

Carboniferous U-Pb-Calibrated Cyclostratigraphy and Relative Sea Level History: Donets Basin, Ukraine*

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Abstract

The Donets Basin of Eastern Ukraine preserves a Carboniferous record of near-continuous, rapid sedimentation in an aulacogen of the European craton. We present a relative sea level history of this basin based on more than 200 high-resolution core logs and more than 20 outcrop sections that together define clear stratigraphic and spatial trends. Recently developed, high-resolution time constraints calibrate these records to an unprecedented degree (Davydov et al., 2008).

Donets Basin sedimentation during the Late Paleozoic Ice Age (LPIA) can be broadly characterized in terms of three facies assemblages, reflecting a paralic depositional environment with fully marine to fully terrestrial paleotropical deposits. Facies belts group into widely correlable, regularly repeating (cyclic) sequences that meet the definition of cyclothems. These cyclothems constitute composite sequences, with bundling of cyclothem sequences showing longer-term sea level trends. More than 240 cyclothems can be described for a 30 my period of the Carboniferous, reflecting sea level change on the short to long term during the onset and apogee of the LPIA. These records show at least six major relative sea level regressions with major sea level transgressions following these events. Six intervals interpreted to represent potentially globally ice-free conditions or glacial minima are indicated, with at least six discrete periods corresponding to glaciation recorded. Periods of regional aridity are also inferred (intercalated limestones and evaporites, evaporite deposits) for periods of high-latitude glacial minima while increased coal deposits and indicators of increased regional seasonality and humidity define periods of glacial maxima. These findings are in broad agreement with recently-developed high-latitude sedimentary records of LPIA glaciation.

References

Blakey, R.C., 2008, Gondwana Paleogeography from assembly to breakup – A 500 m.y. odyssey, *in* C.R. Fielding, T.D. Frank, and J.L. Isbell, (eds.), Resolving the Late Paleozoic Ice Age in Time and Space: GSA, Special Paper 441, p. 1-28.

Davydov, V.I., J.L. Crowley, M.D. Schmitz, and V.I. Poletaev, 2010, High-precision U-Pb zircon age calibration of the global Carboniferous time scale and Milankovitch band cyclicity in the Donets Basin, eastern Ukraine: *Geochemistry Geophysics Geosystems* G super 3, v. 11/2, p. Citation 00AA04.

Rygel, M.C., C.R. Fielding, T.D. Frank, and L.P. Birgenheier, 2008, The magnitude of late Paleozoic glacioeustatic fluctuations; a synthesis: *Journal of Sedimentary Research*, v. 78/8, p. 500-511.

Carboniferous U-Pb-calibrated cyclostratigraphy and relative sea level: Donets Basin, Ukraine

J. Mike Eros

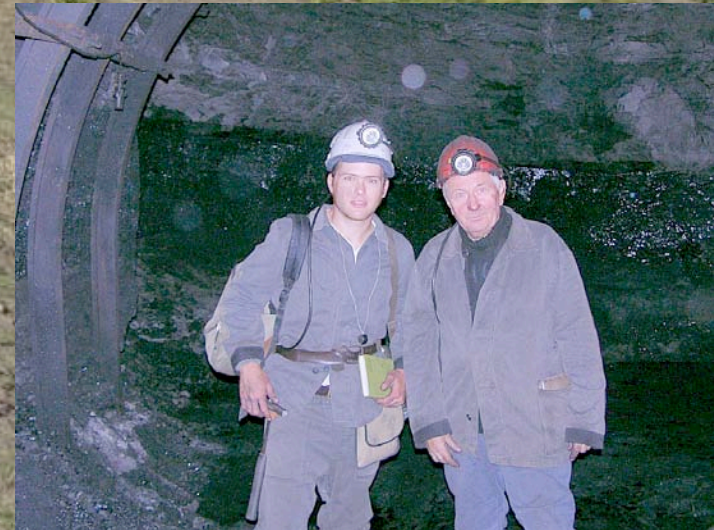
ExxonMobil Development Company

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Neil Tabor, Geology Department, Southern Methodist University;

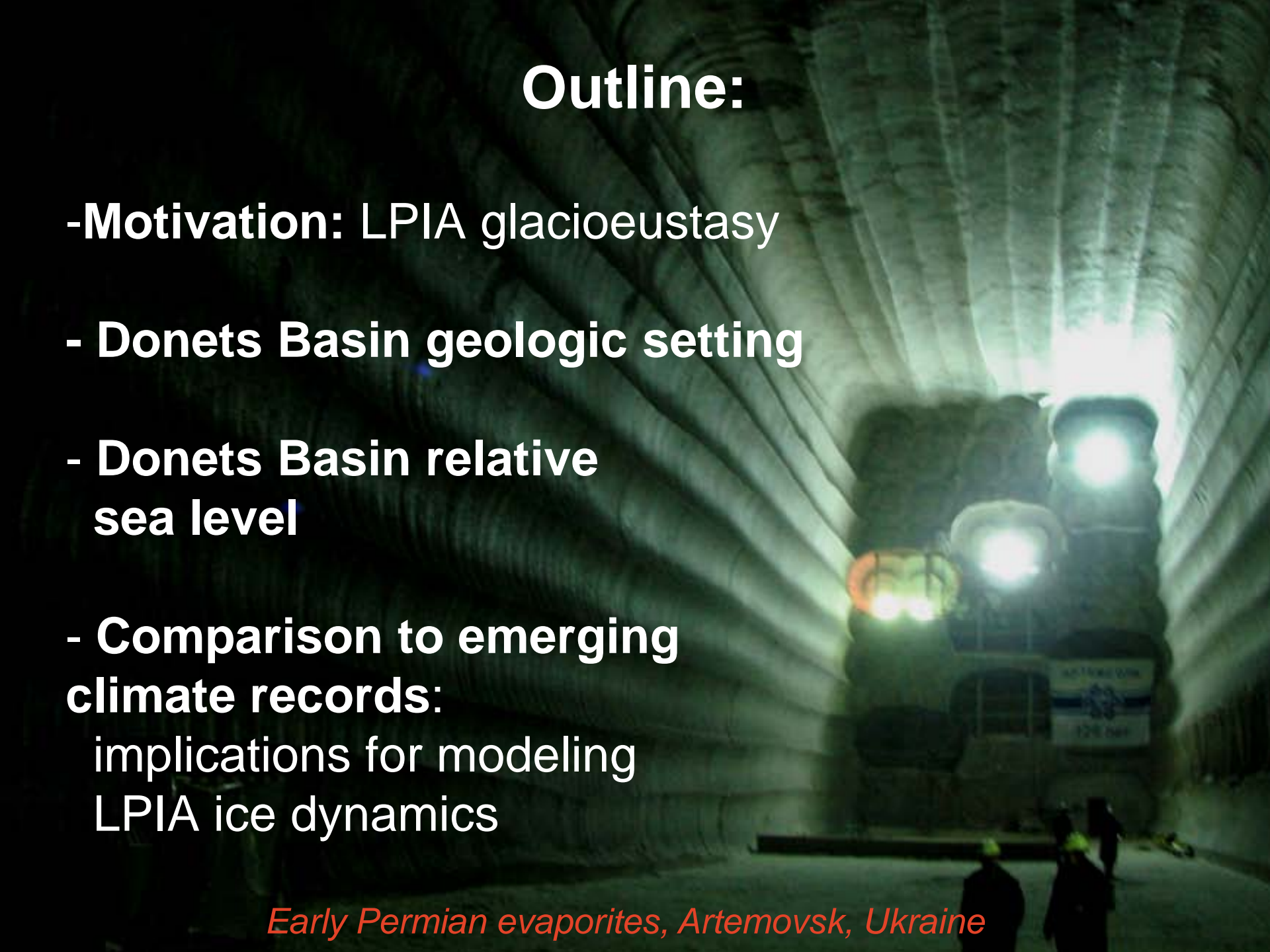
Erik Gulbranson, Department of Geology, UC Davis



Outline:

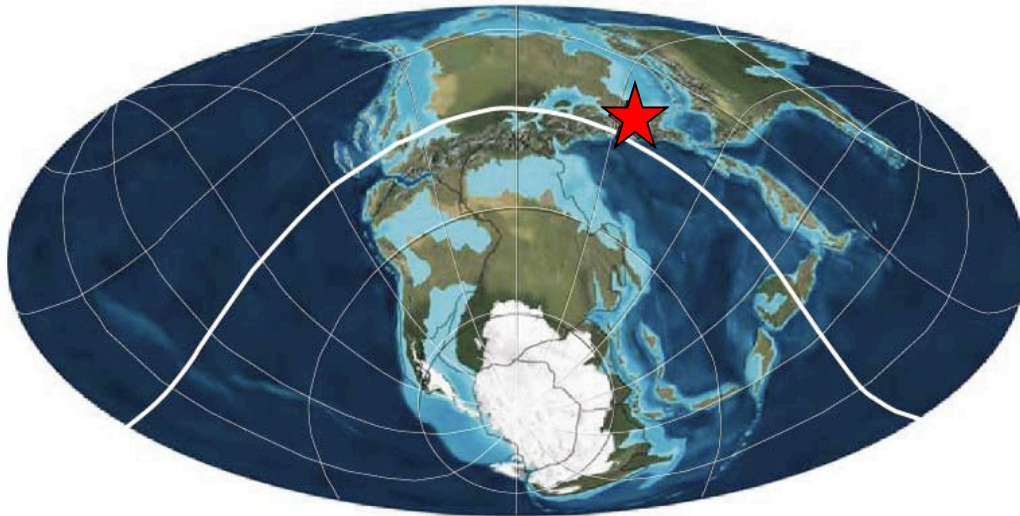
- **Motivation:** LPIA glacioeustasy
- **Donets Basin geologic setting**
- **Donets Basin relative sea level**
- **Comparison to emerging climate records:**
implications for modeling
LPIA ice dynamics

Early Permian evaporites, Artemovsk, Ukraine

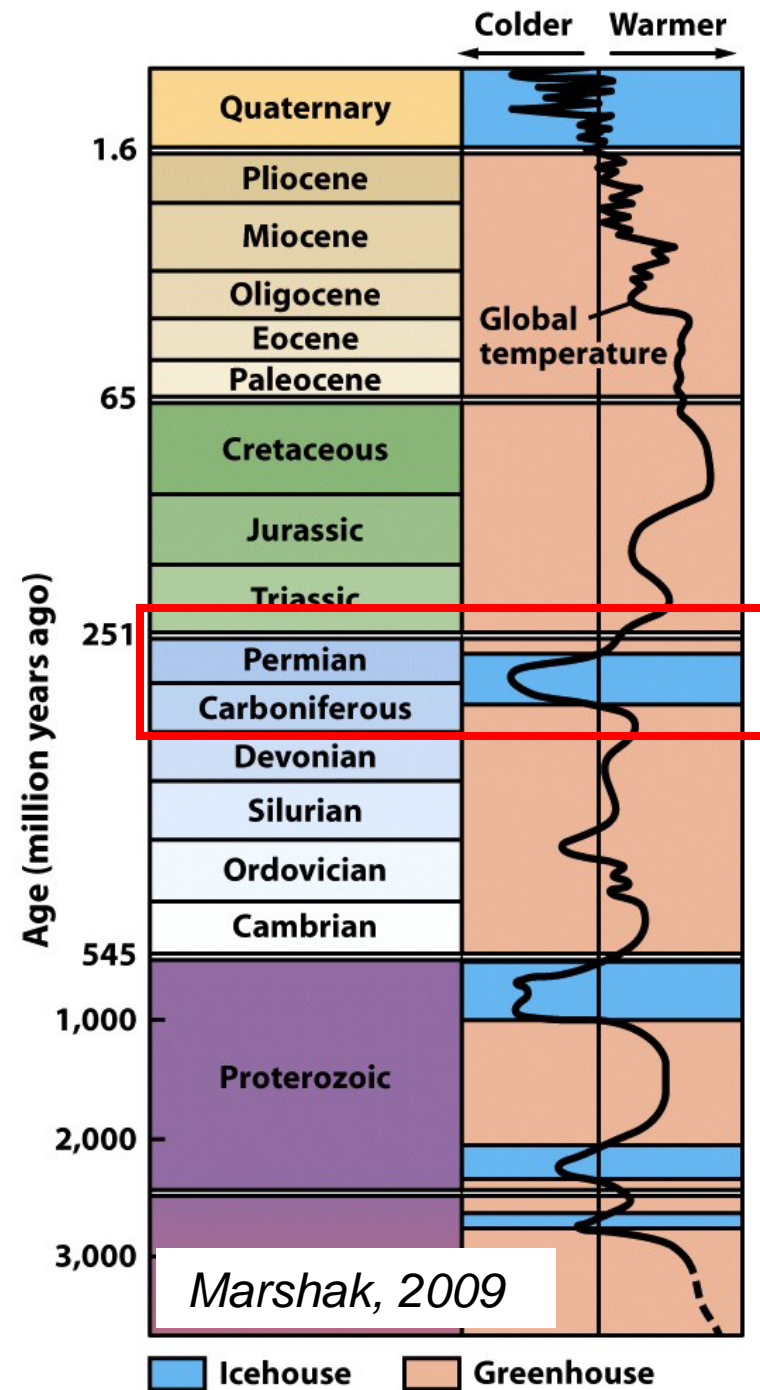


Motivation:

