
330
335
340
345
350
355
360
358.9
323.2 Ma
330.9 Ma
346.7 Ma
MISSISSIPPIAN
UPPER
MIDDLE MISSISSIPPIAN
LOWER MISSISSIPPIAN
Serpukhovian
Viséan
Tournaisian
Famennian
Serpukhovian
Viséan
Tournaisian
Zapaltyubian
Protvian
Steshevian
Taurusian
Venevian
Mikhailovian
Aleksinian
Tulian
Bobrikian
Radaevkian
Kosvian
Kizelian
Cherepetian
Karakubian
Upian
Malevkian
Gumerovian
SILESIAN
DINANTIAN
Namurian (part)
Viséan
Tournaisian
Chokierian
Arnsbergian
Pendleian
Warnantian
Livian
Molini-acian
Ivorian
Hastarian
Brigantian
Asbian
Holkerian
Arundian
Chadian
Courceyan
Chesterian
Meramecian
Osagean
Kinderhookian
Tatangian
Aikuanian
Dewuan
Shangsian
Jiusian
Tangbagouan
DEVONIAN SYSTEM
modified from Heckel (2008)



The radiometric dates and divisions are from Davydov *et al.* (2012) - The Geologic Time Scale 2012 and are the same as those on the ICS chart developed for the 34th International Geologic Congress in Brisbane, 2012.



CARBONIFEROUS DIVISIONS IN GENERAL USE PRIOR TO 2003

The subsystems were called Upper and Lower Carboniferous instead of Mississippian and Pennsylvanian.

Most units that we consider to be stages were called series.

The stages are our regional substages from Western Europe.

BASE OF CARBONIFEROUS SYSTEM

SYSTEM	SUBSYSTEM	SERIES	STAGE	AGE Ma
			GSSP	298.9 ± 0.2
CARBONIFEROUS	PENNSYLVANIAN	UPPER	Gzhelian 4.8 Myr	303.7 ± 0.1
			Kasimovian 3.3 Myr	307.0 ± 0.2
		MIDDLE	Moscovian 8.2 Myr	315.2 ± 0.2
	24.3 Myr	LOWER	Bashkirian 8 MYr	323.2 ± 0.4
			GSSP	
	MISSISSIPPIAN	UPPER	Serpukhovian 7.7 Myr	330.9 ± 0.3
		MIDDLE	Viséan 15.8 Myr	346.7 ± 0.4
			GSSP	
	35.7 Myr	LOWER	Tournaisian 12.2 Myr	358.9 ± 0.4

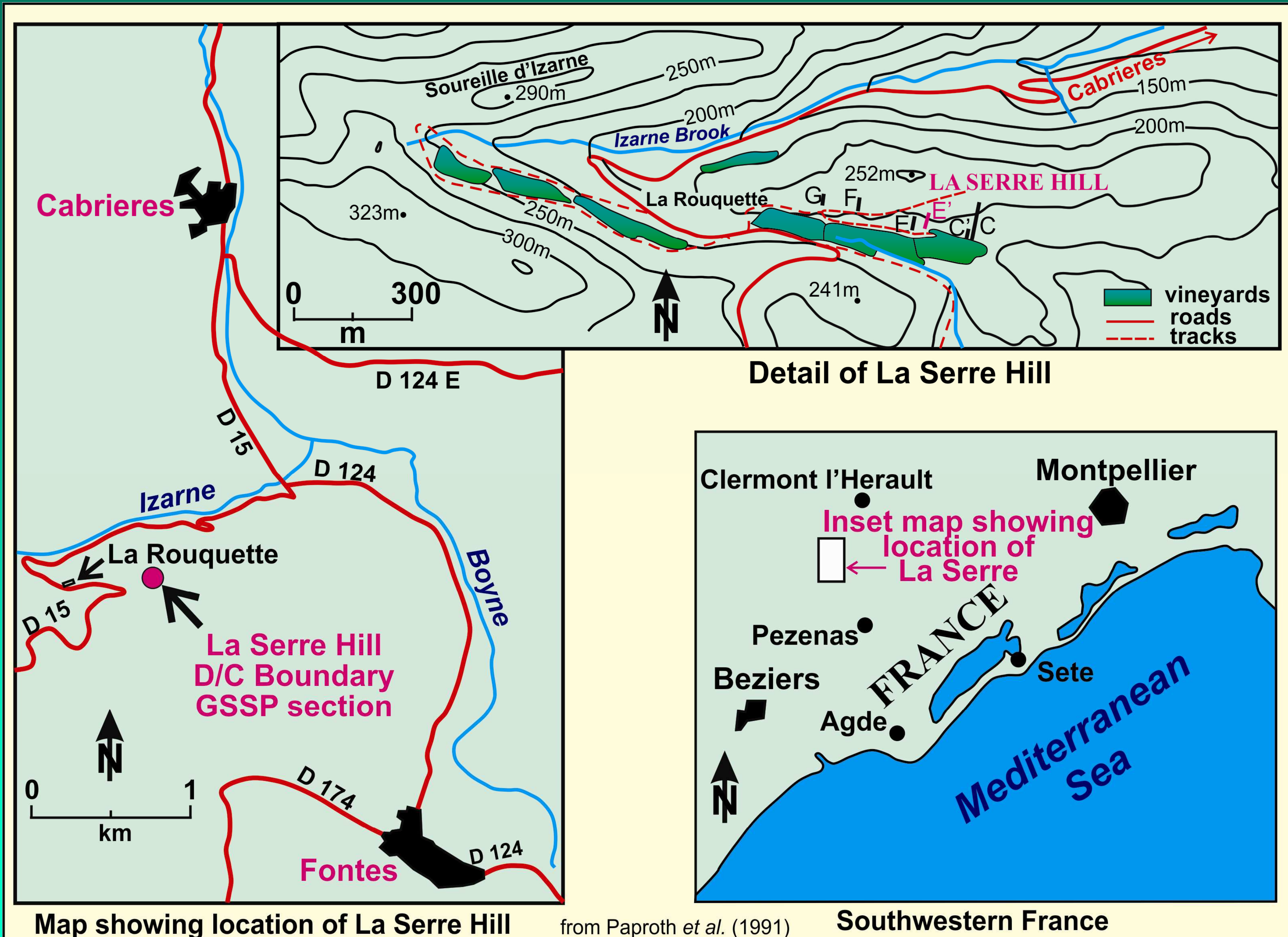
GLOBAL CARBONIFEROUS DIVISIONS

from Heckel (2004) and Heckel and Clayton (2006)

Divisions are the result of ballots taken by SCCS in 2003 and ratified by ICS and IUGS in 2004; ages from GTS 2012 and ICS chart developed for 34th IGC

The next 5 slides discuss and illustrate the GSSP at the base of the Carboniferous System, which is also the base of the Mississippian Subsystem, Lower Mississippian Series, and Tournaisian Stage. SCCS Task Group Chairman - Markus Aretz (France).

The GSSP for the base of the Carboniferous is on La Serre Hill in southern France and is defined by the FAD of conodont *Siphonodella sulcata* (Paproth *et al*., 1991).

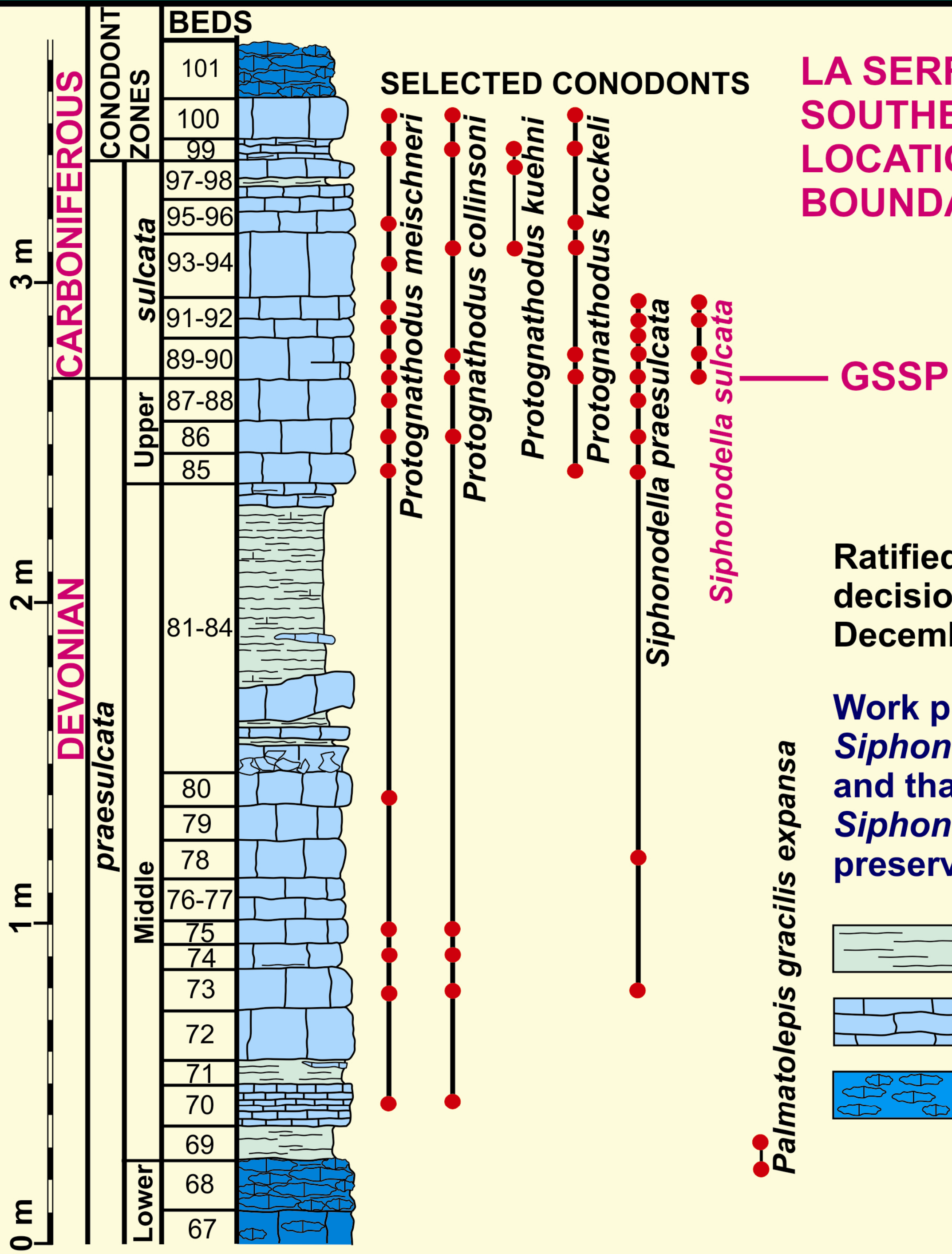


Location of the La Serre section in the Montagne Noir, southern France. The section contains the contested GSSP for the base of the Carboniferous System.

Photograph on left shows beds from about number 60 to 90 in trench E' on La Serre Hill, France. Current GSSP for base of Carboniferous lies at base of bed 89 but *Siphonodella sulcata* was recently found as low as bed 84b by Kaiser (2009). Section contains nodular, deep-water limestone but is mainly a turbiditic succession containing re-sedimented ooids, conodonts and other fossils.

Photograph on right shows the upper part of the GSSP section in trench E’ on La Serre Hill, France. Beds from about number 79 to 90 can be seen. The current GSSP for the base of the Carboniferous is at the base of bed number 89 but *Siphonodella sulcata* was recently found as low as bed 84b (Kaiser, 2009).

LA SERRE SECTION, MONTAGNE NOIR, SOUTHERN FRANCE SHOWING CURRENT LOCATION OF DEVONIAN/CARBONIFEROUS BOUNDARY GSSP



Ratified as GSSP by the ICS in July, 1989 and decision published by Paproth *et al.* in December, 1991 v. 14 of Episodes.

Work published by Sandra Kaiser (2009) indicates *Siphonodella sulcata* occurs as low as bed 84b and that an evolutionary lineage from *Siphonodella praesulcata* to *S. sulcata* is not preserved in the section.

Shale and mudstone

Limestone

Nodular limestone

(Section modified from Flajs and Feist 1988)

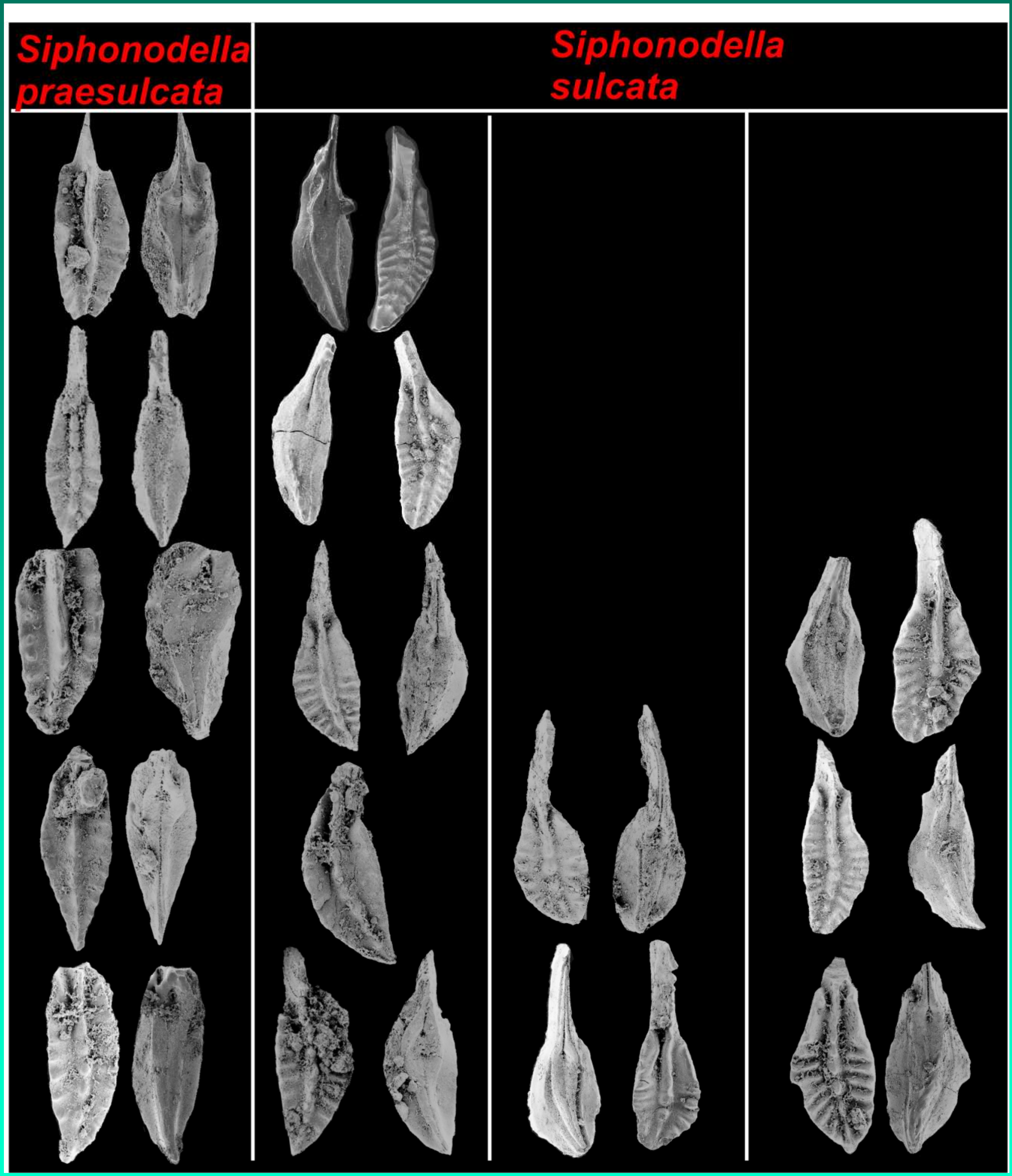
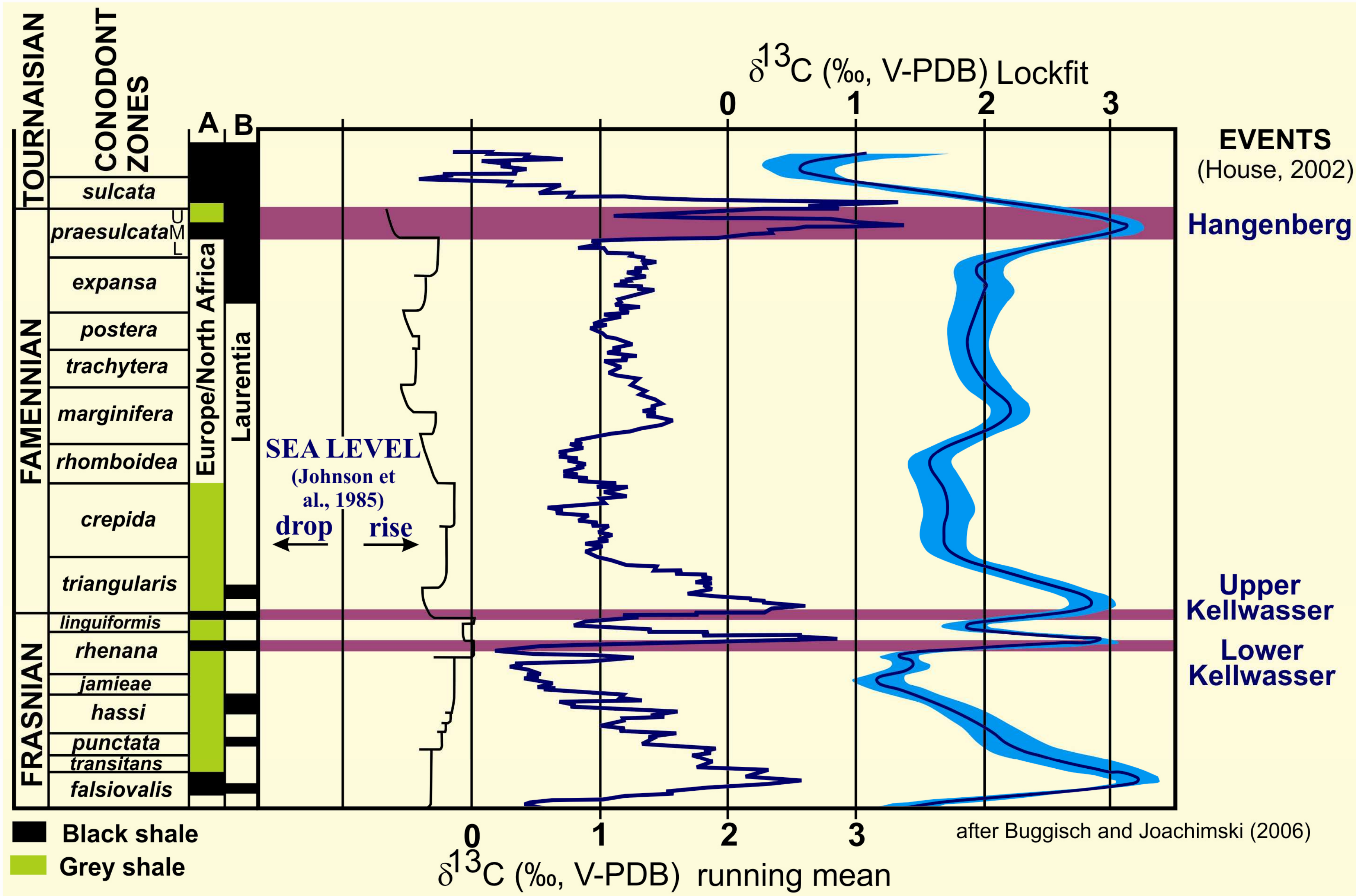