Emerging records challenge the long-established model of a single continuous late Paleozoic 'icehouse'



Blakey, 2008

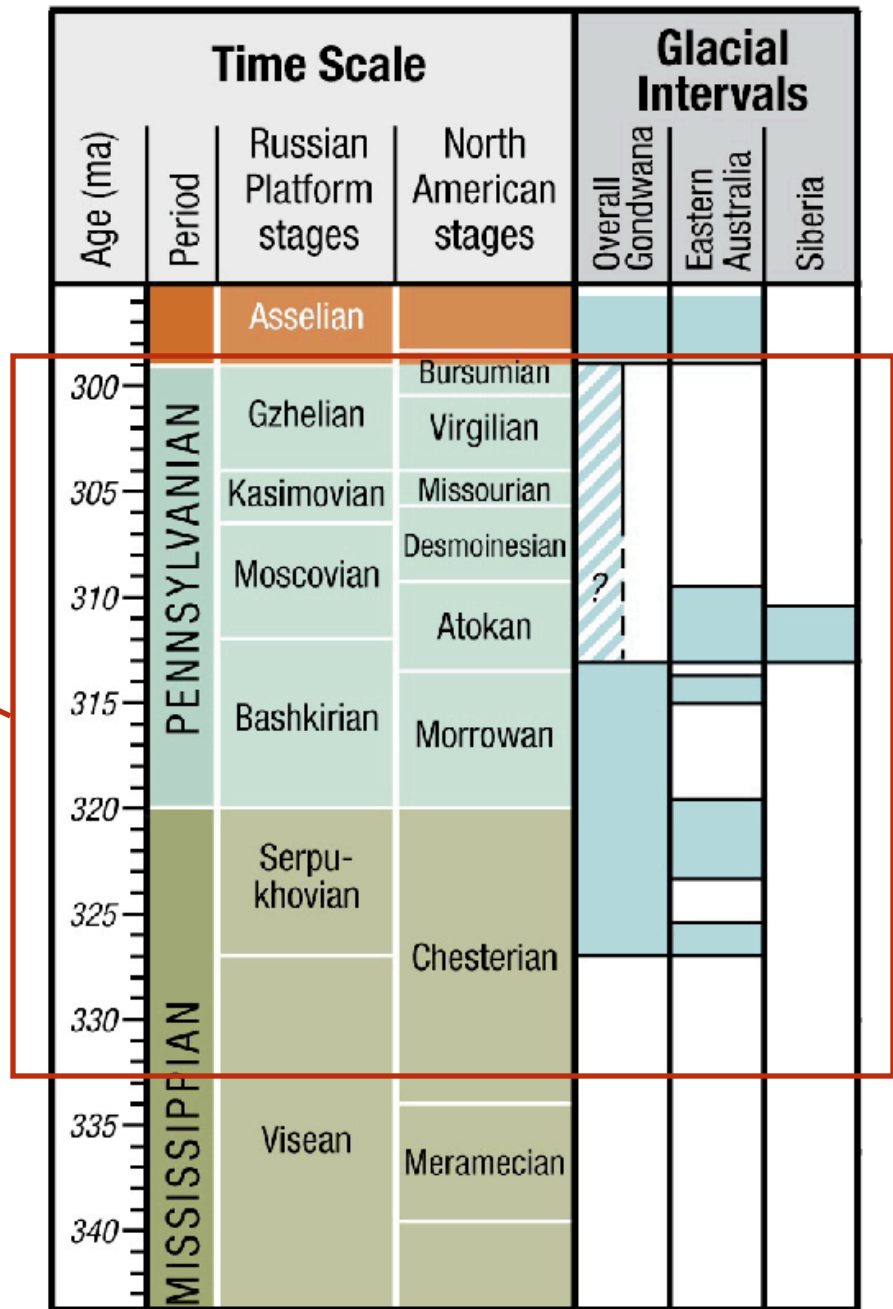
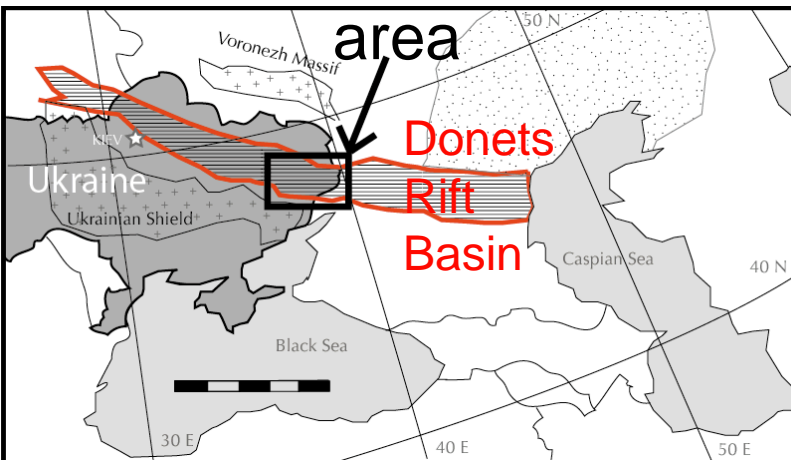


Recent evidence suggests a dynamic late Paleozoic Ice Age (LPIA)

This study →

Field

area



Rygel et al. (2008), adapted by Montanez et al. (in prep.)



Main Research Questions:

1. What is the record of glacioeustasy and climate in the Donets succession?

Why this basin? = *extensive biostratigraphic age control, classic cyclothem deposits, accessible outcrop, thick continuous record*

2. What insight does the Donets record provide into the evolving model of the late Paleozoic Ice age?

Take-home message:

- The Donets records a hierarchy of relative sea-level changes including multiple 1-4 Myr duration lowstands
- Marked episodes of longer-term sea level fall correlate with recent high latitude records of glaciation
 - First near-field cyclothem record to confirm the dynamic nature of the LPIA in U-Pb dated temporal resolution



U-Pb Geochronology

West. Europe		North America		Age		Regional Formation		Donets Basin Biostratigraphy		
				Ma		Reginal Stage		<i>fusulinids</i>	<i>conodonts</i>	<i>ammonoids</i>
Lebach	Autunian	Nealian	300	PERMIAN	Asselian	n/a		<i>Sphaeroschwagerina gigas</i>		
					298.7	Kartamyshsky		BREAK	<i>S. fusiformis</i>	no record
Kuzel		Bursin.				Mironovsky		<i>Sphaeroschwagerina aktjubensis</i>	<i>St. wabaunsensis</i>	
Stephanian C	Stephanian	Misso-Virgilian			Gzhelian	Kalinovsky		<i>Ul. bosbytauensis-Schw. robusta</i>	<i>Streptognath. elongatus</i>	
					303.2		BREAK	<i>Shagon. implexa</i>	?	
Stephanian B								<i>Shagonella proimpressa</i>	<i>Streptognathodus simulator</i>	no record
Stephanian A								<i>Rauserites rossicus</i>		
Cantabrian	Stephanian				Kasimovian	Toretsky		<i>Rauserites ofive</i>	<i>Idiognathodus toretzianus</i>	
					306.65			<i>Rauserites quasiarcticus</i>	<i>Idiognathodus sagittalis</i>	
Asturian	Westphalian	Desmoinesian	310					<i>Montiparus subcrassulus</i>	<i>St. subexcelsus</i>	
								<i>Montiparus paramontiparus</i>		
Bolsovian	Westphalian	Atokan						<i>Protriticites pseudomontiparus</i>	<i>Neognathodus roundyi</i>	<i>Gonioglyphioceras</i>
								<i>Pr. ovoides-Præobs. burkemensis</i>	<i>Streptognath. cancellosus</i>	<i>Gonioloboceras</i>
Duckmantian	Westphalian							<i>Fusulinella colaniae</i>	<i>Neogn. medexultimus-Streptognath. concinnus</i>	<i>Weideyceras cambriense</i>
								<i>Ozawainella stellae</i>		
Langsettian	Westphalian							<i>Fusulinella subpulchra-Citrinoides schellwieni</i>	<i>Streptognathodus transitivus</i>	
								<i>Aljutovella priscoidea</i>		<i>Antracoceras</i>
Yeadonian	Westphalian							<i>Aljutovella aljutovica</i>	<i>Declinagnathodus donetzianus</i>	<i>Diaboloceras</i>
								<i>Al. tikhonovichi-Verella spicata</i>	<i>Decl. marginodosus</i>	
Marsdenian	Westphalian							<i>Pr. rhomboides-Oz. pararhomboidalis</i>	<i>Idiognathoides tuberculatis Id. fossatus</i>	<i>Donetzoceras</i>
								<i>Prof. primitiva-Oz. alchewskiensis</i>	<i>Streptognath. expansus</i>	<i>Gastrioceras listeri</i>
Kinderscotian	Westphalian							<i>Ozawainella umbonata</i>	<i>Idiognathodus sinuatus</i>	<i>Bilinguites superbilinguis</i>
								<i>Pseudostaffella praegorskyi</i>	<i>Id. des sulcatus parvus</i>	
Alportian	Westphalian							<i>Pseudostaffella antiqua</i>	<i>Idiognathoides sinuatus</i>	<i>Cnc. cancellatum</i>
								<i>Eostaffella postmosquensis</i>	<i>Idiognathoides sulcatus</i>	<i>R. reticulatum</i>
Chokerian	Westphalian							<i>Plectostaffella varvariensis</i>	<i>Idiognathoides sulcatus</i>	<i>R. berestovens</i>
								<i>Seminovella elegantula</i>	<i>Declinagnath. noduliferus</i>	<i>Homoceratoides</i>
Arnsbergian	Namurian							<i>Globivalvulina kâmensis</i>	<i>D. noduliferus inaequalis</i>	<i>S. beshevensis</i>
								<i>Monotaxinoides transitorius</i>	<i>Gnathodus postbilineatus</i>	<i>Nuculoceras donbassicum</i>
Pendleian	Chesterian							<i>Eosigmoilina explicata</i>	<i>Gnathodus bollandensis</i>	<i>Cravenoceras beschevense</i>
								<i>Eostaffella mirifica</i>	<i>Adetognathus unicornis</i>	
Warnantian	Brig.							<i>Loeblichia minima</i>	<i>Cavustognathus naviculus</i>	<i>Eumorphoceras donbassicum</i>
								transitional assemblage	no record	<i>Donbarites modestus</i>
								<i>Betpakodiscus cornuspiroides</i>	?	
								<i>Endostaffella parva</i>		
								<i>Euxinita efremovi</i>	<i>Lochriea nodosa</i>	
								<i>Betpakodiscus compressus</i>	<i>Gnathodus girtyi girtyi</i>	
									<i>Lochriea mononodosa</i>	



New U-Pb
age from
zircons
(ID-TIMS)

Davydov
et al.,
2010, G³

U-Pb Geochronology

West. Europe		North America	Age	Regional Formation	
			Ma		Regional Stage
Lebach	Autunian	Nealian	300	PERMIAN	Asselian
Kuzel		Bursin.			n/a
Stephanian C	Stephanian	Misso.Virgilian	303.2		Kartamyshsky
Stephanian B Stephanian A					Mironovsky
Cantabrian	Westphalian	Desmoinesian	310		Kalinovsky
Asturian					Toretsky
Bolsovian	Westphalian	Atokan	314.6		Kasimovian
Duckmantian					306.65
Langsettian	Westphalian		320		Isaevsky (Sanzharovsky)
Yeadonian					307.26
Marsdenian	Namurian		322.8		Moscovian
Kinderscotian					310.55
Alportian	Chesterian		330		Gorlovsky (Sabovsky)
Chokerian					312.01
Arnsbergian	Brig.		330.0		Mar'evsky
Pendleian					312.23
Warnantian					313.16
					Kamensky
					314.40
					Krasnodonsky
					Makeevsky
					Bashkirian
					Avdot'insky
					Blagodatnensky
					Manuilovsky
					Feninsky
					Voznesenian
					Zapaltjubian
					Novolyubovsky
					Prokhorovsky
					Serpukhovian
					328.22
					Samarsky
					Mezhevskoy
					Visean



New U-Pb
age from
zircons
(ID-TIMS)

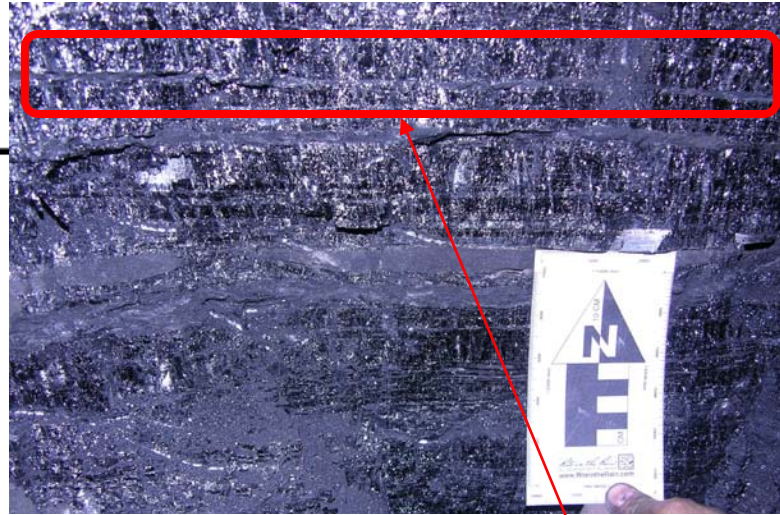


Davydov
et al.,
2010, G³



U-Pb Geochronology

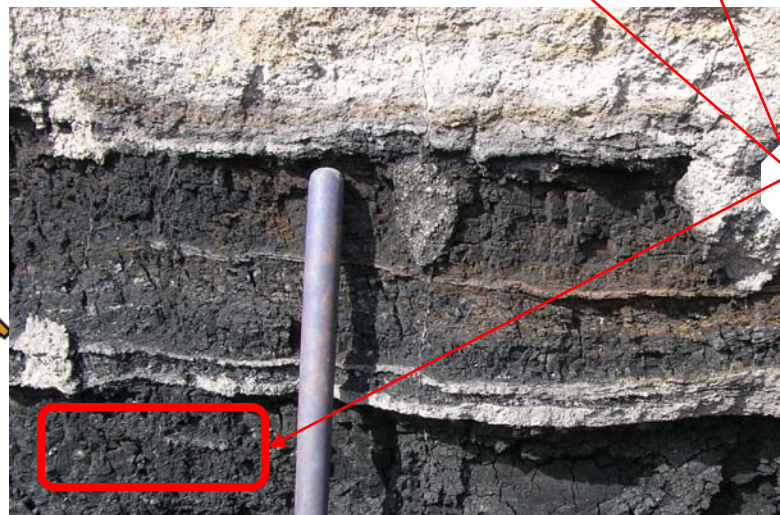
West. Europe		North America	Age	Regional Formation	
			Ma		
Lebach	Autunian	Nealian	300	PERMIAN	Asselian
Kuzel		Bursin.			n/a
Stephanian C	Stephanian	Misso.Virgilian	303.2		Kartamyshsky
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Asturian					Gzhelian
Bolsovian	Westphalian	Atokan	314.6		Kasimovian
Duckmantian					Toretsky
Langsettian	Westphalian		320		Isaevsky (Sanzharovsky)
Yeadonian					Moscovian
Marsdenian	Namurian		322.8		Gorlovsky (Sabovsky)
Kinderscotian					Mar'evsky
Alportian	Chesterian		330		Kamensky
Chokerian					Krasnodonsky
Arnsbergian	Brig.		330.0		Makeevsky
Pendleian					Bashkirian
Warnantian					Avdot'insky
					Blagodatskiy
					Manuilovsky
					Feninsky
					Voznesenian
					Zapaltjubian
					Novolyubovskiy
					Prokhorovskiy
					Serpukhovian
					Samarsky
					Mezhevskoy
					Visean



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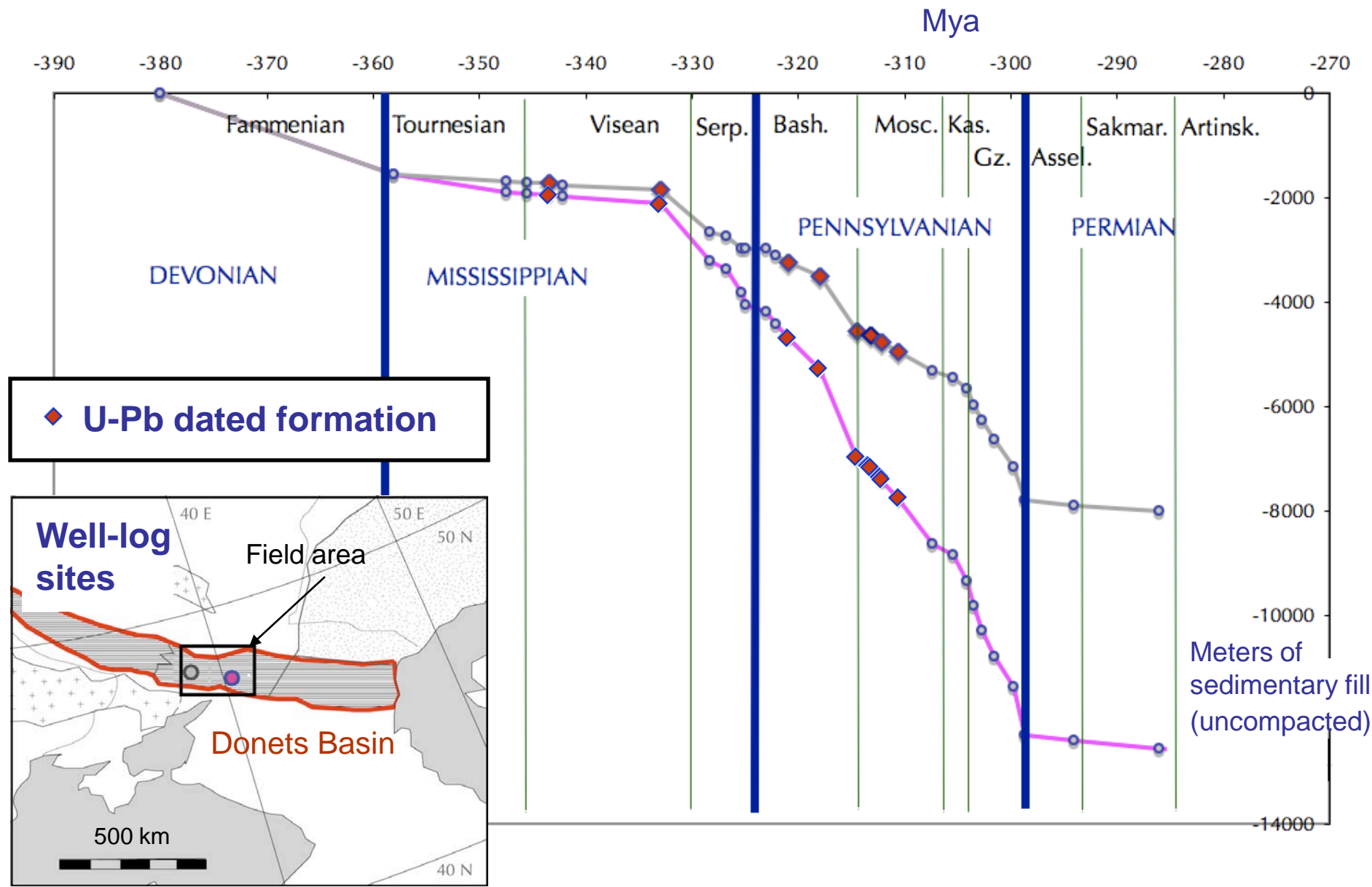