Plate showing elements of the conodonts ***Siphonodella sulcata*** and ***S. praesulcata*** from the La Serre GSSP section (from Sandra Kaiser).

Separating ***S. sulcata*** from ***S. praesulcata*** is somewhat subjective and based largely on the curvature of the carina and pseudokeel.

S. praesulcata shows curvatures between 0^{o} and less than 15^{o} degrees with median value of 7^{o}.

The curvature of ***S. sulcata*** has a median value of about 15^{o} and ranges from about 12^{o} to 24^{o} (Flajs and Feist, 1988).



The Hangenberg extinction event occurring slightly below the Famennian-Tournaisian boundary greatly influenced the style of sedimentation. The D-C boundary task group is evaluating the multiphase event to see if some component of it could be used for defining the GSSP at the base of the Carboniferous.

BASE OF THE VISÉAN STAGE

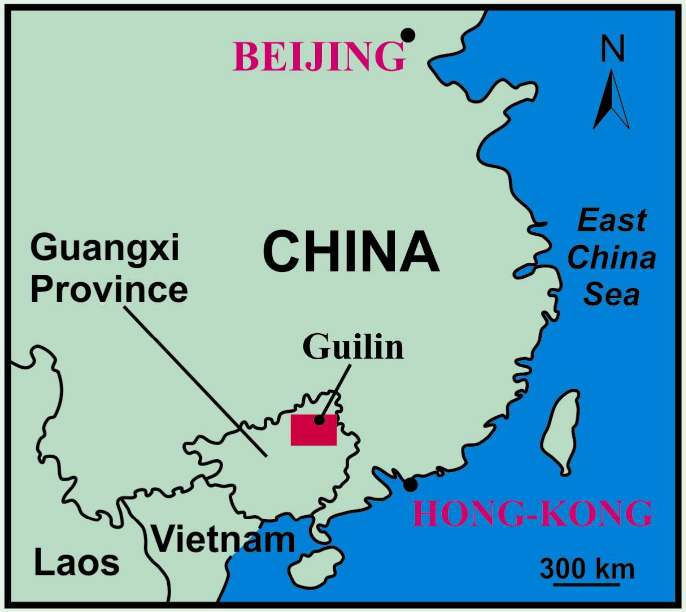
SYSTEM	SUBSYSTEM	SERIES	STAGE		AGE Ma
			GSSP		298.9 ± 0.2
CARBONIFEROUS	PENNSYLVANIAN	UPPER	Gzhelian	4.8 Myr	303.7 ± 0.1
			Kasimovian	3.3 Myr	307.0 ± 0.2
		MIDDLE	Moscovian	8.2 Myr	315.2 ± 0.2
	24.3 Myr	LOWER	Bashkirian	8 MYr	323.2 ± 0.4
			GSSP		
	MISSISSIPPIAN	UPPER	Serpukhovian	7.7 Myr	330.9 ± 0.3
		MIDDLE	Viséan	15.8 Myr	346.7 ± 0.4
			GSSP		
	35.7 Myr	LOWER	Tournaisian	12.2 Myr	358.9 ± 0.4

GLOBAL CARBONIFEROUS DIVISIONS

from Heckel (2004) and Heckel and Clayton (2006)

Divisions are the result of ballots taken by SCCS in 2003 and ratified by ICS and IUGS in 2004; ages from GTS 2012 and ICS chart developed for 34th IGC

The next 4 slides discuss and illustrate the GSSP at the base of the Viséan Stage, which is also the base of the Middle Mississippian Series. Task Group Chairman – George Sevastopulo (Republic of Ireland).



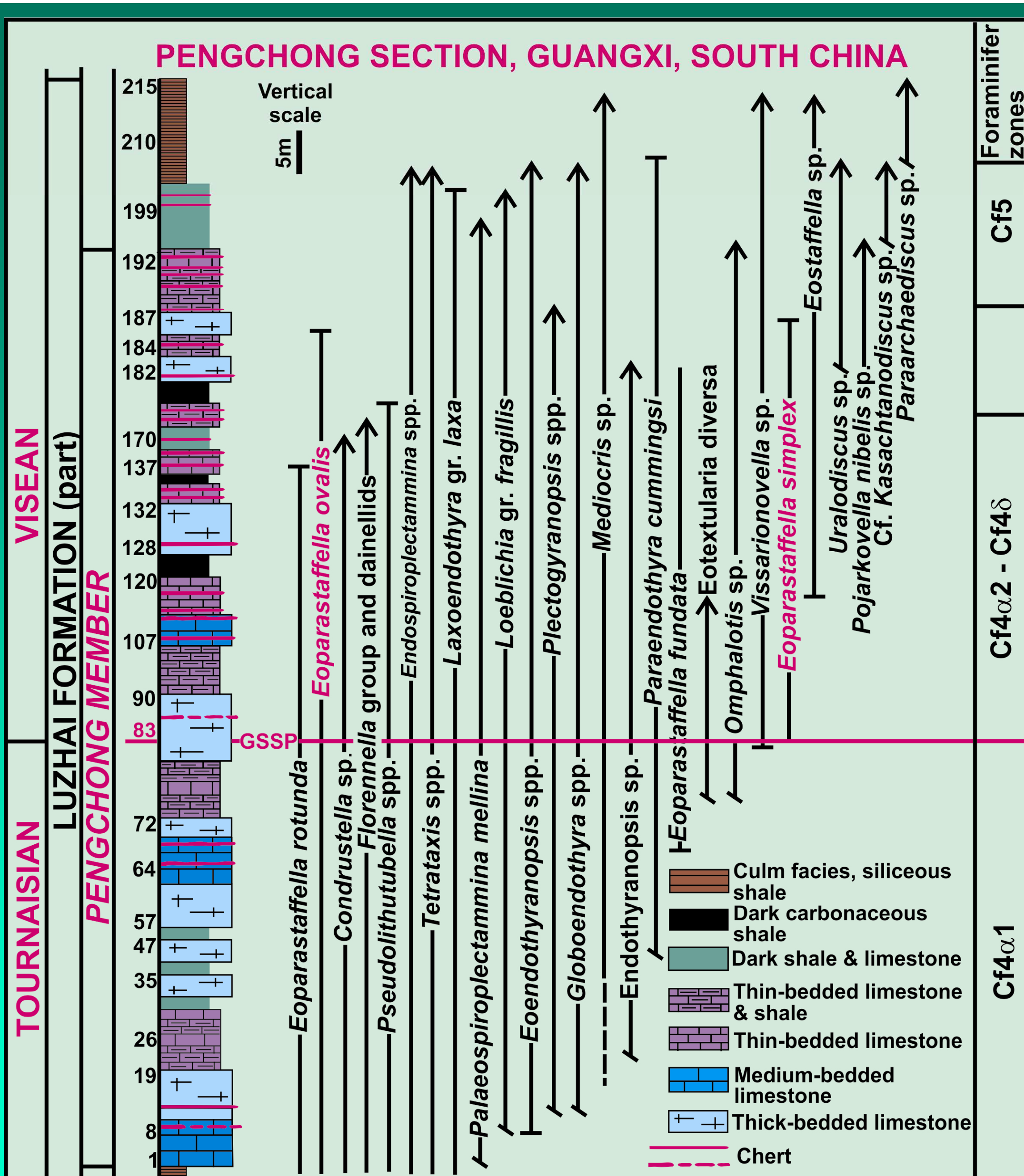
Map of southeast China showing location of study area (red rectangle)

Map of northern Guangxi showing location of Pengchong section

Proposal for Tournaisian/Viséan Boundary GSSP in Pengchong section by Devuyst *et al.* (2003) was approved by the SCCS in late 2007 and subsequently ratified by the ICS and IUGS.

from Devuyst *et al.*, 2003

Maps showing location of the Pengchong section in Guangxi Province South China. The section contains the GSSP for the base of the Global Viséan Stage.



First appearance of *Eoparasteffella simplex* in lineage *Eoparastaffella ovalis - Eoparastaffella simplex* defines GSSP at base of Viséan at bottom of bed 83.
from Devuyst *et al.* (2003)

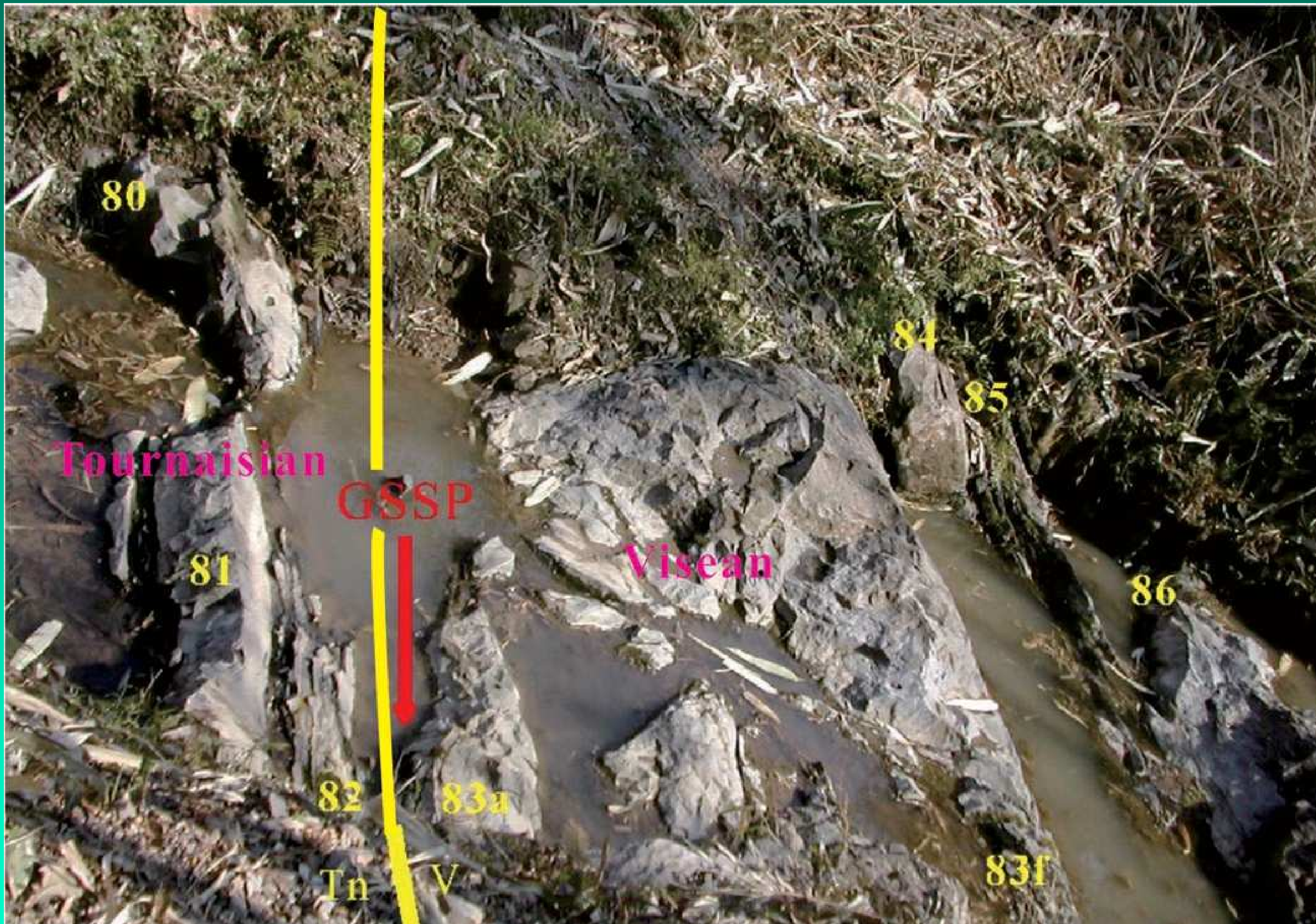
SIMPLIFIED VERSION OF STRATIGRAPHIC LOG SHOWING VISÉAN-TOURNAISIAN BOUNDARY INTERVAL IN THE PENGCHONG SECTION OF SOUTH CHINA

The figure shows the ranges and partial ranges of the most important foraminifers in the Pengchong section and the location of the GSSP at the base of bed number 83. The succession is dominated by well-bedded skeletal limestone deposited in basin environments well below storm-wave base.

STATUS

The proposal for this GSSP was submitted in 2003 and ratified by the SCCS and ICS in late 2007. The final report is being written by George Sevastopulo.