Davydov
et al.,
2010, G³

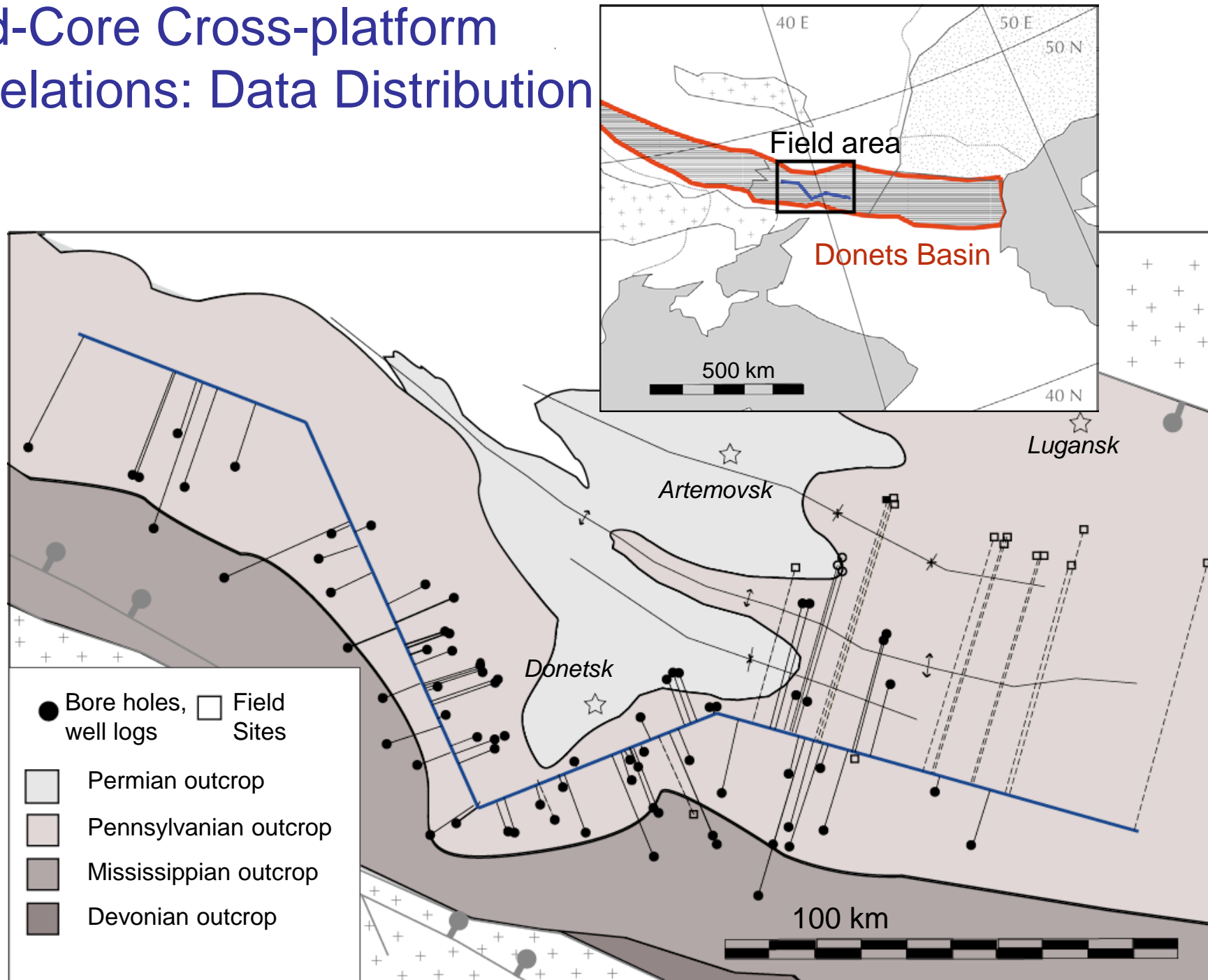


Volcanic
ash
interbeds

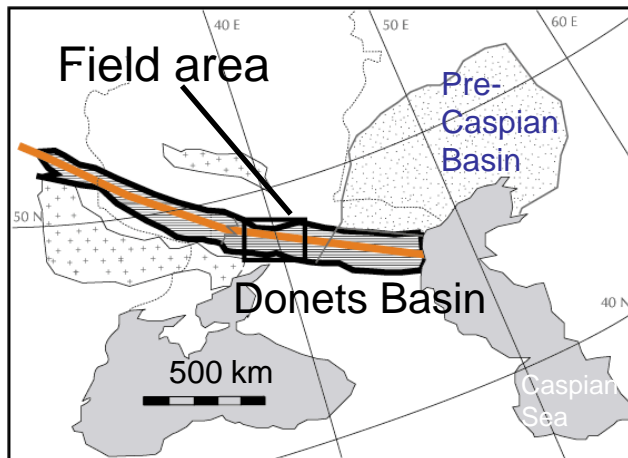
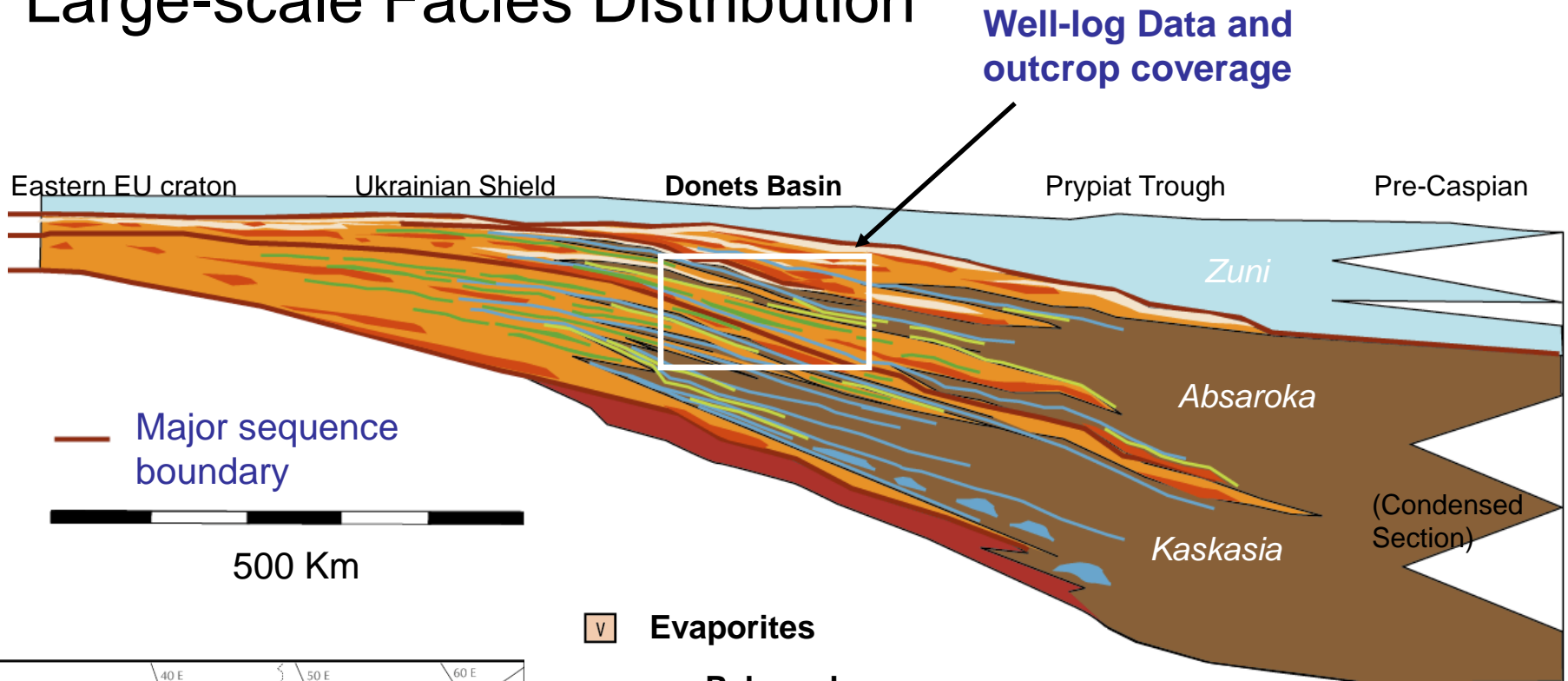
Subsidence History