Overview of the Pengchong section in small stream by village of Pengchong in Guangxi Province, South China showing rhythmically bedded slope limestone characteristic of section. The section contains the GSSP for the Viséan-Tournaisian boundary (see Devuyst *et al*., 2003). Photo courtesy Yuping Qi and Wenkun Qie at Nanjing Institute of Geology and Paleontology.



Photograph showing location of the Tournaisian-Viséan boundary GSSP at base of limestone bed 83 in the Pengchong section, South China. Photo courtesy Yuping Qi and Wenkun Qie at Nanjing Institute of Geology and Paleontology.

BASE OF THE SERPUKHOVIAN STAGE

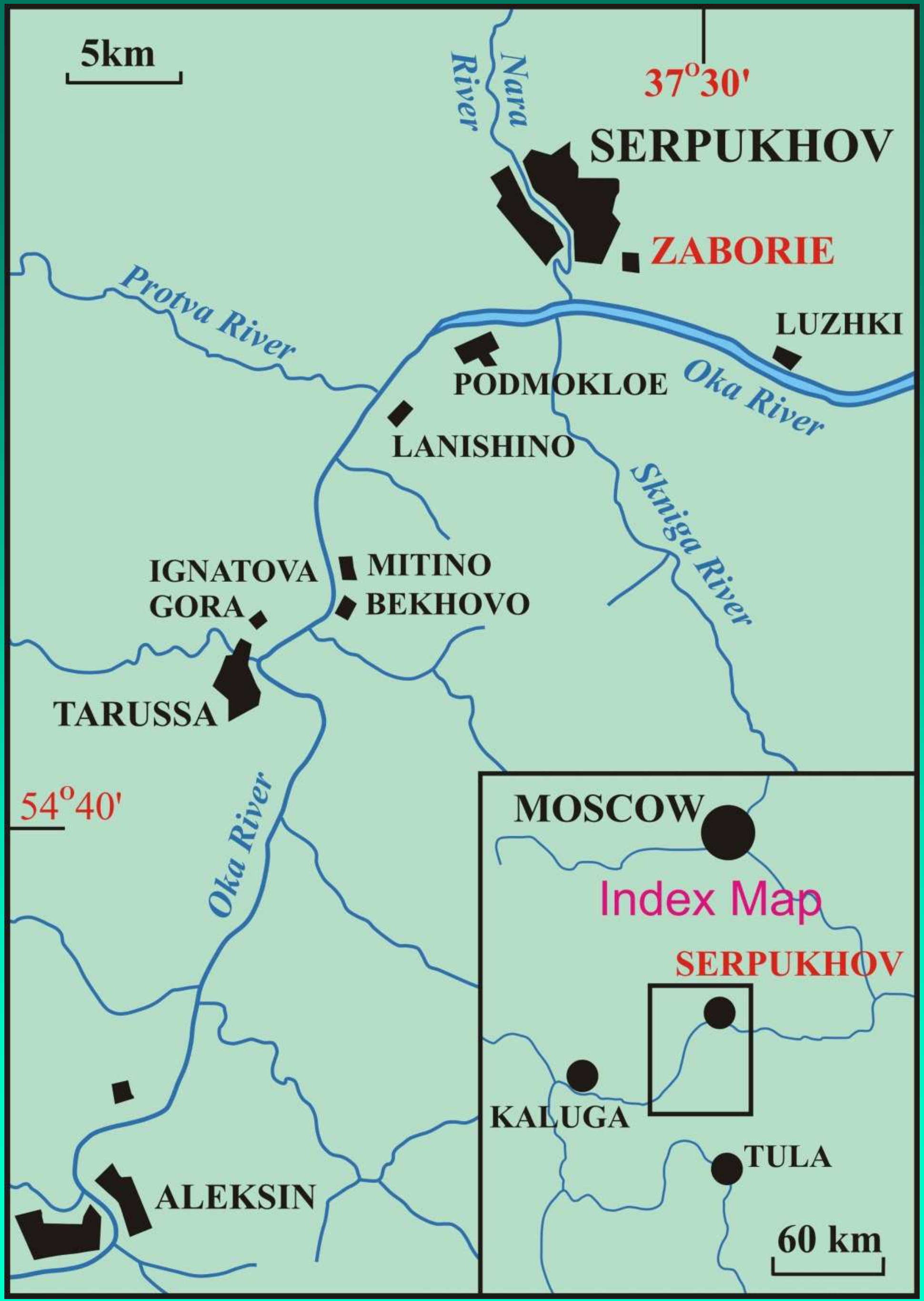
SYSTEM	SUBSYSTEM	SERIES	STAGE	AGE Ma
			GSSP	298.9 ± 0.2
CARBONIFEROUS	PENNSYLVANIAN 24.3 Myr	UPPER	Gzhelian 4.8 Myr	303.7 ± 0.1
			Kasimovian 3.3 Myr	307.0 ± 0.2
		MIDDLE	Moscovian 8.2 Myr	315.2 ± 0.2
		LOWER	Bashkirian 8 MYr GSSP	323.2 ± 0.4
	MISSISSIPPIAN 35.7 Myr	UPPER	Serpukhovian 7.7 Myr	330.9 ± 0.3
		MIDDLE	Viséan 15.8 Myr GSSP	346.7 ± 0.4
		LOWER	Tournaisian 12.2 Myr	358.9 ± 0.4

GLOBAL CARBONIFEROUS DIVISIONS

from Heckel (2004) and Heckel and Clayton (2006)

Divisions are the result of ballots taken by SCCS in 2003 and ratified by ICS and IUGS in 2004; ages from GTS 2012 and ICS chart developed for 34th IGC

The next 13 slides illustrate and discuss the base of the Serpukhovian Stage, which is also the base of the Upper Mississippian Series. The SCCS task group for the Viséan/Serpukhovian boundary is currently evaluating two prime candidate sections: the Verkhnyaya Kardailovka section in the southern Urals of Russia and the Nashui section in South China. Task Group Chairman – Barry C. Richards (Canada).

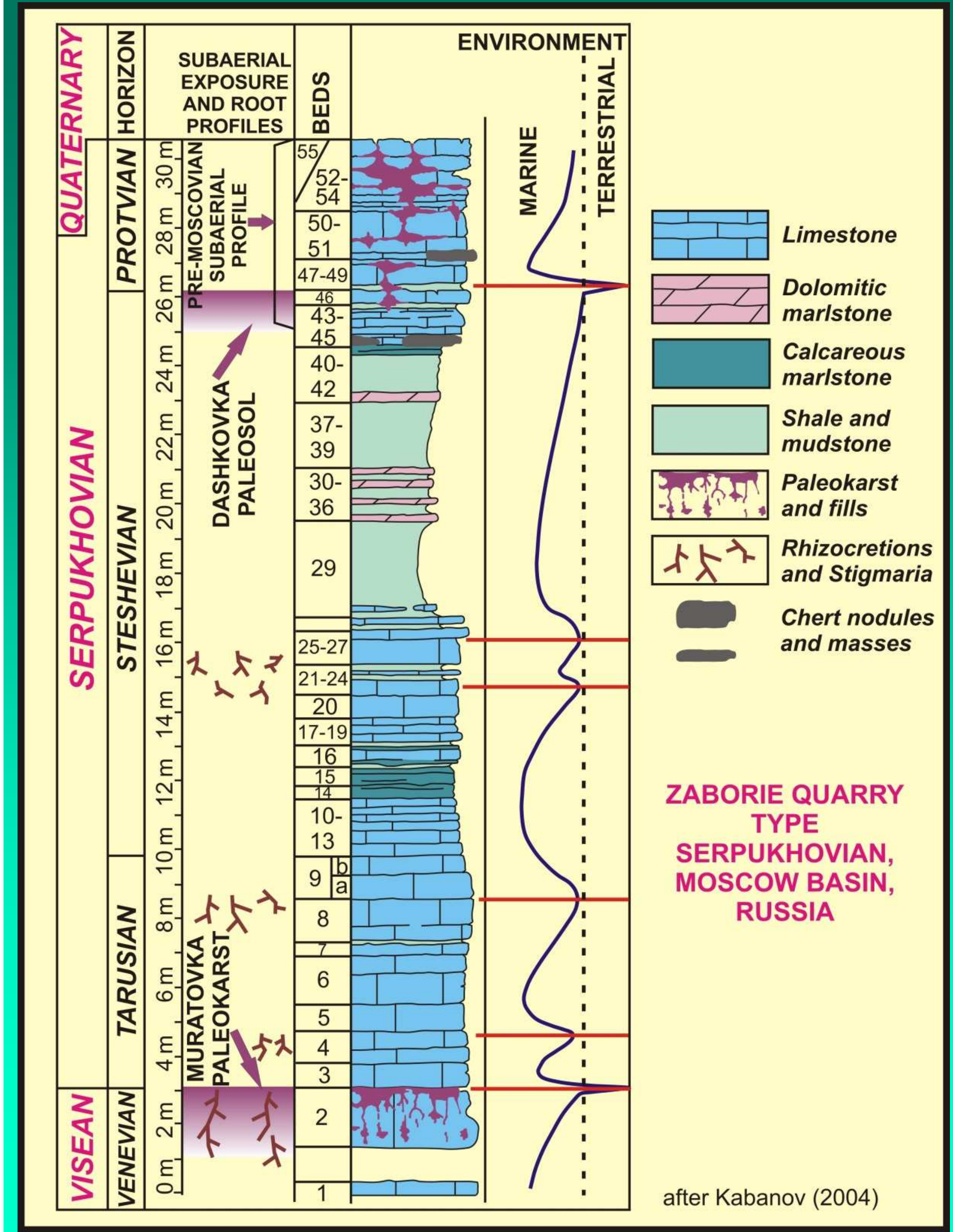


MAP SHOWING LOCATION OF LECTOSTRATOTYPE OF THE SERPUKHOVIAN STAGE BY CITY OF SERPUKHOV, MOSCOW BASIN, RUSSIA

-The Serpukhovian Stage was proposed by Nikitin (1890).

- It was reestablished as a stage to replace the use of Namurian in the Russian stratigraphic scheme in 1974.

- The Serpukhovian is currently internationally recognized as the upper Stage of the Mississippian



STRATIGRAPHIC LOG ILLUSTRATING THE LECTOSTRATOTYPE OF THE SERPUKHOVIAN STAGE

1) Base of lectostratotype of Serpukhovian is unconformable on paleokarst at top of Venevian Horizon/Substage.
2) Top of Serpukhovian is unconformable and includes pre-Moscovian subaerial profile.
3) The lectostratotype is incomplete comprising the Tarusian, Steshevian, and Protvian horizons/substages.
4) The Zapaltyubinian Horizon/Substage of the Serpukhovian parastratotype in the Donets Basin, Ukraine is absent.
5) Lectostratotype of Serpukhovian is thin – about 28 m thick.
6) Section is dominated by shallow-marine carbonates and has paleosols and karstified deposits.

Novogurovskii quarry in Moscow Basin south of Moscow. This reference section for the Serpukhovian Stage lies south of Serpukhov and the Zaborie quarry, which contains the lectostratotype. Arrow 1 indicates Viséan-Serpukhovian Stage boundary, arrow 2 indicates approximate location of top of Serpukhovian and sub-Moscovian unconformity.