Field-Core Cross-platform Correlations: Data Distribution



Large-scale Facies Distribution



V Evaporites

xxxx Paleosols

Fluvial conglomerates

Fluvial Sandstones

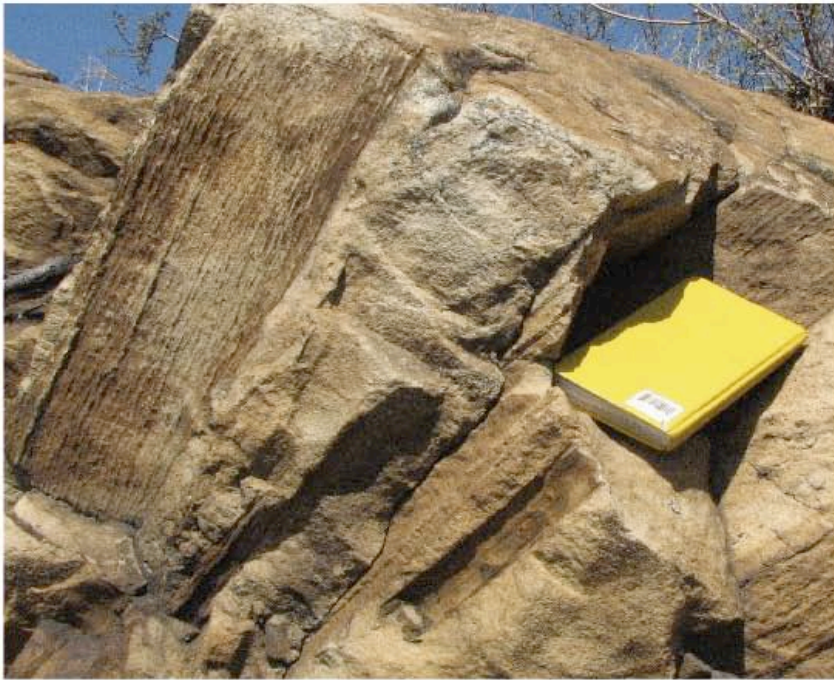
Coals

Transgressive marine sandstones

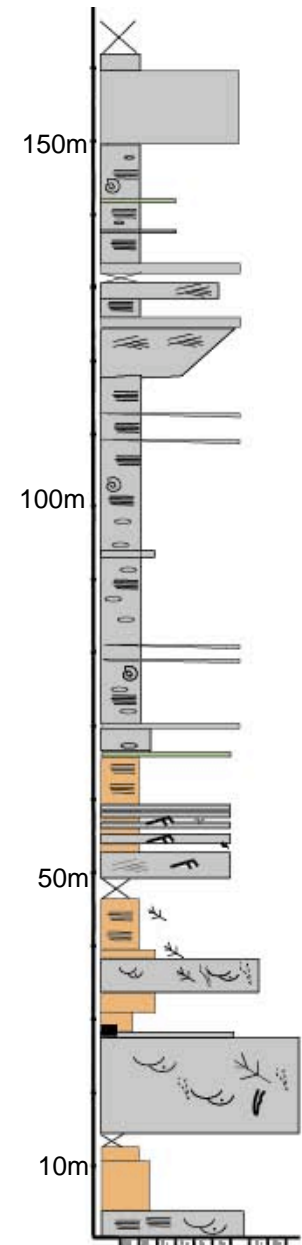
Delta-top facies

Marine limestones

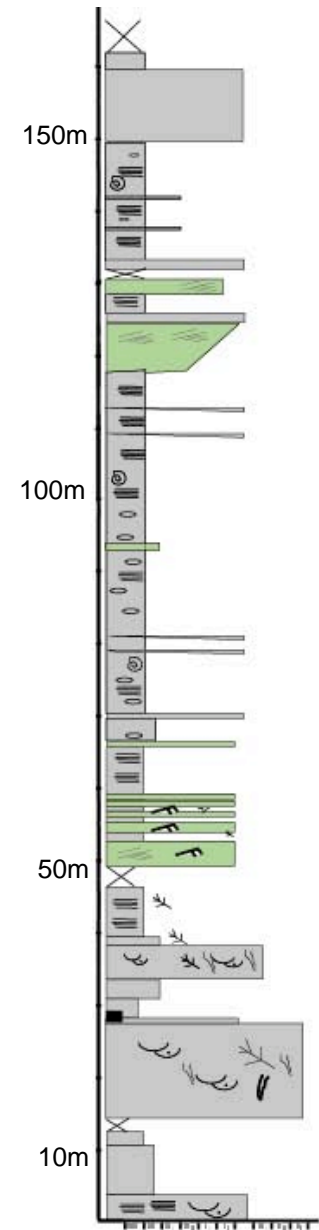
Pro-delta and marine mudstones



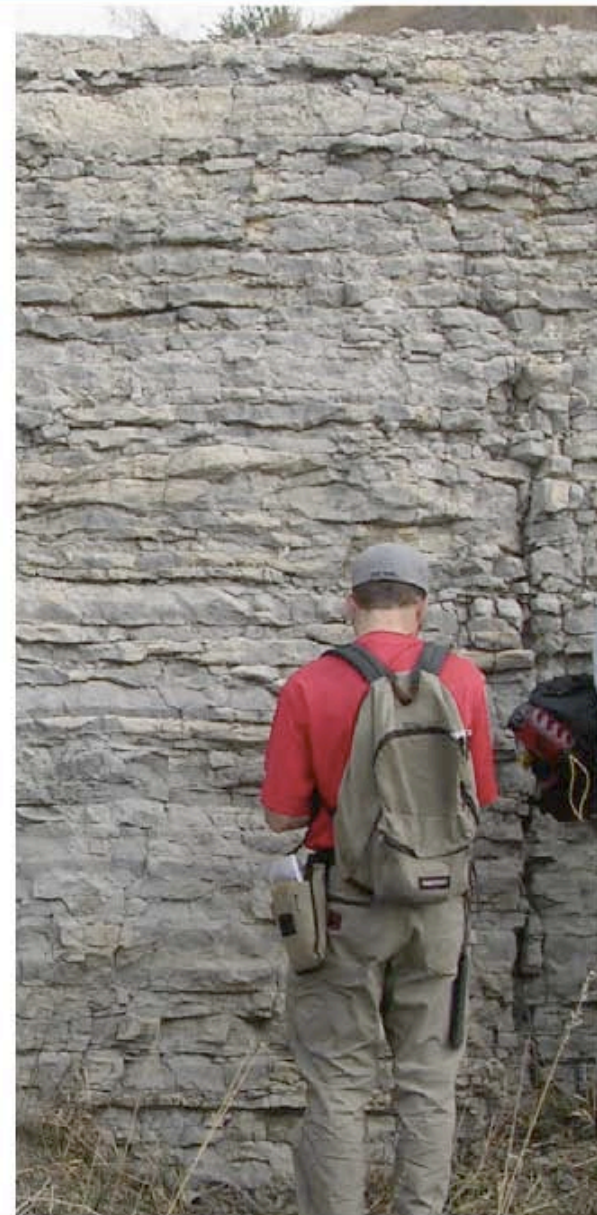
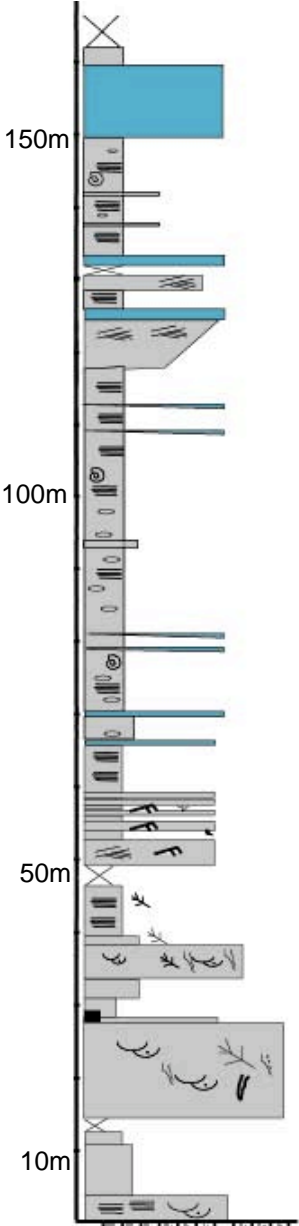
Facies Types: Delta Top Mudstones/Siltstones



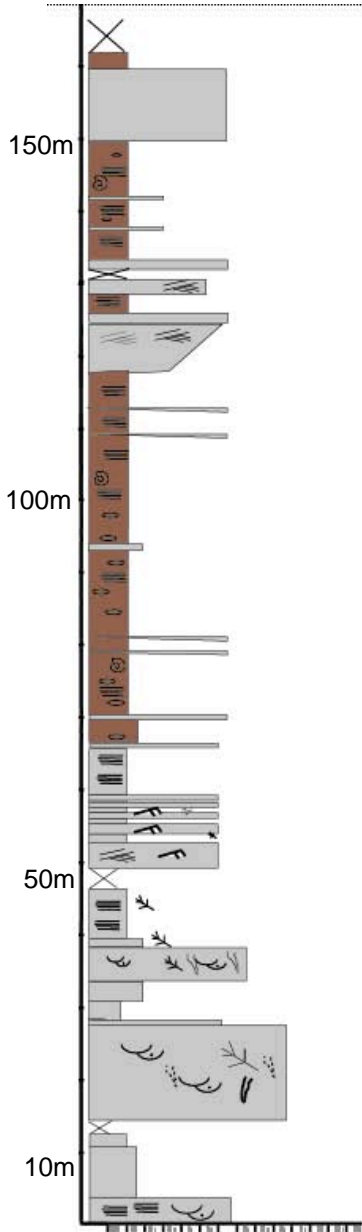
Facies Types: Transgressive Marine Sandstones



Facies Types: Marine Limestones



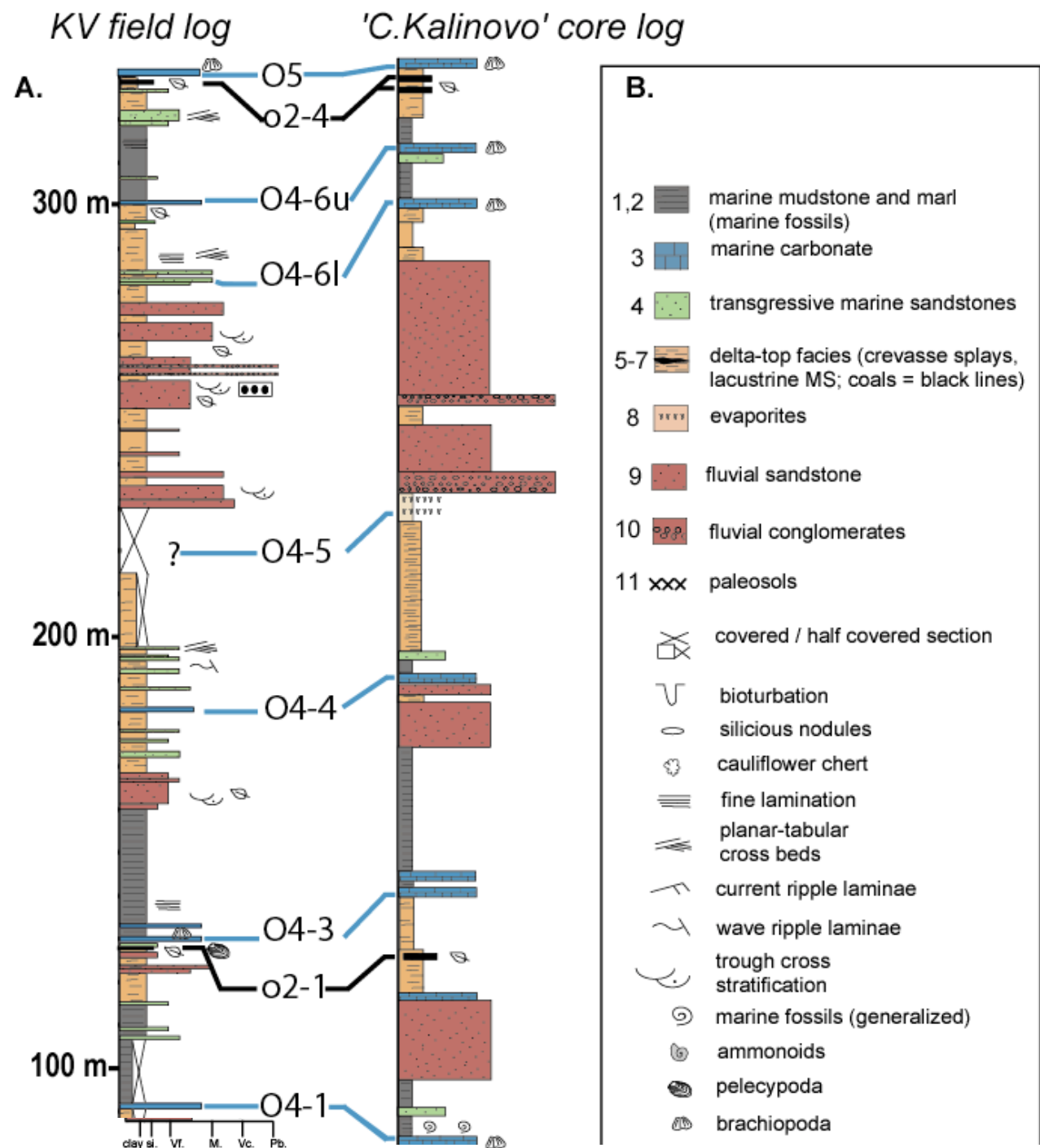
Facies Types: Prodelta / Marine Mudstones



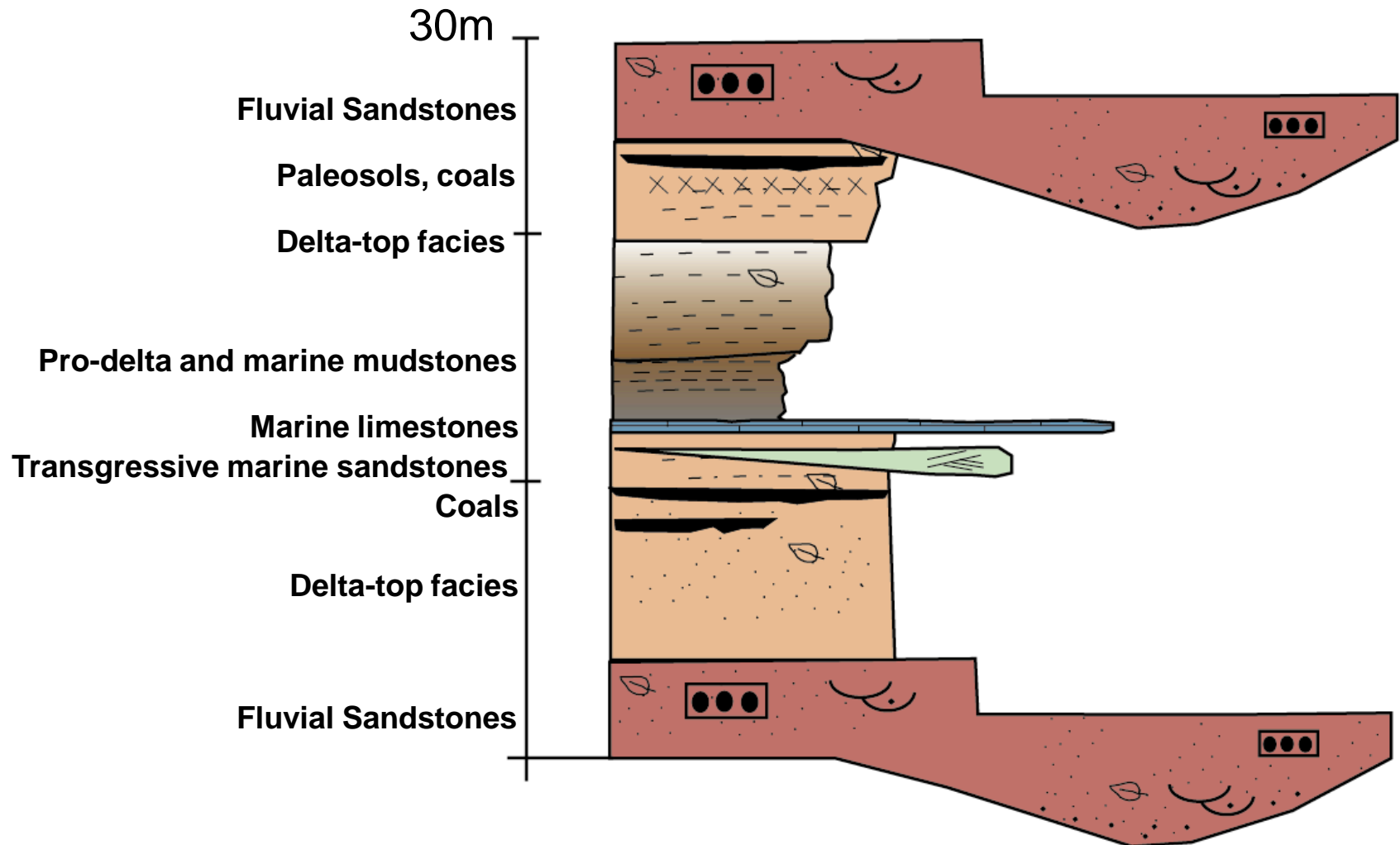
Field-core correlation

Note: evaporites not observed in outcrop

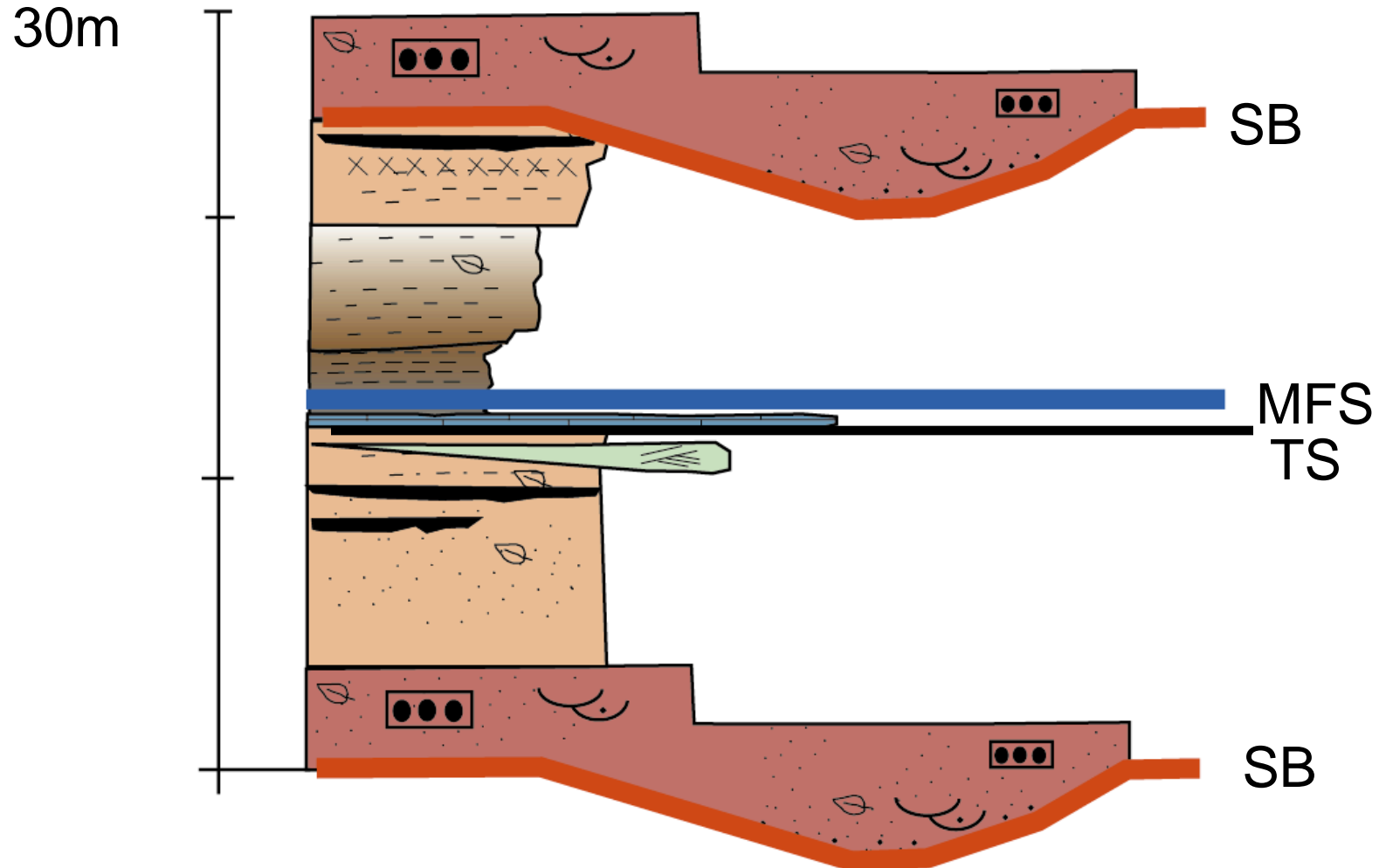
Core data derived from Makarov et al. (1982)



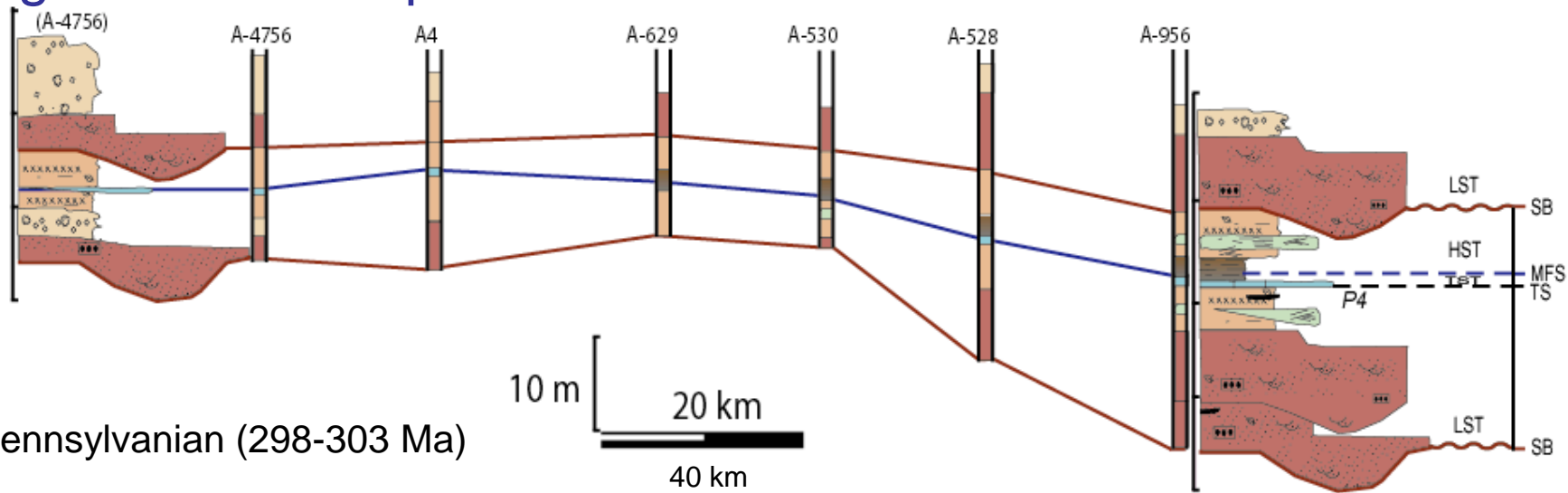
Typical Donets cyclothems: fully terrestrial to fully marine