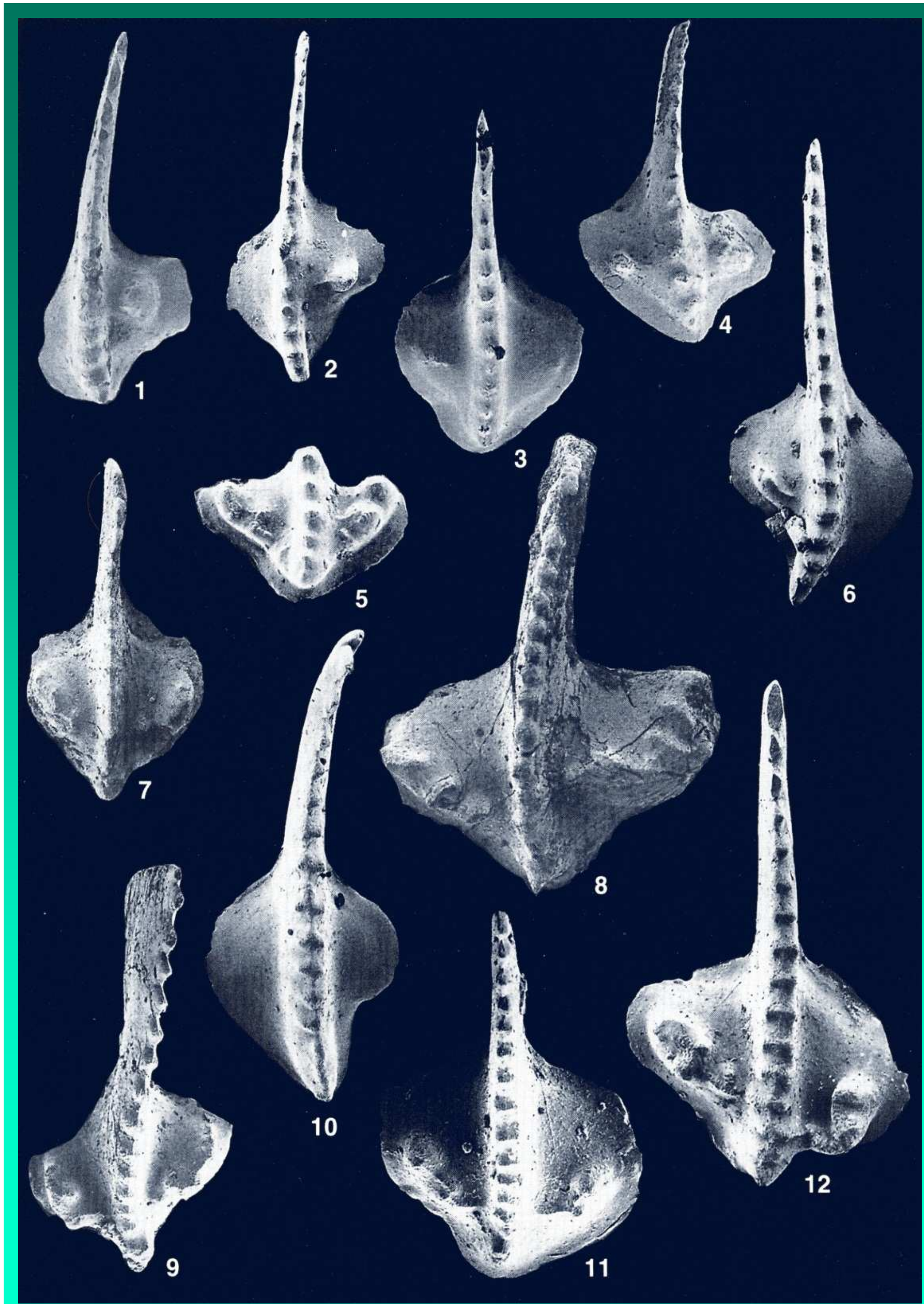


PLATE SHOWING CONODONTS OF THE GENUS *LOCHRIEA*

Figs. 1-2: *Lochriea mononodosa*

Figs. 3-4: *Lochriea nodosa*

Figs. 5, 7-9, 11-12 *Lochriea ziegleri*

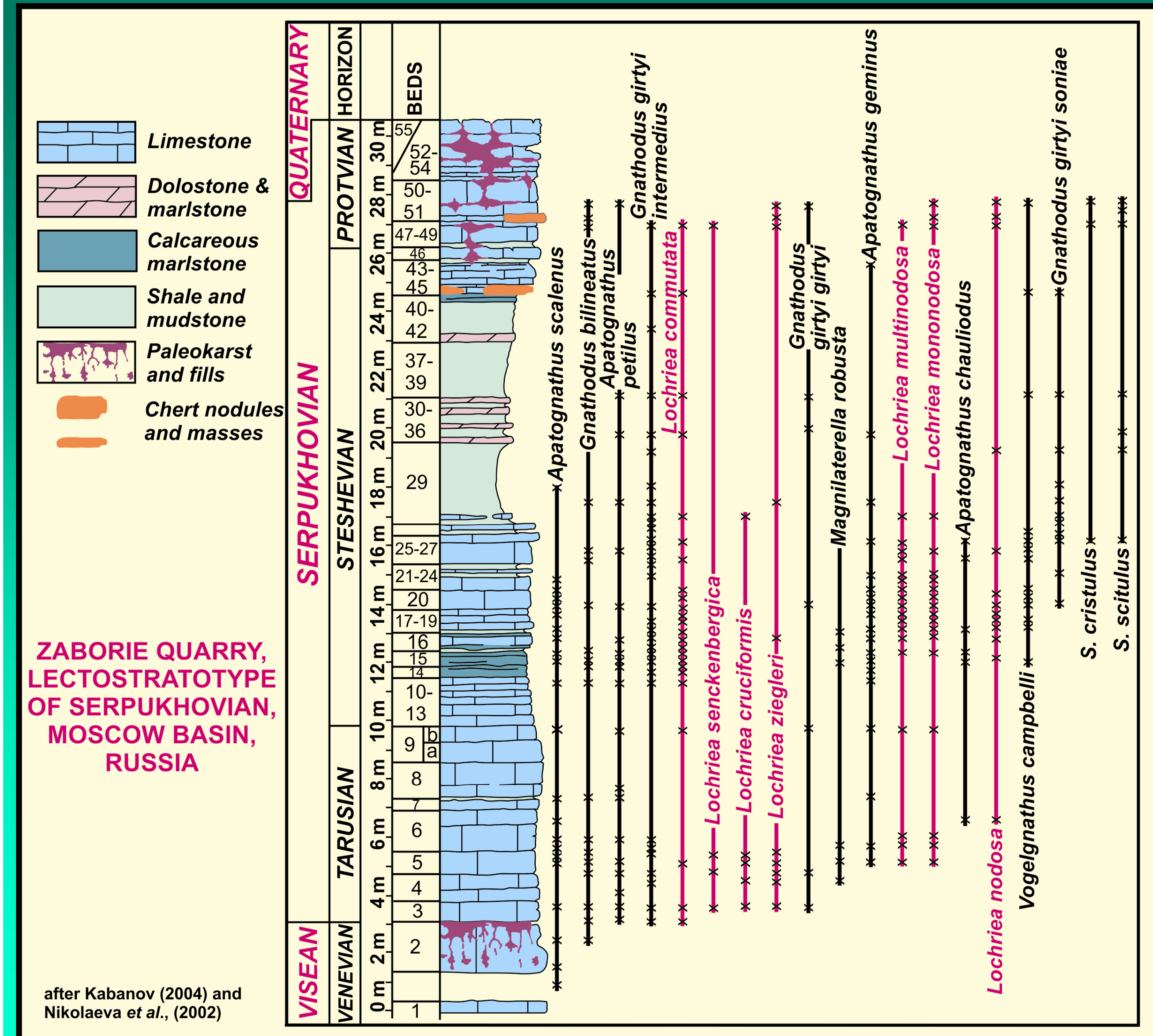
Fig. 6: *Lochriea monocostata*

Fig, 10: *Lochriea commutata*

For boundary definition, the Viséan/Serpukhovian task group thinks the first appearance of the conodont *Lochriea ziegleri* in lineage *L. nodosa* to *L. ziegleri* is the best option.

Lochriea* is currently considered to be a senior synonym of *Paragnathodus

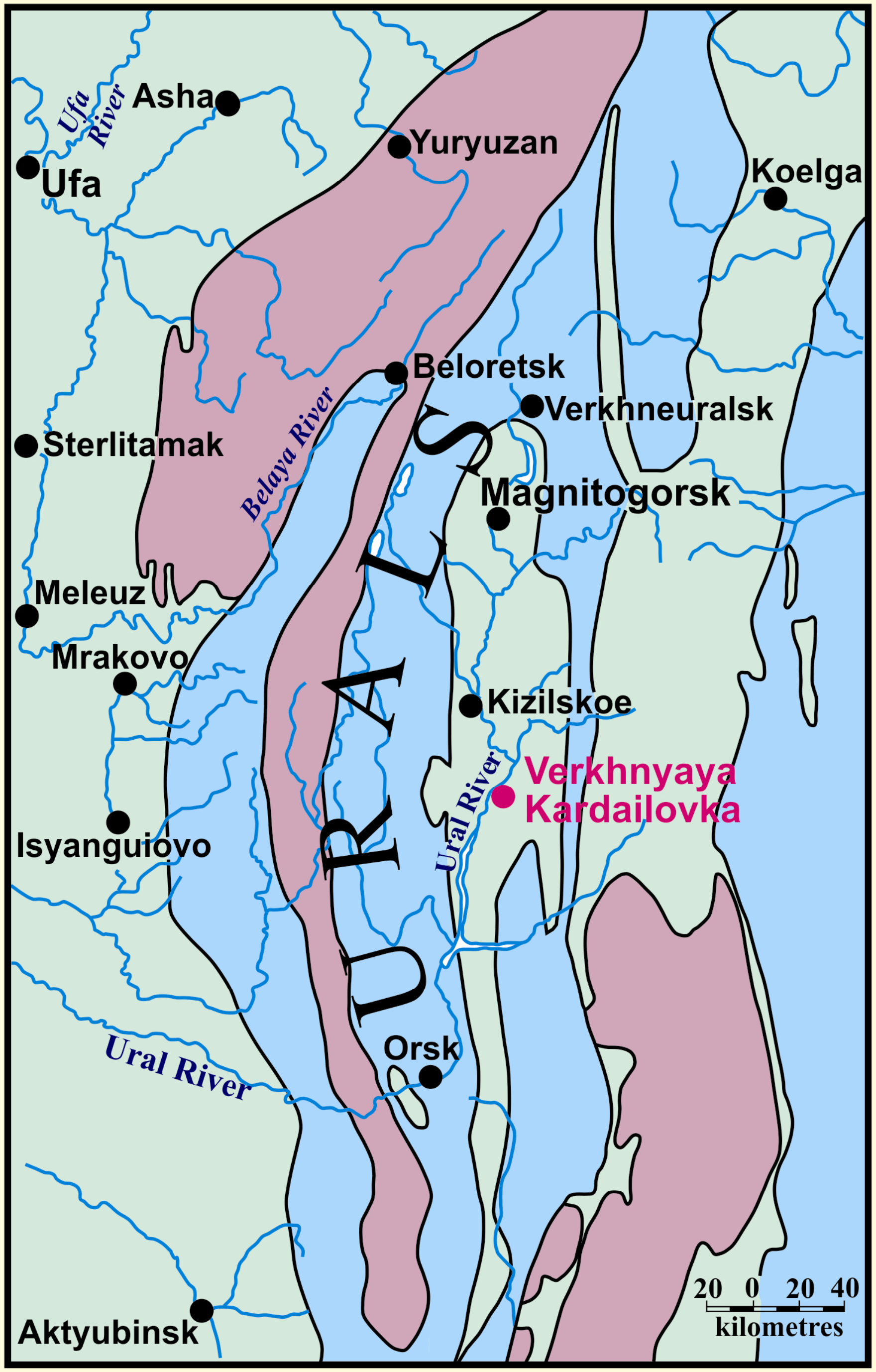
from Skompski *et al*. (1995)



RANGES OF CONODONTS IN THE ZABORIE QUARRY, LECTOSTRATOTYE OF THE SERPUKHOVIAN

The figure shows that *Lochriea ziegleri* appears near the base of the lectostratotype of the Serpukhovian along with *L. nodosa.* This is not a first evolutionary appearance and *L. ziegleri* has been found slightly lower in the nearby Novogurovskii quarry.

MAP SHOWING LOCATION OF VERKHNYAYA KARDAILOVKA SECTION ON SOUTHEAST FLANK OF SOUTHERN URAL MOUNTAINS, RUSSIA



Pre-Paleozoic and metamorphic rocks

Pre-Carboniferous Paleozoic rocks

Carboniferous and younger rocks

1. The Verkhnyaya Kardailovka section is one of the two best candidate sections for the GSSP at the base of the Serpukhovian.

2. The succession was deposited in in the Magnitogorsk-Bogdanovsk Graben at water depths ranging from shallow neritic to deep water.

3. The boundary interval is dominated by deep-water, nodular, skeletal lime mudstone and wackestone containing abundant ammonoids

after Nikolaeva *et al.*, 2001

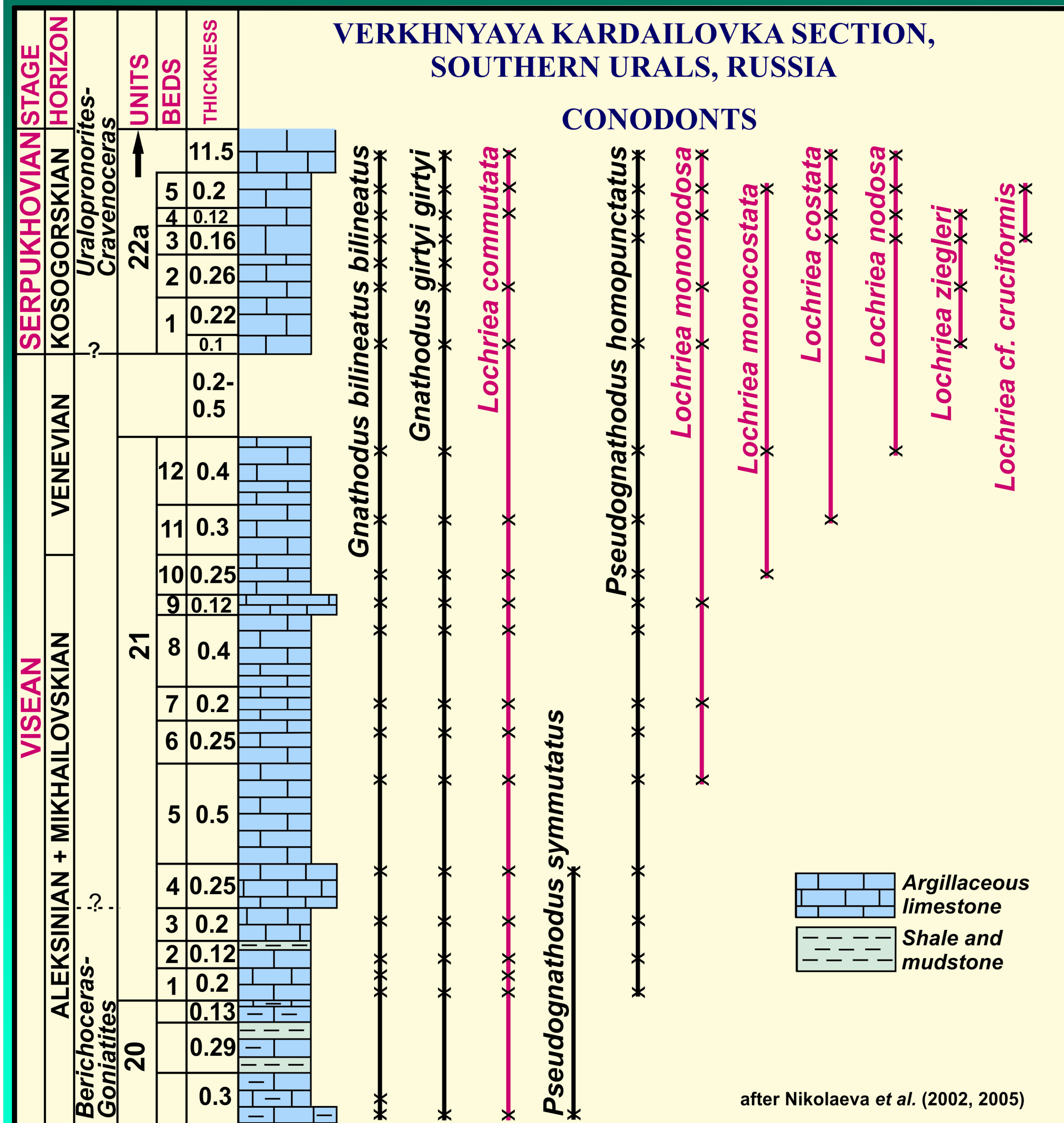
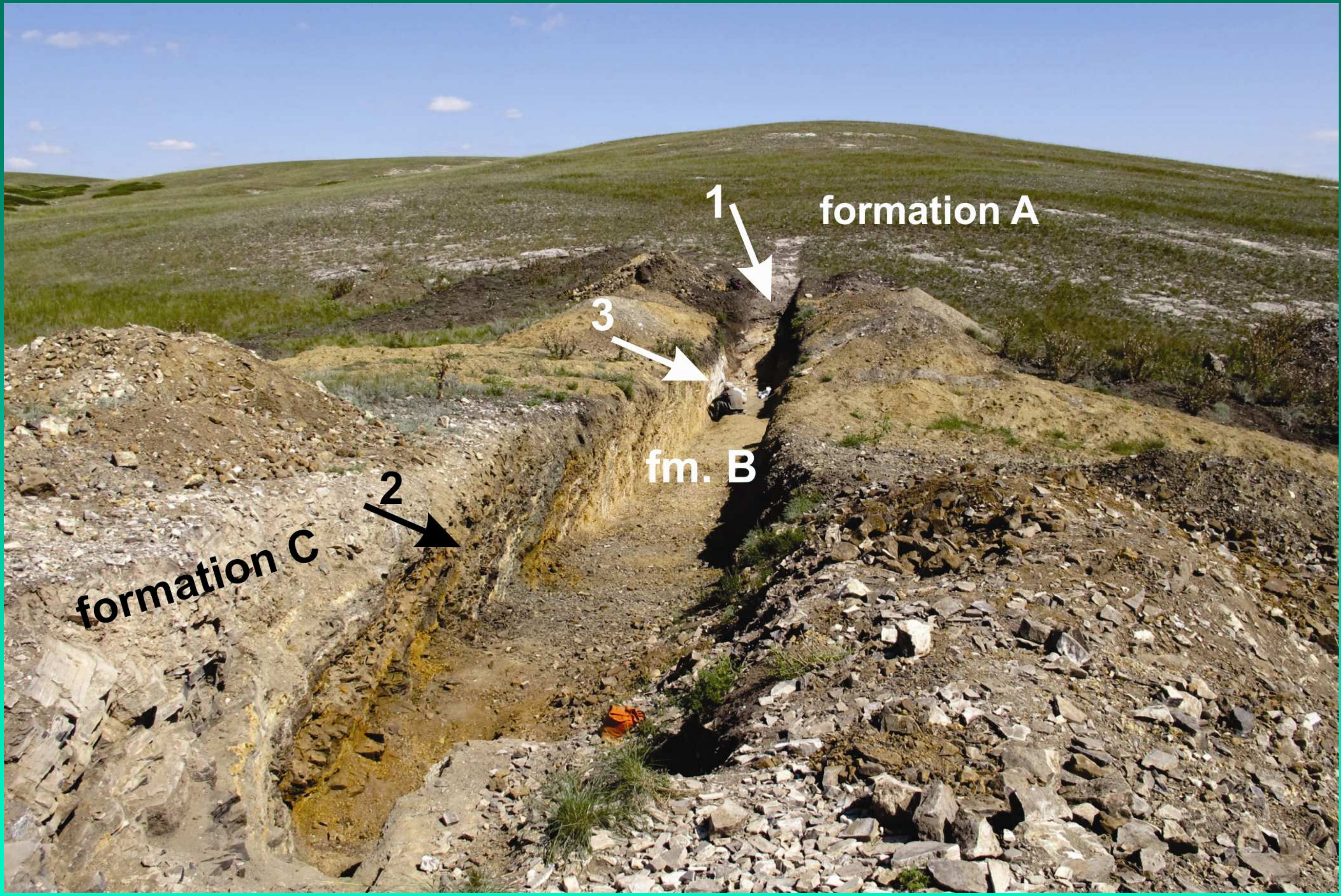


CHART SHOWING DISTRIBUTION OF CONODONTS AT LEVEL OF THE VISÉAN-SERPUKHOVIAN BOUNDARY IN THE VERKHNYAYA KARDAILOVKA SECTION

Section contains abundant conodonts and ammonoids; foraminifers occur but are not abundant.