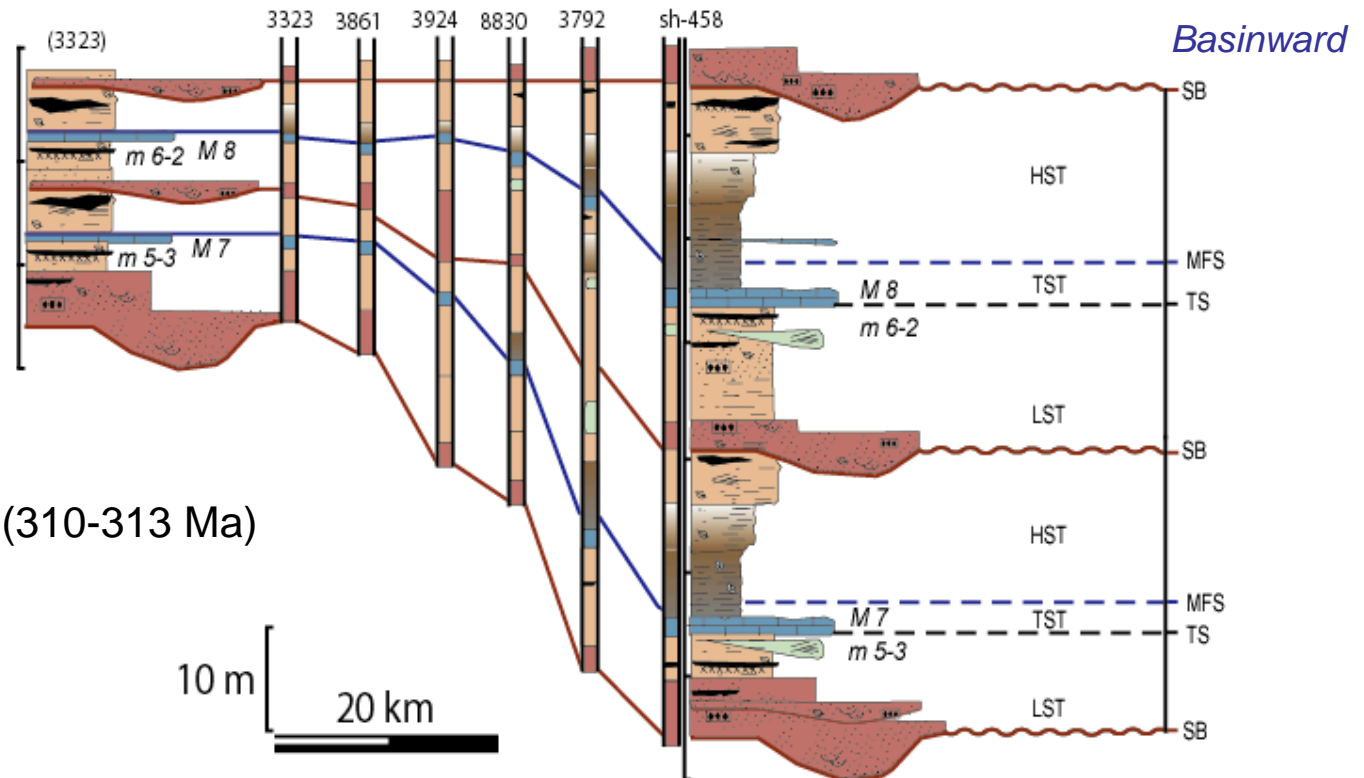
Typical Cyclothem: a sequence



Tracing individual sequences

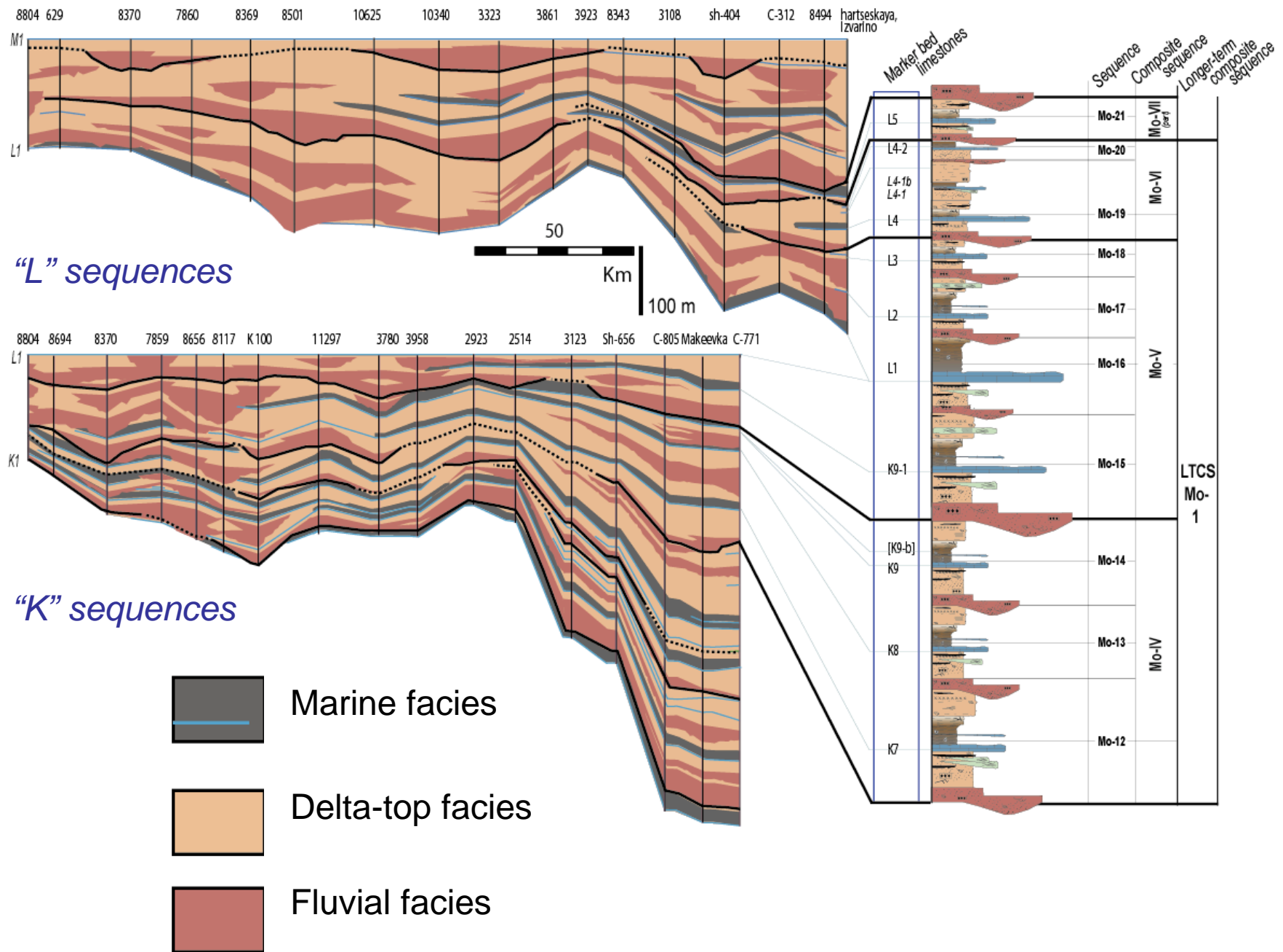


Landward

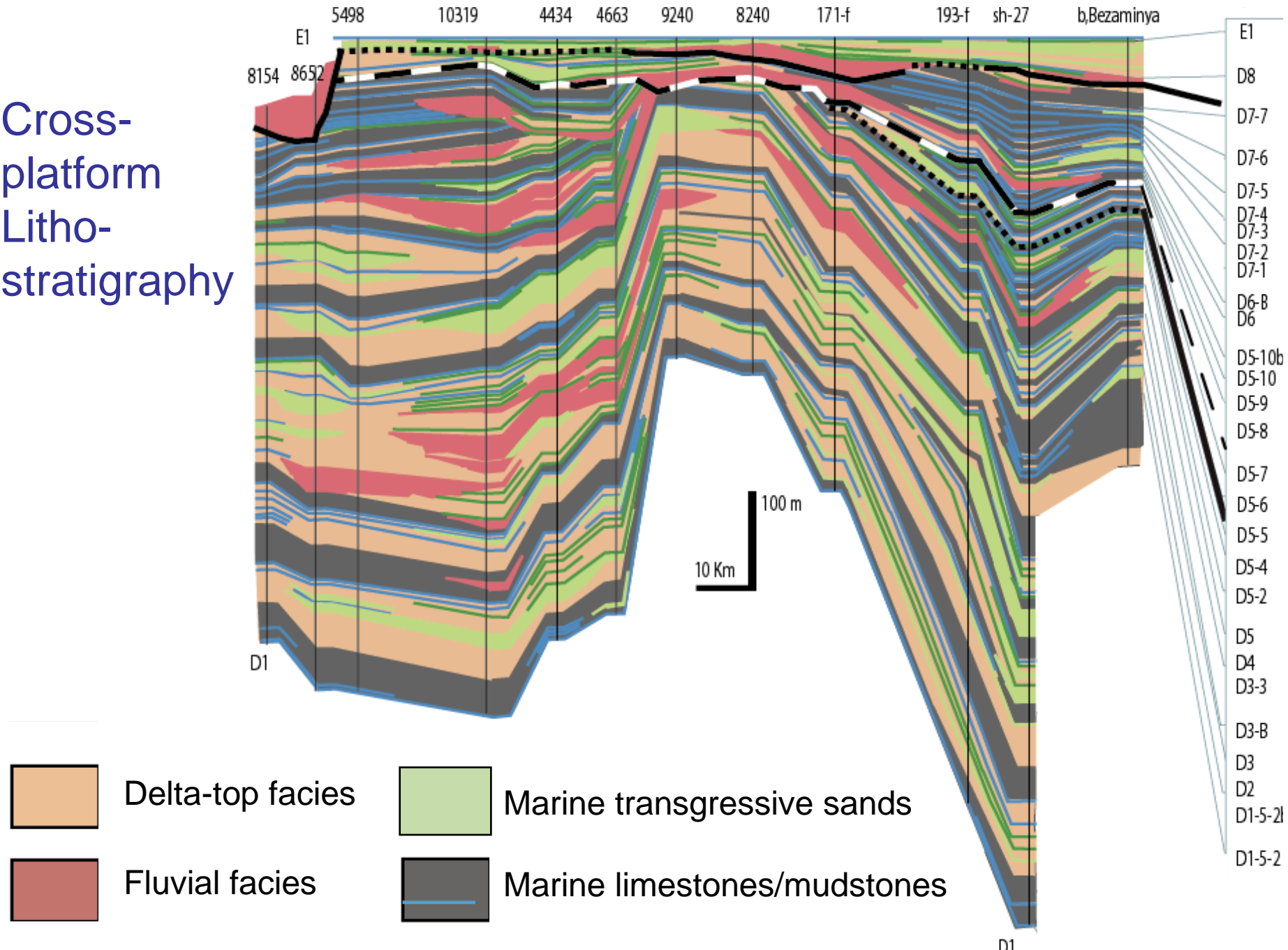


Basinward





Tracing individual sequences

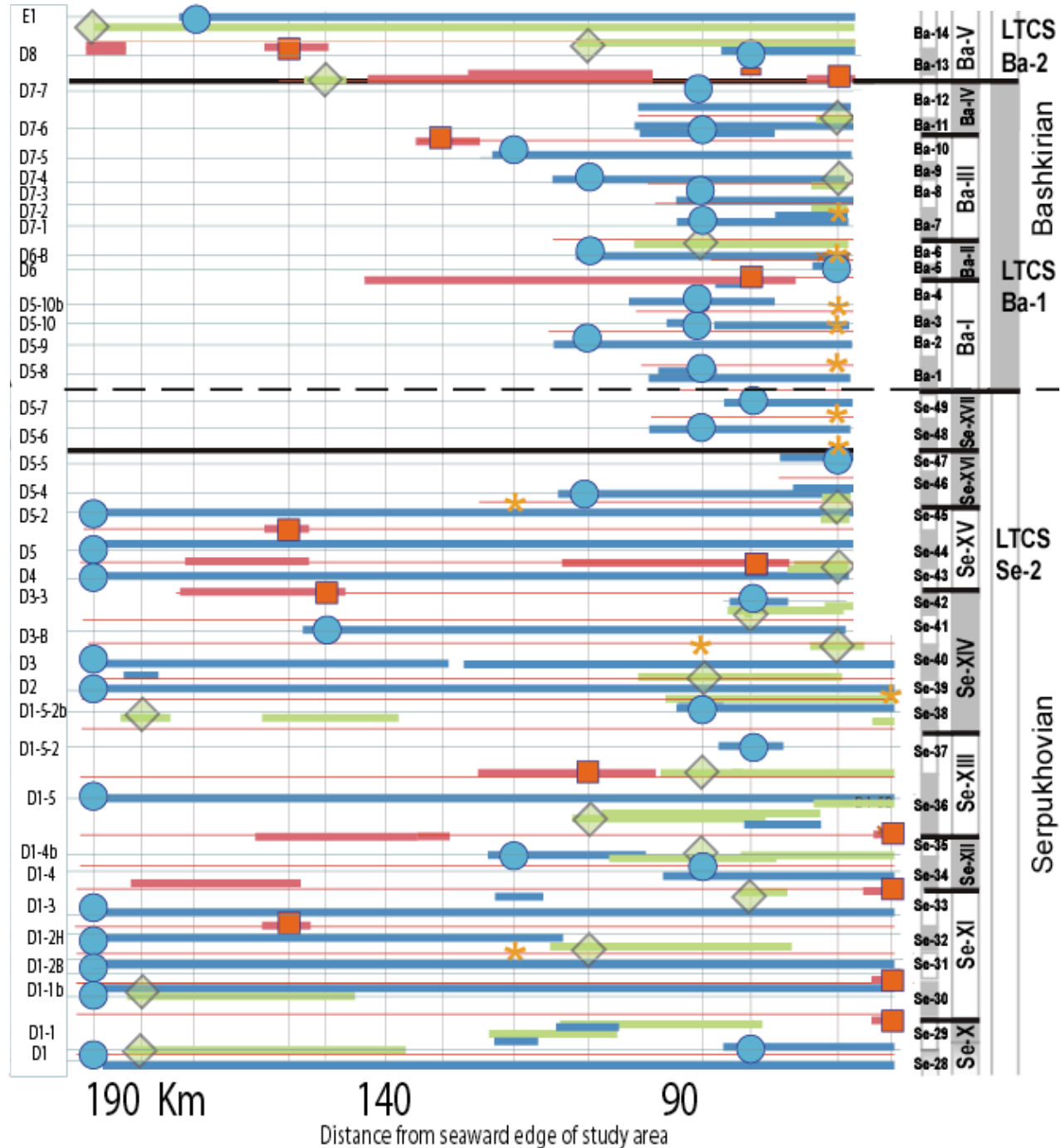


Cross-
platform
Litho-
stratigraphy

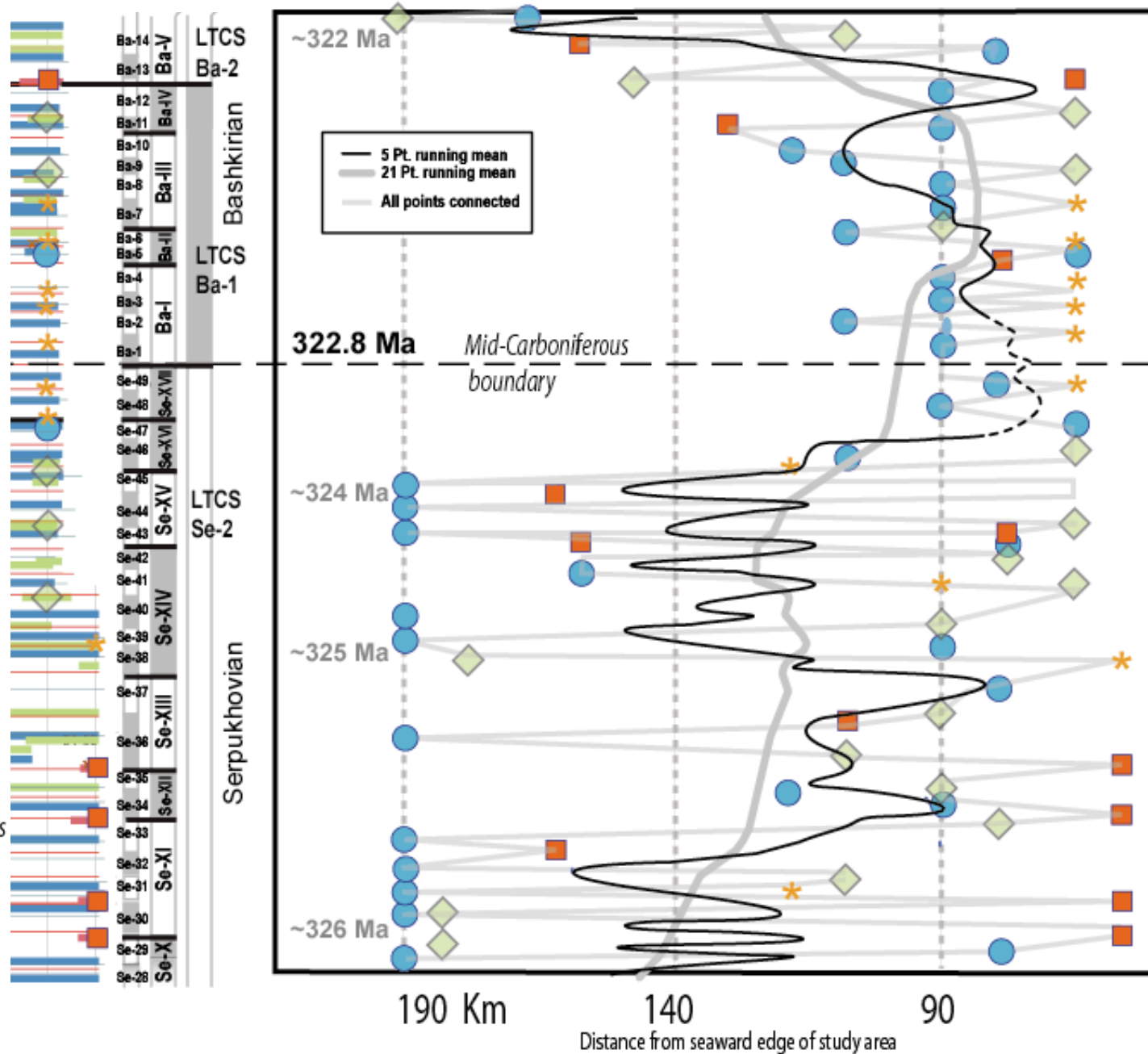


Cross-platform chronostratigraphy

-  *Most basinward extent of fluvial Sandstone*
-  *Most landward extent of marine limestone*
-  *Most landward extent of transgressive beach-sand facies*
-  *Most basinward extent of paleosols*



-  Most basinward extent of fluvial Sandstone
-  Most landward extent of marine limestone
-  Most landward extent of transgressive beach-sand facies
-  Most basinward extent of paleosols



Donets
Basin
Generalized
Lithology

Long-term Relative Sea Level