Lochriea nodosa **appears below** ***L. ziegleri*** **and** ***L. cruciformis*** **appears slightly higher.**

At this location, the Viséan/Serpukhovian boundary is currently placed at first appearance of ***L. ziegleri*** **in an unnamed limestone-dominated formation called formation C.**



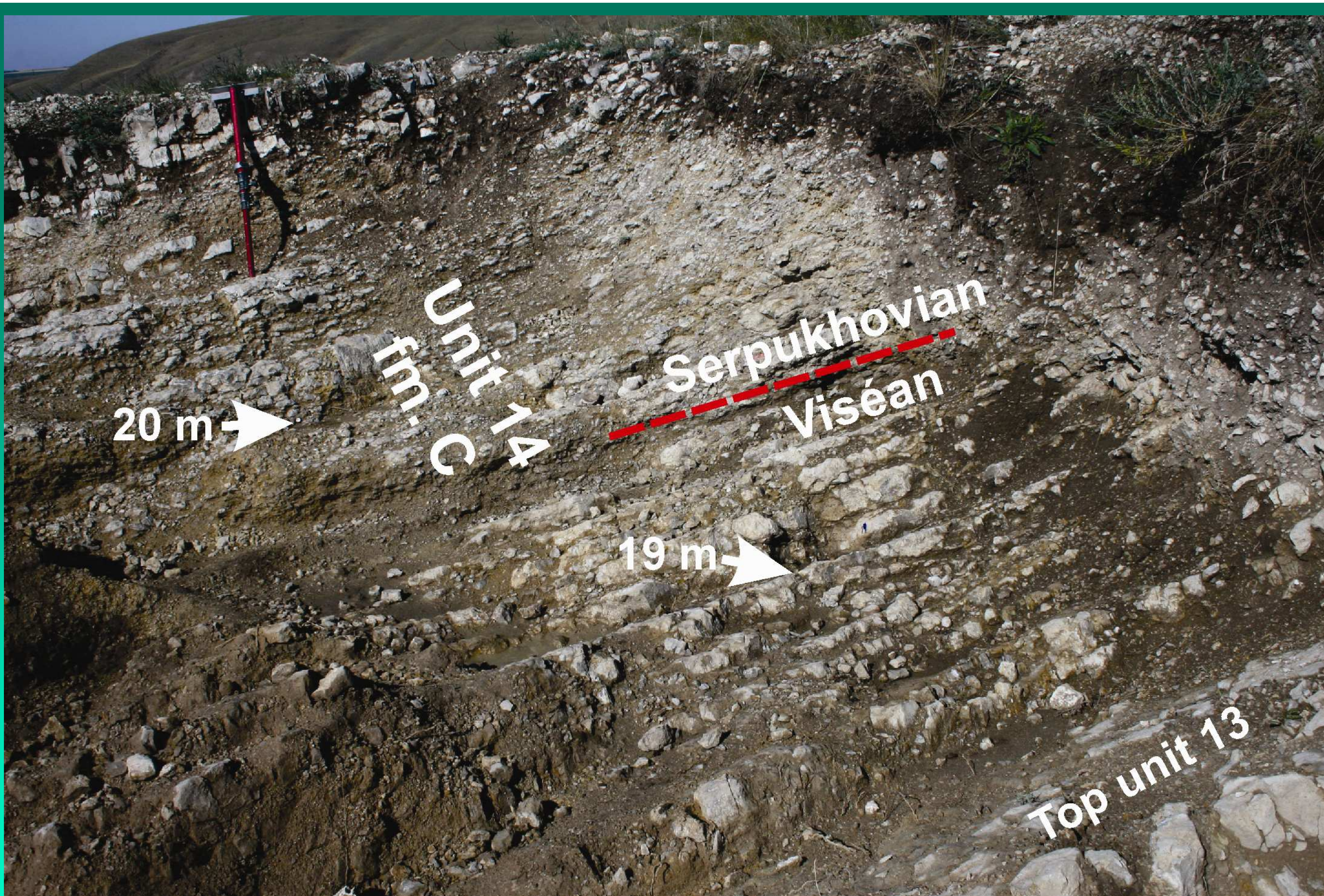
Lower part of the Verkhnyaya Kardailovka section showing middle and Upper Viséan volcanics siliciclastics, and carbonates exposed during recent excavations. Arrow 1 indicates top of the middle Viséan crinoidal limestone unit of formation A. Formation B is dominated by volcanic ash, tuffaceous siltstone and mudstone. Limestone of lower formation C is exposed at the lower left (arrow 2 indicates base). People (arrow 3) in trench provide scale.

VISÉAN-SERPUKHOVIAN AMMONOIDS FROM VERKHNYAYA KARDAILOVKA SECTION ON URAL RIVER, SOUTH URALS, RUSSIA

The Viséan/Serpukhovian boundary task group started to evaluate the FAD of *L. ziegleri* for boundary definition in 2003 at the XVICCP in Utrecht.

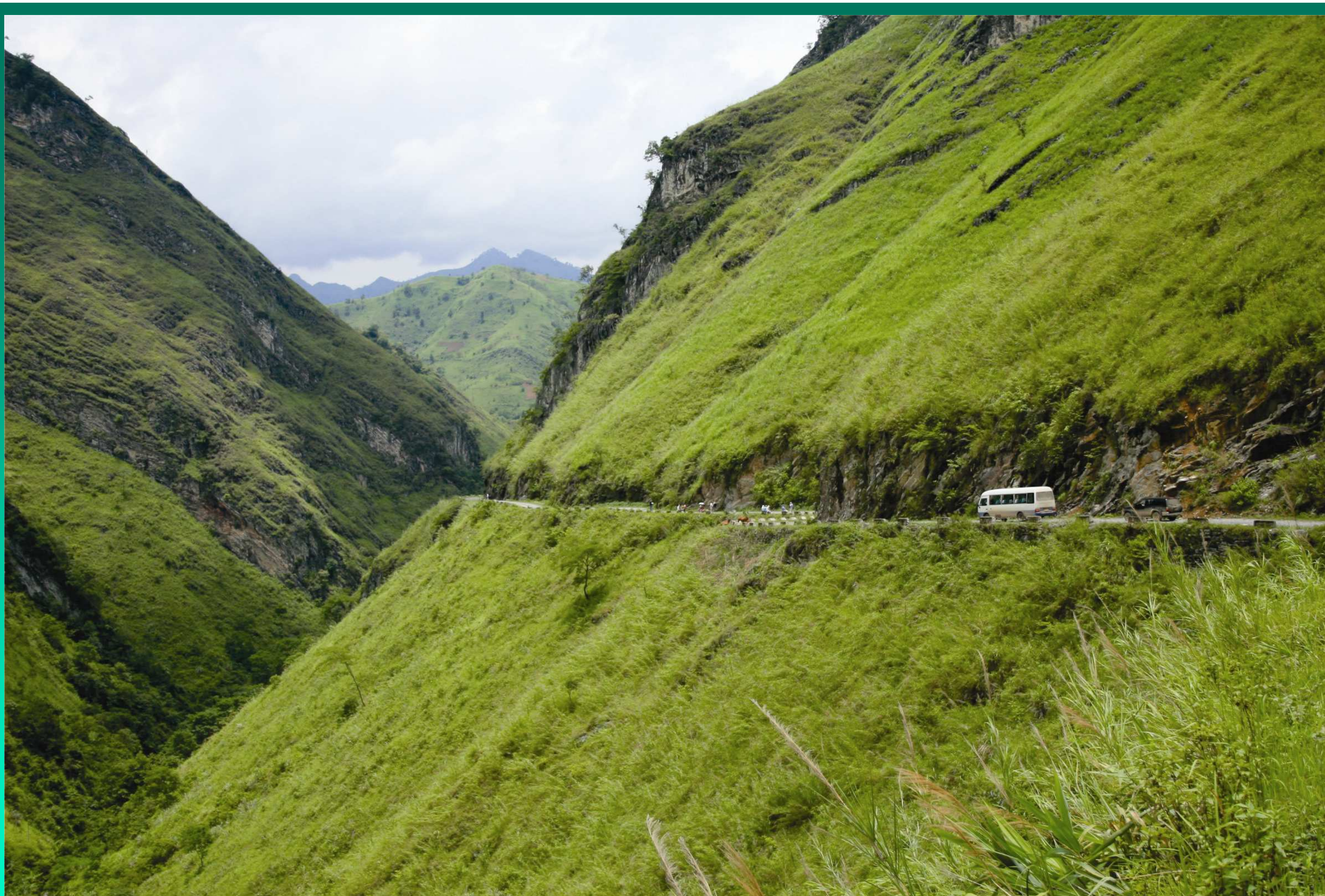
Prior to 2003, the Viséan-Serpukhovian boundary was traditionally placed at the base of beds containing the ammonoids *Cravenoceras* and /or *Edmooroceras pseudocoronula.*

From Nikolaeva *et al*., (2009)

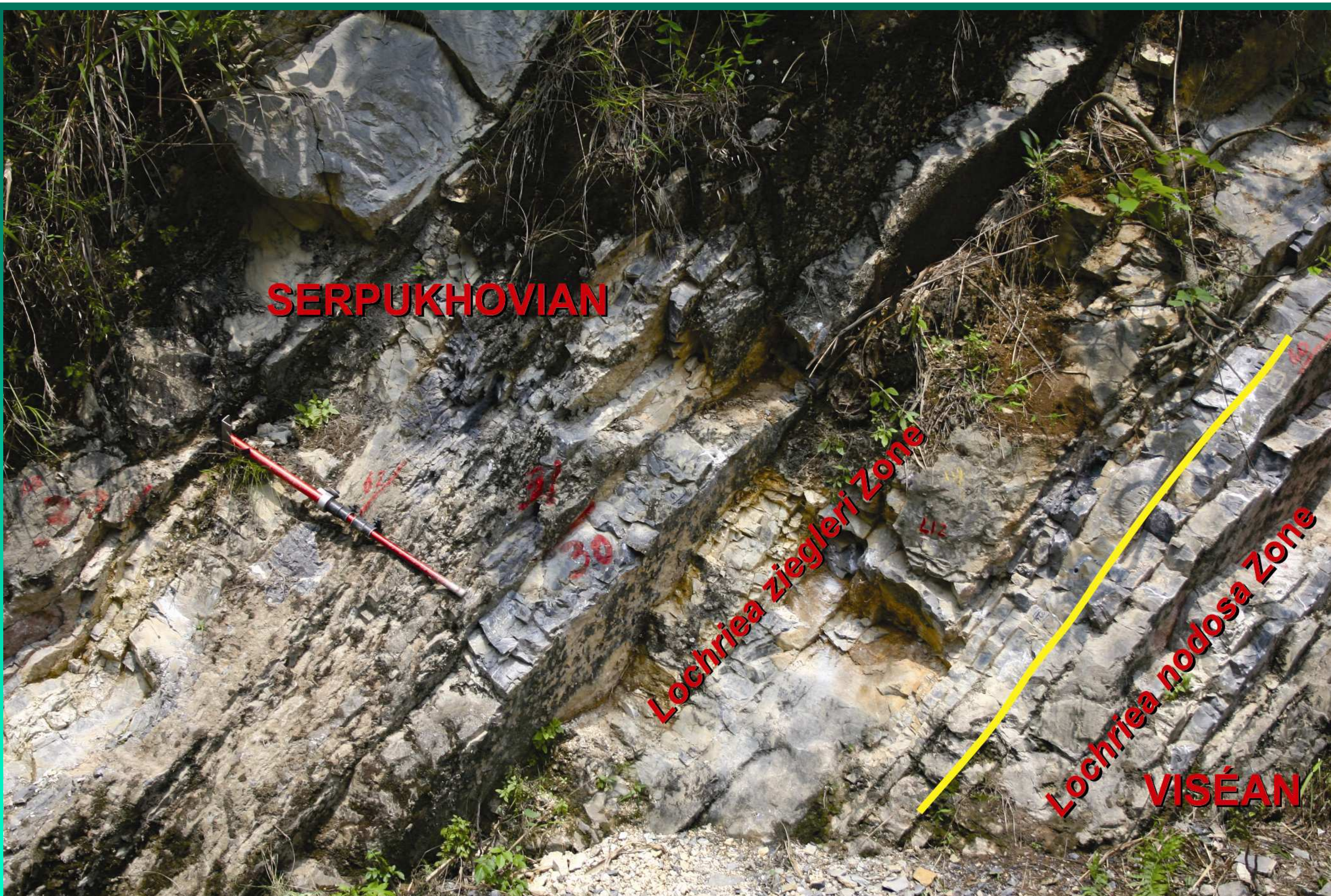


Viséan-Serpukhovian boundary level in unnamed formation C of the Verkhnyaya Kardailovka section in the South Urals, Russia. Succession comprises stylonodular, skeletal lime mudstone and wackestone of deep-water basin origin and contains several ammonoid horizons. The 19 m and 20 m arrows point to aluminum pins used to mark section and give stratigraphic position above the base of the section. One metre-long Jacob's staff at upper left provides scale.

Location of Nashui section in southern Guizhou Province, S. China. This is another of the numerous Eurasian section that preserve the *Lochriea nodosa* to *L. ziegleri* lineage and is one of the two best candidate sections for the GSSP at the base of the Serpukhovian if the *Lochriea* lineage is used for boundary definition.



Mountains of southern Guizhou Province, south China showing Carboniferous strata deposited on the south China Block. Exposures along the road contain the Nashui (Naqing) section, a succession of basin- to middle- slope carbonates extending from the upper Viséan into the Lower Permian without significant structural breaks. The section includes one of the two best candidate sections being considered for the GSSP at the base of the Serpukhovian Stage.



Basin to lower-carbonate-slope deposits (turbidites and nodular thin-bedded basin facies) in Nashui section at level of Viséan-Serpukhovian Boundary (17.94 m above base of section).

BASE OF PENNSYLVANIAN SUBSYSTEM AND BASHKIRIAN STAGE

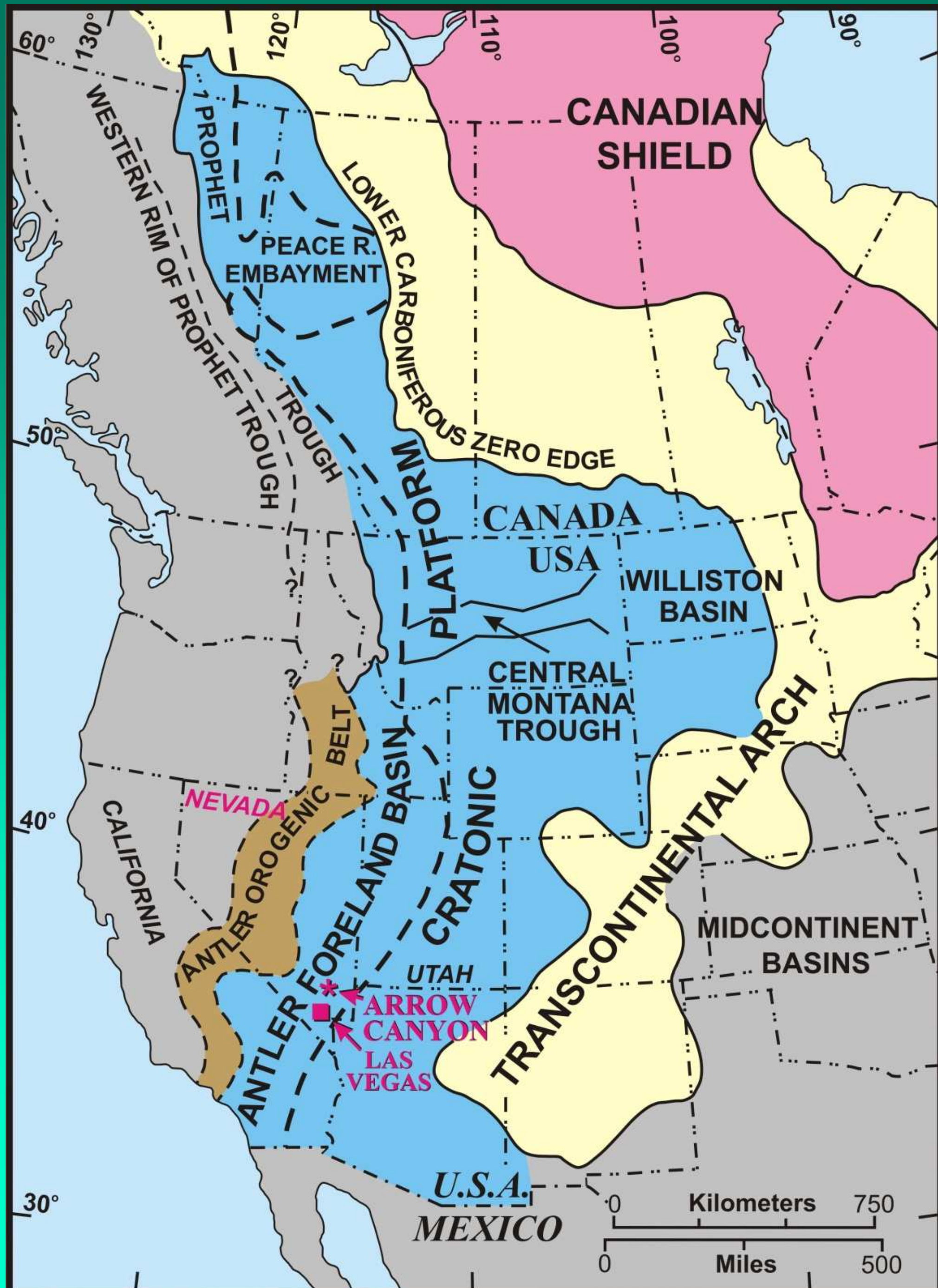
SYSTEM	SUBSYSTEM	SERIES	STAGE	AGE Ma
			GSSP	298.9 ± 0.2
CARBONIFEROUS	PENNSYLVANIAN 24.3 Myr	UPPER	Gzhelian 4.8 Myr	303.7 ± 0.1
			Kasimovian 3.3 Myr	307.0 ± 0.2
		MIDDLE	Moscovian 8.2 Myr	315.2 ± 0.2
		LOWER	Bashkirian 8 MYr	
			GSSP	323.2 ± 0.4
	MISSISSIPPIAN 35.7 Myr	UPPER	Serpukhovian 7.7 Myr	330.9 ± 0.3
		MIDDLE	Viséan 15.8 Myr	
			GSSP	346.7 ± 0.4
		LOWER	Tournaisian 12.2 Myr	358.9 ± 0.4

GLOBAL CARBONIFEROUS DIVISIONS

from Heckel (2004) and Heckel and Clayton (2006)

Divisions are the result of ballots taken by SCCS in 2003 and ratified by ICS and IUGS in 2004; ages from GTS 2012 and ICS chart developed for 34th IGC

The next 5 slides discuss and illustrate the GSSP at the base of the Bashkirian Stage, which is also the base of the Pennsylvanian Subsystem and Lower Pennsylvanian Series. The base is defined by a GSSP at Arrow Canyon in southern Nevada, U.S.A.



MAP OF SOUTHWESTERN NORTH AMERICA SHOWING MAIN CARBONIFEROUS TECTONIC ELEMENTS AND DISTRIBUTION OF CARBONIFEROUS STRATA

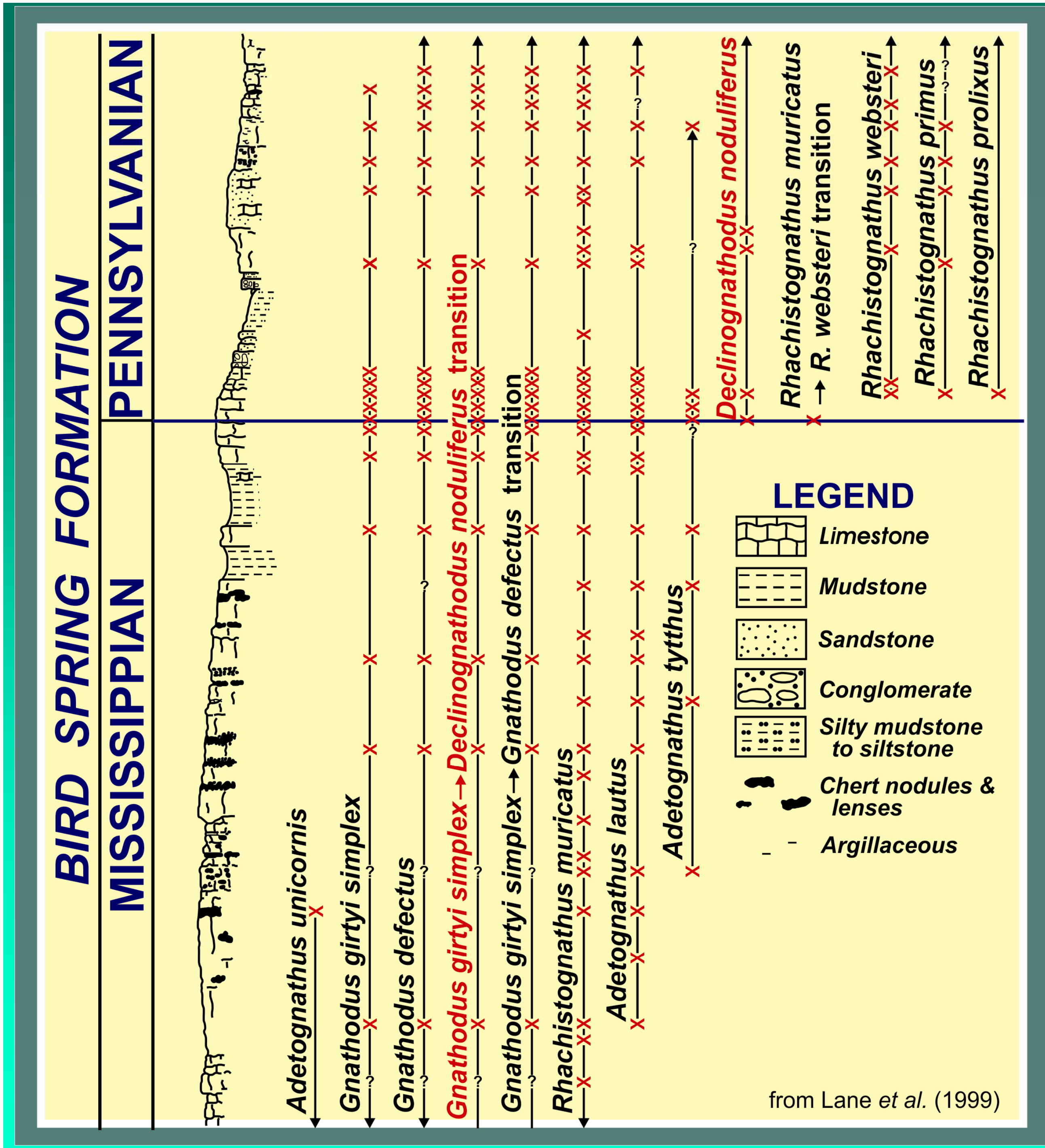
The map shows location of the GSSP for the base of the Pennsylvanian at Arrow Canyon in southern Nevada, U.S.A.

CARBONIFEROUS STRATA

LOWER PALEOZOIC STRATA

PRECAMBRIAN ROCKS

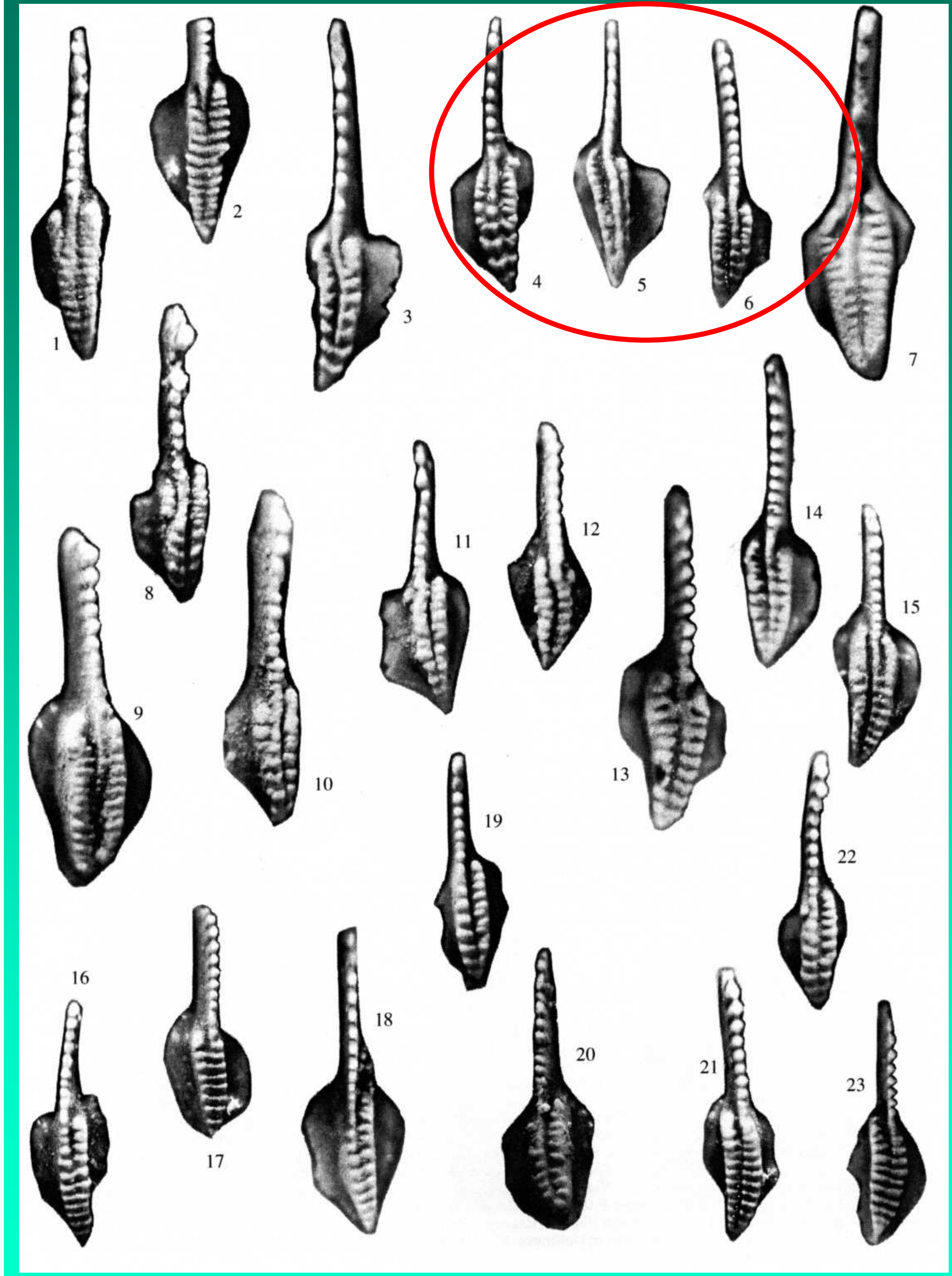
from Lane *et al.* (1999)



SIMPLIFIED VERSION OF SECTION CONTAINING MID-CARBONIFEROUS BOUNDARY GSSP AT ARROW CANYON, NEVADA

Figure shows established occurrences of the most important conodonts at the boundary level.

The GSSP for the base of the Pennsylvanian (base Bashkirian Stage) is defined by the first evolutionary occurrence of the conodont *Declinognathodus noduliferous* s.l. in the chronocline *Gnathodus girtyi simplex* – *D. noduliferous* (Lane *et al*., 1999)



CONODONTS FROM THE BASHKIRIAN STAGE IN THE SOUTHERN URALS

Plate shows several species of *Declinognathodus,* including *D. inaequalis* [elements 4-6, 14] and *Idiognathodes* (from Kulagina *et al*. (2000).

When *D. noduliferus s.l.* was chosen as the index at the 10th International Congress of Carboniferous Geology and Stratigraphy in Madrid (1983), the taxon included the subspecies *D. noduliferus noduliferus*, *D. noduliferus inaequalis*, and *D. noduliferus japonicus*.

Several conodont experts now separate the subspecies into discrete species.

Many biostratigraphers currently use the FAD of *D. noduliferus inaequalis* (*D. inaequalis*) for boundary definition because the lowest occurrence of *Declinognathodus* in the bed containing the GSSP at Arrow Canyon is *D. noduliferus inaequalis* (Nemyrovska *et al*., 2011).

Section containing the mid-Carboniferous boundary GSSP (Serpukhovian-Bashkirian boundary) at Arrow Canyon, Nevada, USA. The GSSP lies in the limestone bed indicated by the arrow behind the girl. The limestone unit containing the boundary interval is overlain by Bashkirian peritidal and continental siliciclastics.

Photograph of the Askyn section, which is the hypostratotype of the Bashkirian Stage. Section is situated about 100 km southeast of the city of Ufa in the southern Urals of Russia. The section is on the bank of the Askyn River near Solontsy village and preserves both the Serpukhovian-Bashkirian and Bashkirian-Moscovian boundaries. The Bashkirian stratotype is on the Yuruzan River in Russia but at that section the Bashkirian-Moscovian boundary is not exposed. The Bashkirian Stage was proposed by Semikhatova (1934).

BASE OF THE MOSCOVIAN STAGE AND MIDDLE PENNSYLVANIAN SERIES

SYSTEM	SUBSYSTEM	SERIES	STAGE	AGE Ma
CARBONIFEROUS	PENNSYLVANIAN (24.3 Myr)	UPPER	GSSP	298.9 ± 0.2
			Gzhelian 4.8 Myr	303.7 ± 0.1
			Kasimovian 3.3 Myr	307.0 ± 0.2
		MIDDLE	Moscovian 8.2 Myr	315.2 ± 0.2
		LOWER	Bashkirian 8 MYr	323.2 ± 0.4
	MISSISSIPPIAN (35.7 Myr)	UPPER	GSSP Serpukhovian 7.7 Myr	330.9 ± 0.3
		MIDDLE	Viséan 15.8 Myr	346.7 ± 0.4
		LOWER	GSSP Tournaisian 12.2 Myr	358.9 ± 0.4

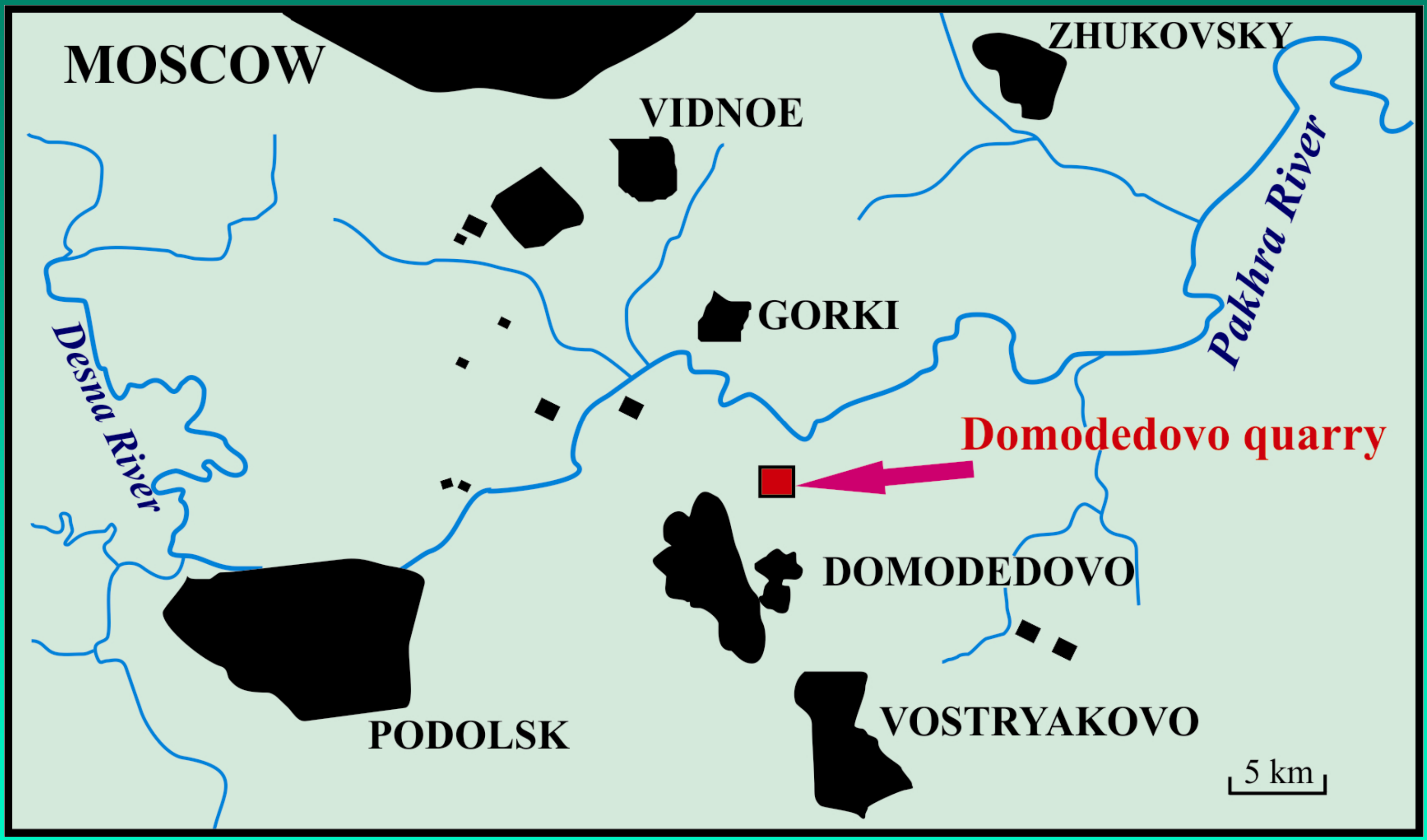
GLOBAL CARBONIFEROUS DIVISIONS

from Heckel (2004) and Heckel and Clayton (2006)

Divisions are the result of ballots taken by SCCS in 2003 and ratified by ICS and IUGS in 2004; ages from GTS 2012 and ICS chart developed for 34th IGC

The next 5 slides discuss and illustrate the base of the Moscovian Stage, which is also the base of the Middle Pennsylvanian Series. The base of the Moscovian has not been defined by a GSSP and the index for the boundary has not been chosen. Chairman – Alexander S. Alekseev (Russian Federation).

MAP SHOWING LOCATION OF THE DOMODEDOVO QUARRY, LOCATION OF THE NEOSTRATOTYPE OF THE MOSCOVIAN STAGE



The historical stratotype of the Moscovian Stage was in a large quarry on the Moscow River by village of Myachkovo southeast of Moscow that does not exist now because of urban development. Succession in Domodedovo quarry was deposited in the Moscow Basin. The Moscovian Stage was formally proposed by Nikitin (1890).

Typical exposure of the limestone-dominated upper Moscovian and lower Kasimovian succession in the Domodedovo quarry, location of the neostratotype of the Moscovian Stage, Moscow Basin, Russia.

CONODONTS AND FUSULINOIDEANS ARE BEING INVESTIGATED AS EVENT MARKERS FOR BASE OF MOSCOVIAN

CONODONT PROPOSAL

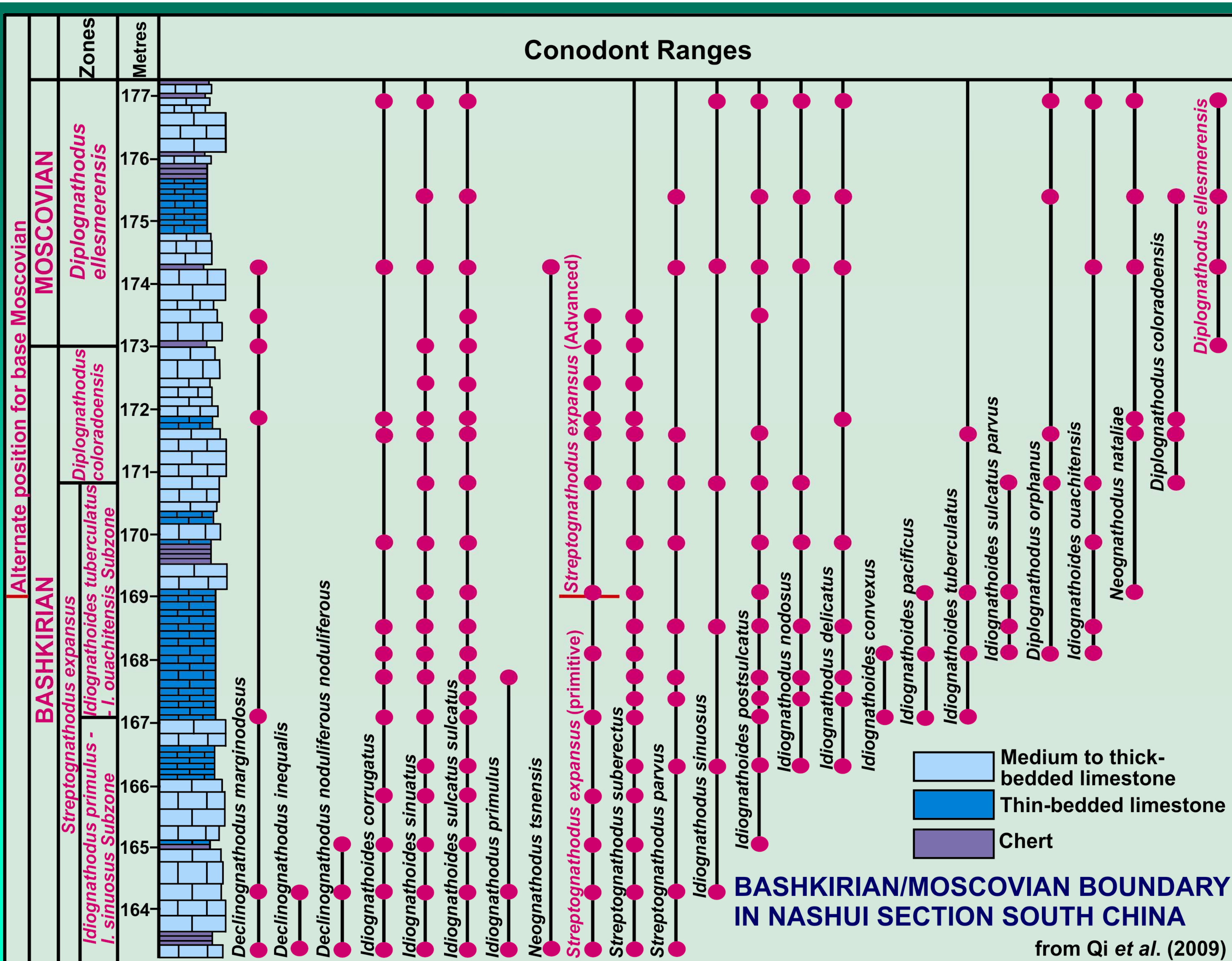
Several conodonts have been proposed as potential indices for the GSSP but only *Diplognathodus ellesmerensis* and *Declinognathodus donetzianus* have received substantial support from the task-group.

Data from the Nashui (Naqing) section in South China indicate that the FAD of *D. ellesmerensis* in the lineage *Diplognathodus coloradoensis–D. ellesmerensis* is one of the best potential boundary markers. *D. ellesmerensis* is easy to identify, the species has been recognized in China, Russia, North America, and it occurs in the lowermost Moscovian in the type Moscovian area.

The FAD of *D. donetzianus* has long been consider as a potential index but its apparent absence in North American prevented it from being an ideal candidate. Work *et al*. (2012) recently found the species in the Appalachian Basin, U.S.A.

FUSULINOIDEAN PROPOSAL

John Groves (former chairman of Bashkirian-Moscovian boundary task group) and several other task-group members recently developed a proposal to mark the base of the Moscovian using the FAD of the fusulinoidean genus *Eofusulina* in evolutionary continuity with its ancestor *Verella*. The level is the lowest occurrence of a fusulinoidean exhibiting septal fluting across the entire length of its shell. A concern is that there are relatively few sections in which the *Verella–Eofusulina* transition can be documented with closely spaced sampling.



BASHKIRIAN/MOSCOVIAN BOUNDARY IN NASHUI SECTION SOUTH CHINA

from Qi *et al.* (2009)

Bashkirian and Moscovian component of the Nashui section is dominated by fine-grained skeletal lime mudstone and wackestone but there are widely spaced coarse beds. Photo shows carbonate debris-flow deposits in Bashkirian strata of Nashui section at 116.78 – 118.45 m above base section. Jacob's staff is one metre long.

BASE OF KASIMOVIAN STAGE AND UPPER PENNSYLVANIAN SERIES

SYSTEM	SUBSYSTEM	SERIES	STAGE	AGE Ma
			GSSP	298.9 ± 0.2
CARBONIFEROUS	PENNSYLVANIAN	UPPER	Gzhelian 4.8 Myr	303.7 ± 0.1
			Kasimovian 3.3 Myr	307.0 ± 0.2
		MIDDLE	Moscovian 8.2 Myr	315.2 ± 0.2
	24.3 Myr	LOWER	Bashkirian 8 MYr	323.2 ± 0.4
			GSSP	
	MISSISSIPPIAN	UPPER	Serpukhovian 7.7 Myr	330.9 ± 0.3
		MIDDLE	Viséan 15.8 Myr	346.7 ± 0.4
			GSSP	
	35.7 Myr	LOWER	Tournaisian 12.2 Myr	358.9 ± 0.4

GLOBAL CARBONIFEROUS DIVISIONS

from Heckel (2004) and Heckel and Clayton (2006)

Divisions are the result of ballots taken by SCCS in 2003 and ratified by ICS and IUGS in 2004; ages from GTS 2012 and ICS chart developed for 34th IGC

The next 4 slides discuss and illustrate the base of the Kasimovian Stage, which is also the base of the Upper Pennsylvanian Series. The base of the Kasimovian has not been defined by a GSSP and the index for the boundary has not been chosen. Chairman – Katsumi Ueno (Japan).

MAP SHOWING LOCATION OF AFANASIEVO QUARRY THE LOCATION OF THE NEOSTRATOTYPE OF THE GLOBAL KASIMOVIAN STAGE

The Moscovian and Kasimovian strata exposed in the quarry lies within the Moscow Basin.

It is the only section in the region where Krevyakinian and Khamovnikian regional substages are accessible and for that reason the section was selected by Makhlina *et al*. (2001) as the neostratotype.

The succession was deposited under influence of glacio-eustatic sea-level fluctuations and main lithological units are separated by paleosols and other stratigraphic breaks.

Slide shows the Moscovian-Kasimovian Stage boundary in the Afanasievo quarry (location of neostratotype of Kasimovian Stage), Moscow Basin near Moscow. The two species of conodont that currently show the best potential for defining the boundary are *Idiognathodus sagittalis* and *Idiognathodus turbatus*. Photograph courtesy Alexander Alekseev.

CONODONTS FROM THE AFANASIEVO QUARRY.

Plate shows several species of *Streptognathodus* and *Idiognathodus* including *I. sagittalis* (specimen M) and *I. turbatus* (specimens L & O), two species that have good potential for defining the Global Moscovian-Kasimovian Stage boundary (from Alekseev *et al*. (2009).

The use of either *Idiognathodus sagittalis* or *Idiognathodus turbatus* as a boundary index would make it necessary to move the base of the Kasimovian up about one substage higher than the traditional base of the Kasimovian - at the base of the Krevyakinian Substage

Photograph showing the Kasimovian and Gzhelian succession in the Nashui section in southern Guizhou Province, South China. This is one of sections being considered as a candidate for the GSSP at base of the Kasimovian. A proposal to use FAD of *Idiognathodus turbatus* is being developed using specimens from the section. The transition from its ancestor *Idiognathodus swadei* is continuous and FAD of *I. turbatus* has been precisely located. The section is dominated by skeletal limestone of slope origin.

BASE OF GZHELIAN STAGE

SYSTEM	SUBSYSTEM	SERIES	STAGE	AGE Ma
			GSSP	298.9 ± 0.2
CARBONIFEROUS	PENNSYLVANIAN	UPPER	Gzhelian 4.8 Myr	303.7 ± 0.1
			Kasimovian 3.3 Myr	307.0 ± 0.2
		MIDDLE	Moscovian 8.2 Myr	315.2 ± 0.2
	24.3 Myr	LOWER	Bashkirian 8 MYr	323.2 ± 0.4
	MISSISSIPPIAN	UPPER	GSSP Serpukhovian 7.7 Myr	330.9 ± 0.3
		MIDDLE	Viséan 15.8 Myr	346.7 ± 0.4
	35.7 Myr	LOWER	GSSP Tournaisian 12.2 Myr	358.9 ± 0.4

GLOBAL CARBONIFEROUS DIVISIONS

from Heckel (2004) and Heckel and Clayton (2006)

Divisions are the result of ballots taken by SCCS in 2003 and ratified by ICS and IUGS in 2004; ages from GTS 2012 and ICS chart developed for 34th IGC

The next 5 slides discuss and illustrate the base of the Gzhelian Stage, which is also the upper stage of the Upper Pennsylvanian Series. Base of Gzhelian has not been defined by a GSSP but the index for the boundary has been chosen and is the conodont *Idiognathodus simulator*. Chairman of Task Group – Katsumi Ueno (Japan).

GZHEL QUARRY THE LOCATION OF THE HISTORICAL STRATOTYPE OF THE GLOBAL GZHELIAN STAGE.

The Gzhelian strata exposed in the Gzhel quarry lies within the Moscow Basin.

The Gzhelian Stage was named by Nikitin in 1890.

A GSSP for base of Gzhelian has not been selected but the FAD of the conodont *Idiognathodus simulator* has been selected for boundary definition.

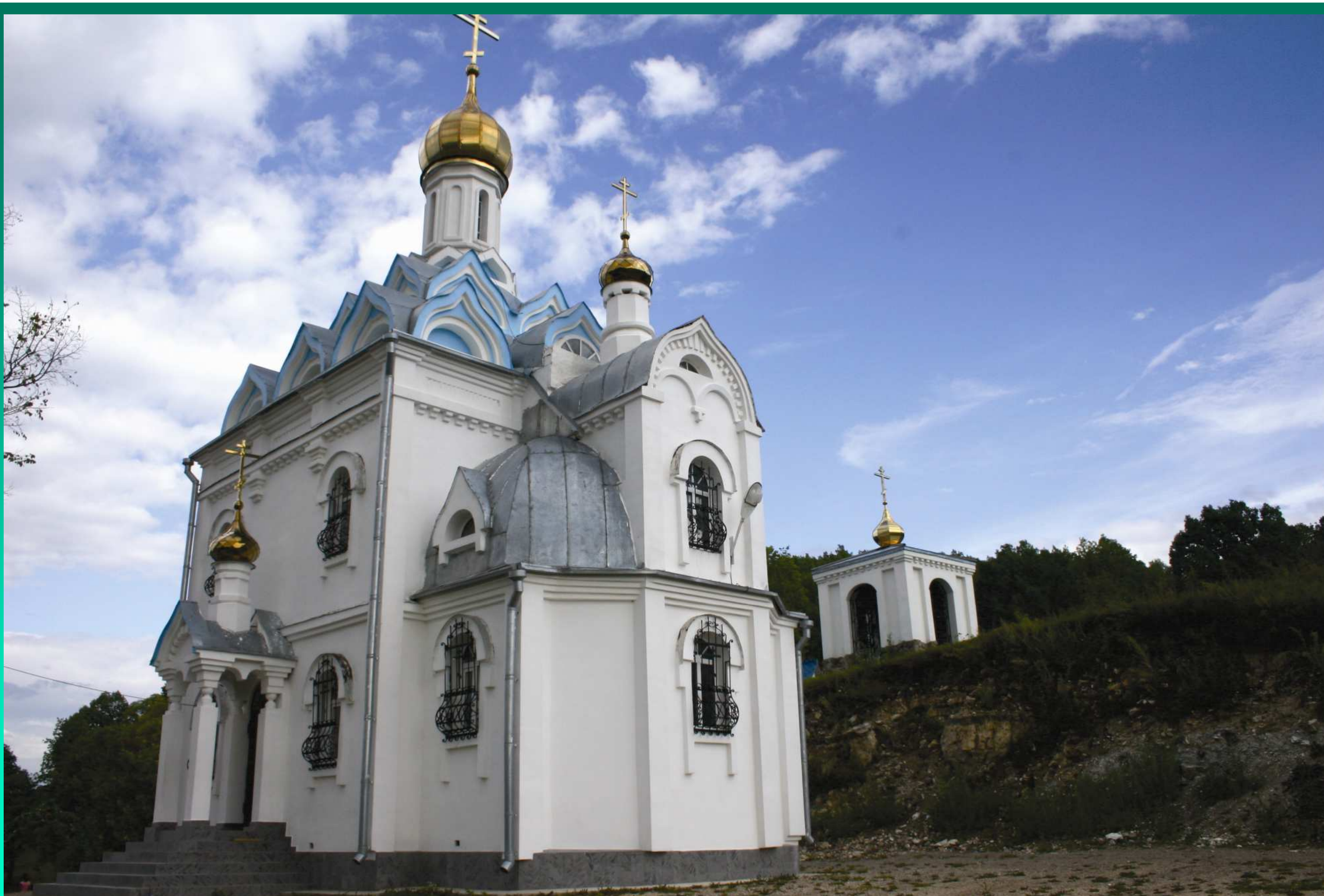
The probable ancestor for *I. simulator* is *Idiognathodus eudorensis* Barrick, Heckel and Boardman (2008).

Photograph showing remnants of the Gzhel quarry, Moscow Basin. This small exposure is the historical stratotype of the Global Gzhelian Stage. Starting at the base, the stage has been divided into four regional substages: Dobryatinian, Pavlovoposadian, Noginskian and Melekhovian. Only the lower part of the stage is currently exposed at the quarry, which has been abandoned and largely reclaimed.

CONODONTS FROM THE GZHEL QUARRY

The plate shows several specimens (Figs. 1-7, 9, 10, 12-15) of *Idiognathodus* ex gr. *I. simulator* and elements (Figs. 8, 11) of *Idiognathodus simulator*, the species used to define the base of the Gzhelian.

from Alekseev *et al*. (2009).



Several candidate sections are being investigated for the GSSP at the base of the Gzhelian. To date, only the Usolka section in the southern Urals of Russia by this church has been formally proposed (Chernykh *et al*., 2006; Davydov *et al*., 2008) as a potential candidate.

The Usolka section in southern Urals of Russia showing Gzhelian to Lower Permian turbidites. The Kasimovian-Gzhelian boundary lies to the right of the exposure and was largely covered when a team of SCCS members visited the locality in 2009. Since 2009, the locality has been extensively excavated and is being restudied.

TOP OF CARBONIFEROUS SYSTEM AND BASE OF PERMIAN SYSTEM

SYSTEM	SUBSYSTEM	SERIES	STAGE	AGE Ma
			GSSP	298.9 ± 0.2
CARBONIFEROUS	PENNSYLVANIAN 24.3 Myr	UPPER	Gzhelian 4.8 Myr	303.7 ± 0.1
			Kasimovian 3.3 Myr	307.0 ± 0.2
		MIDDLE	Moscovian 8.2 Myr	315.2 ± 0.2
		LOWER	Bashkirian 8 MYr	323.2 ± 0.4
			GSSP	
	MISSISSIPPIAN 35.7 Myr	UPPER	Serpukhovian 7.7 Myr	330.9 ± 0.3
		MIDDLE	Viséan 15.8 Myr	346.7 ± 0.4
			GSSP	
		LOWER	Tournaisian 12.2 Myr	358.9 ± 0.4

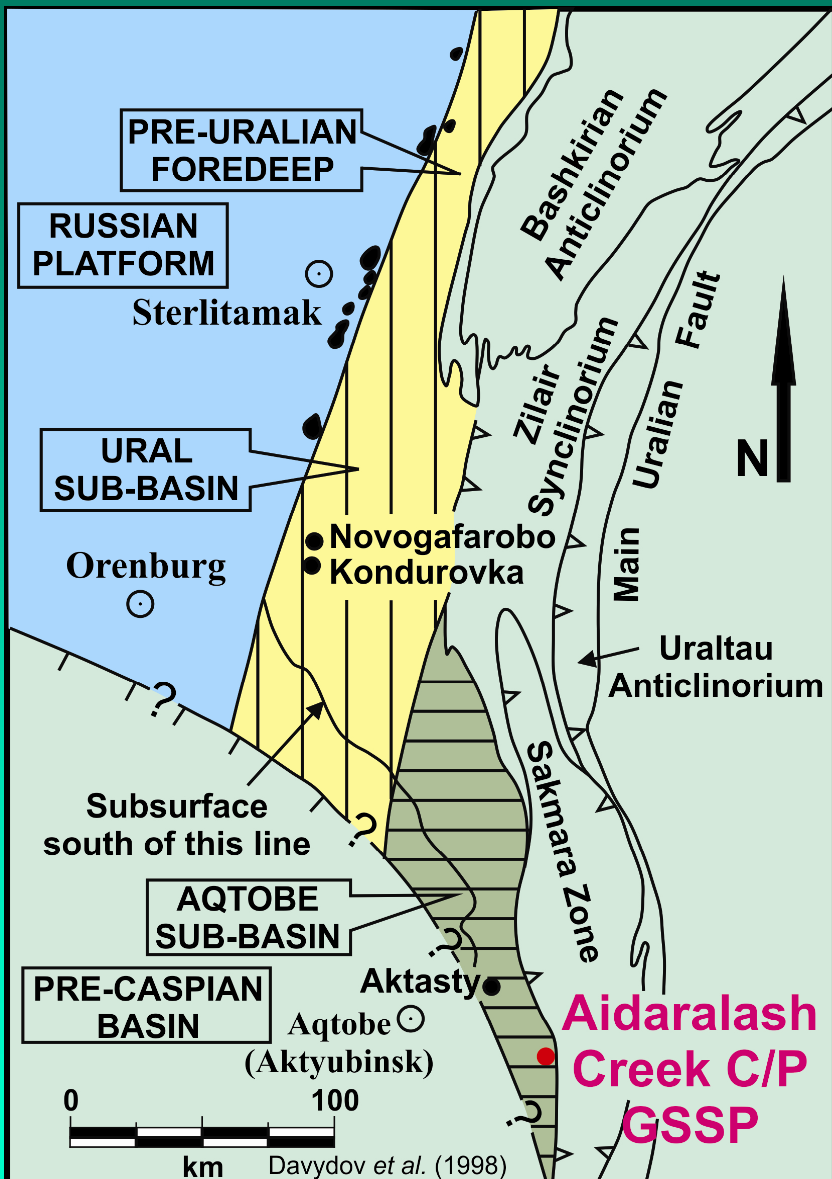
GLOBAL CARBONIFEROUS DIVISIONS

from Heckel (2004) and Heckel and Clayton (2006)

Divisions are the result of ballots taken by SCCS in 2003 and ratified by ICS and IUGS in 2004; ages from GTS 2012 and ICS chart developed for 34th IGC

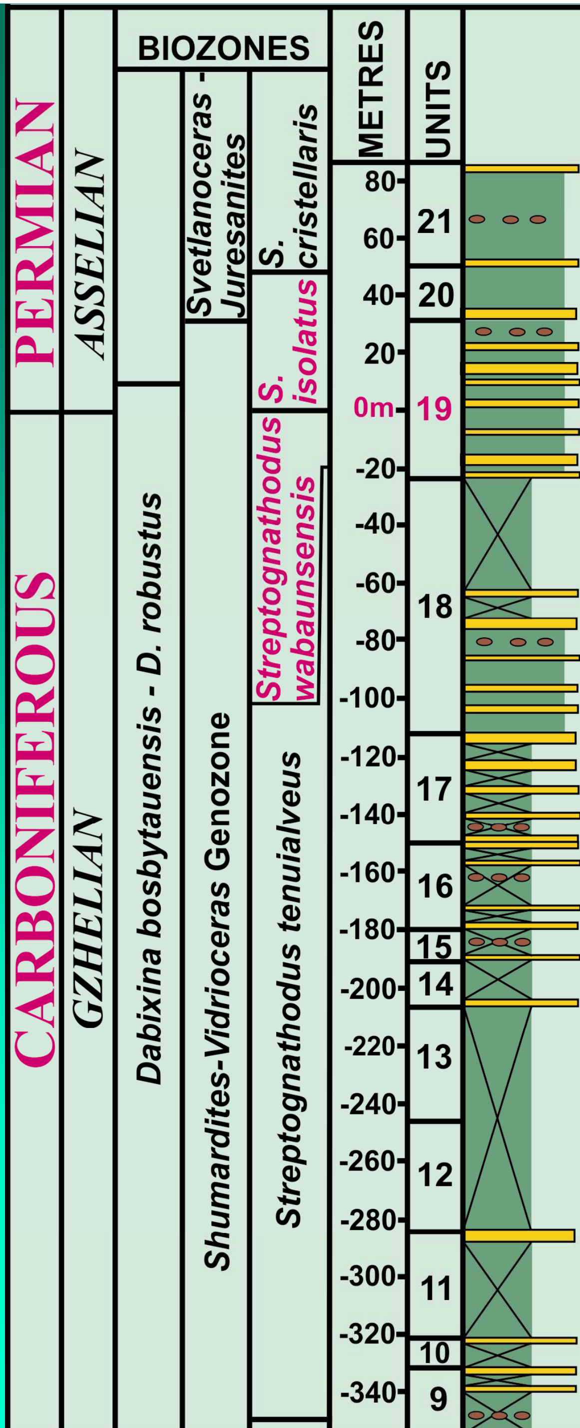
The last boundary we are going to discuss is the base of the Permian System (Asselian Stage) and this boundary is defined by a GSSP in the Aidaralash Creek section in the Urals of northern Kazakhstan.

MAP SHOWING LOCATION OF THE AIDARALASH CREEK SECTION IN THE URALS OF NORTHERN KAZAKHSTAN

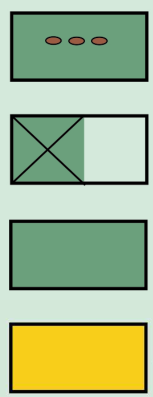


The section contains the Carboniferous-Permian Boundary GSSP. Succession at Aidaralash Creek was deposited in the pre-Uralian Foredeep.

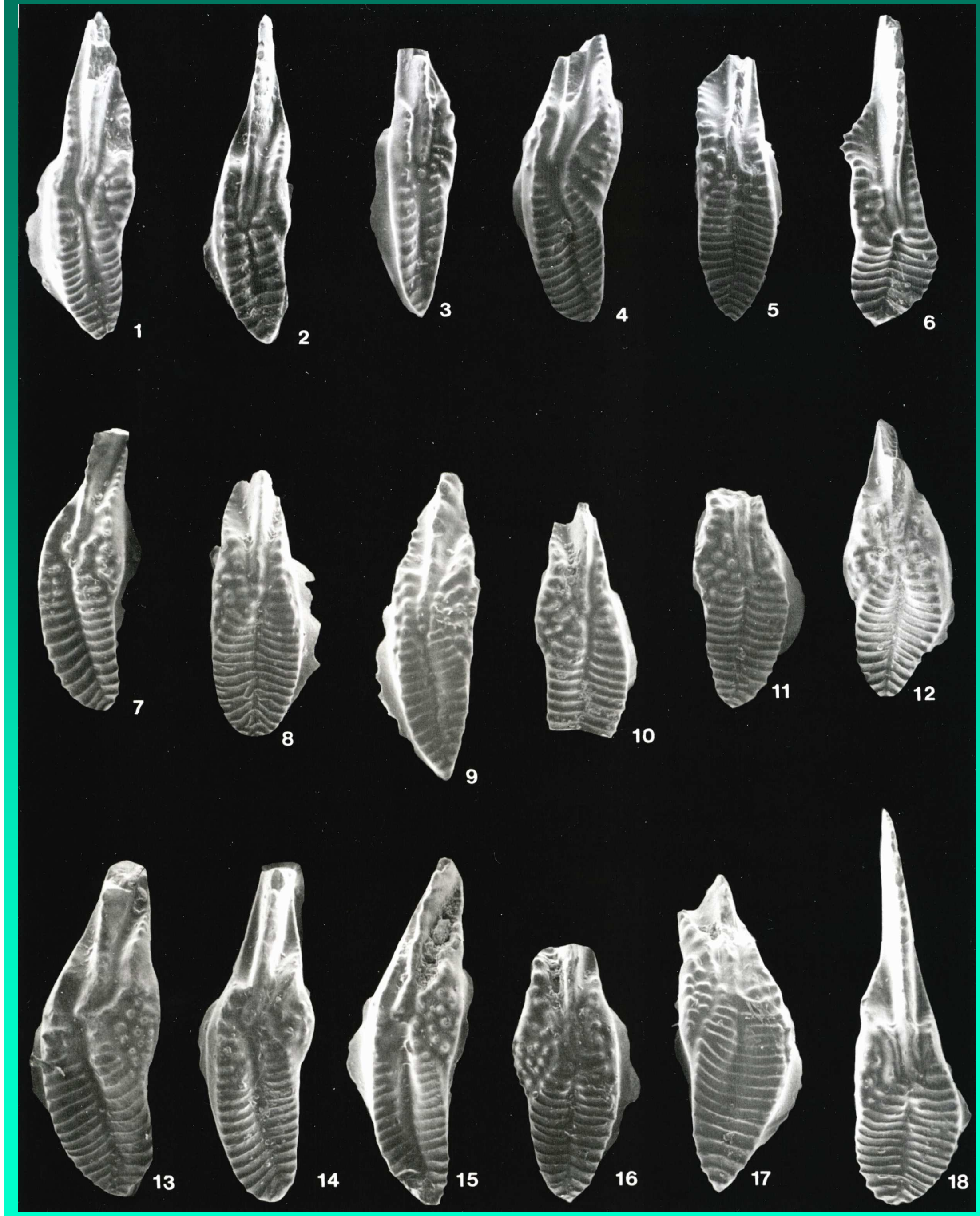
STRATIGRAHIC LOG OF THE AIDARALASH CREEK SECTION



The GSSP for the base of the Permian was ratified by the ICS and IUGS (1996) at Aidaralash Creek and is defined by the FO of conodont *Streptognathodus isolatus* in *Streptognathodus wabaunsensis* chronocline (Davydov *et al.*, 1998).



from Chernykh and Ritter (1997)



CONODONTS FROM THE AIDARALASH SECTION IN NORTHERN KAZAKHSTAN AND USOLKA RIVER SECTION IN THE SOUTHERN URALS OF RUSSIA

Plate showing species from the Gzhelian-Permian boundary interval including *Streptognathodus isolatus* (specimens13-18), used to define the GSSP at the base of the Permian.

***Streptognathodus* wabaunsensis (specimens 8-12), the ancestor of the index species is also shown; from Chernykh *et al*. (1997).**

SUMMARY

1) Progress: bases of the Tournaisian, Viséan, and Bashkirian have been defined by GPPSs; also, top of the Carboniferous System is defined by a GSSP at the base of the Permian.

2) Substantial work remains to establish GSSPs for bases of Serpukhovian, Moscovian, Kasimovian, and Gzhelian. An index taxon has been chosen for the base of the Gzhelian and the search is on to locate a suitable section for the GSSP. A proposal (Usolka section in Urals) has been submitted for the base of the Gzhelian.

3) An index taxon has been selected for the base of the Serpukhovian but not voted on. The task group has located 2 excellent candidate sections for the basal Serpukhovian GSSP.

4) Definitions for the bases of the Moscovian and Kasimovian have not been chosen but good progress has been made. A fusulinid-based proposal has been developed for the base of the Moscovian and conodont-based proposals are being prepared.

5) The GSSP for the base of the Tournaisian at La Serre, France is not viable and the revision may be a long-term project. Both a new index taxon and a stratigraphic section will probably be required.

6) The SCCS needs to preserve the stratotype sections for the Carboniferous stages and ensure preservation and access to sections containing GSSPs.

7) Precision for radiometric ages shown on new Carboniferous stratigraphic charts are high but the final positions of several boundaries have not been chosen.

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