Onlap-Offlap Record

Km

Bashkirian

Serpukhovian

Visean

Integrating
all data:

Short & longer-term
relative sea-level
history

1 of 3

Relative Sea Level Pinning Points

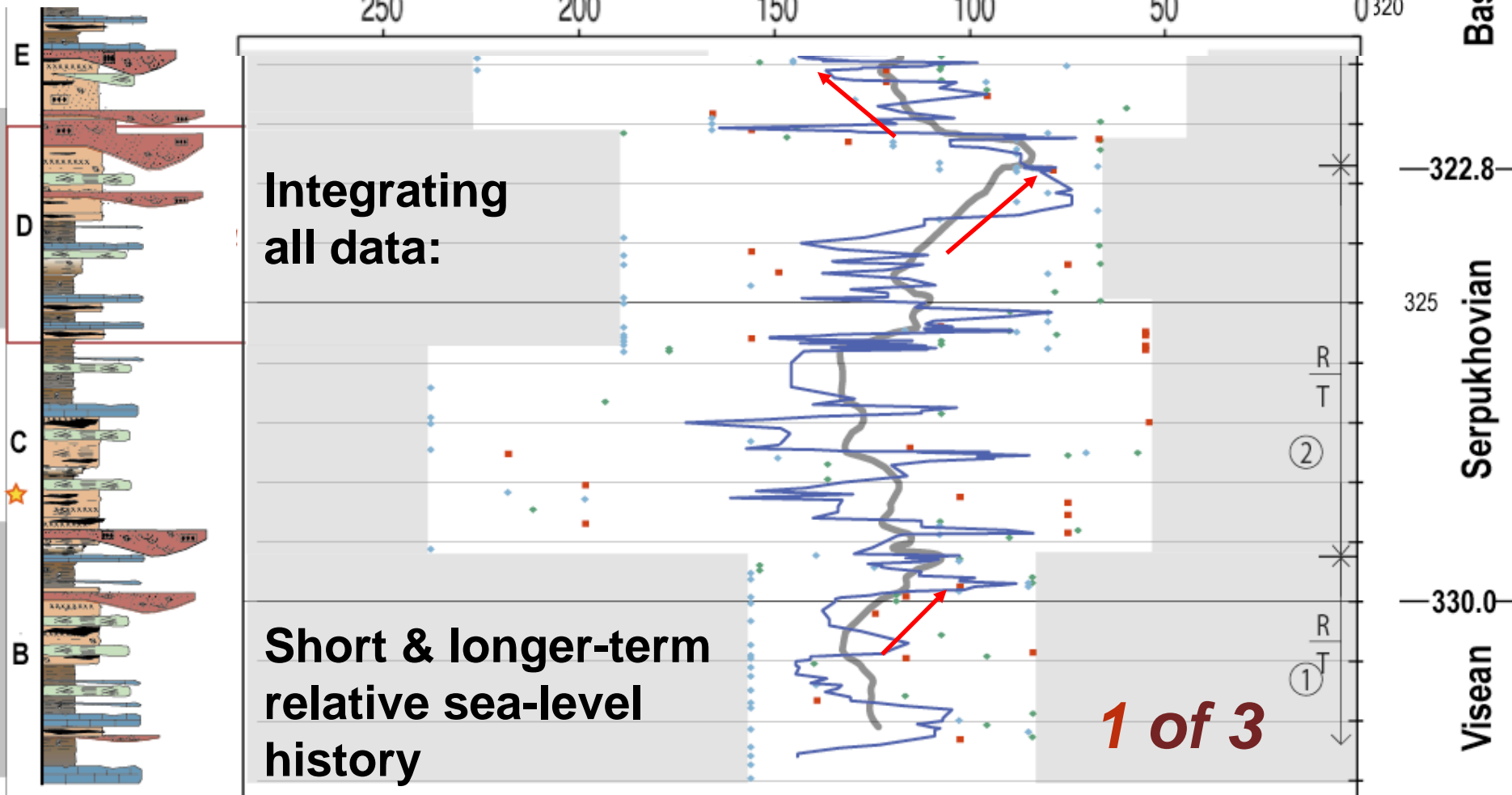
- Maximum landward extent of marine limestone
- Maximum basinward extent of fluvial sandstone
- ◆ Maximum landward extent of transgressive marine sandstone

Relative Sea Level Trend Lines

- 5 point running mean (all points)
- 21 point running mean (all points, smoothed)

Platform area outside of dataset

★ U-Pb age



Donets
Basin
Generalized
Lithology

Long-term Relative Sea Level
Onlap-Offlap Record

Km

—306.65

250

200

150

100

50

0

Integrating
all data: Short &
longer-term relative
sea-level history

2 of 3

R

T

④

310

Moscovian

315

—314.6

③

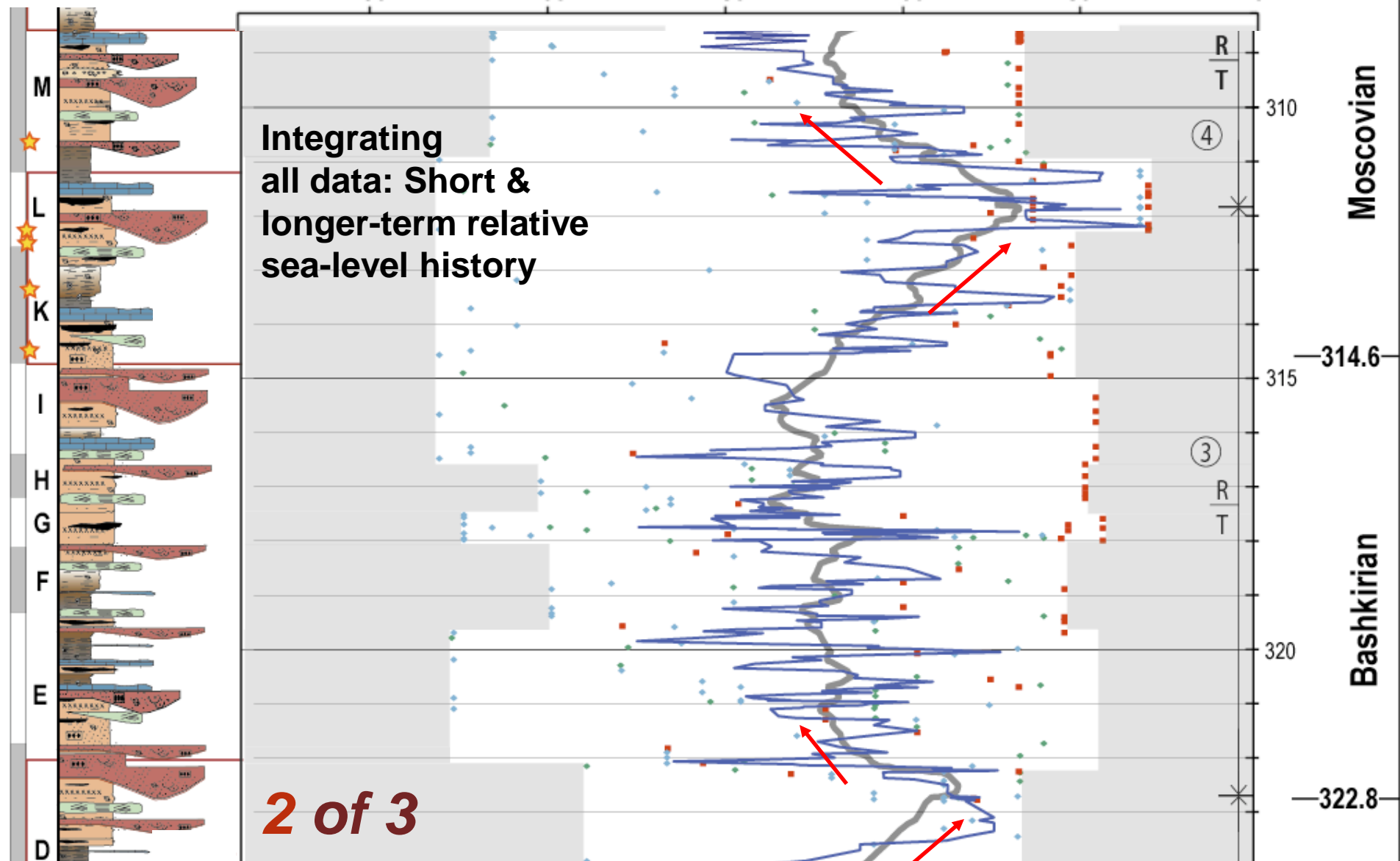
R

T

320

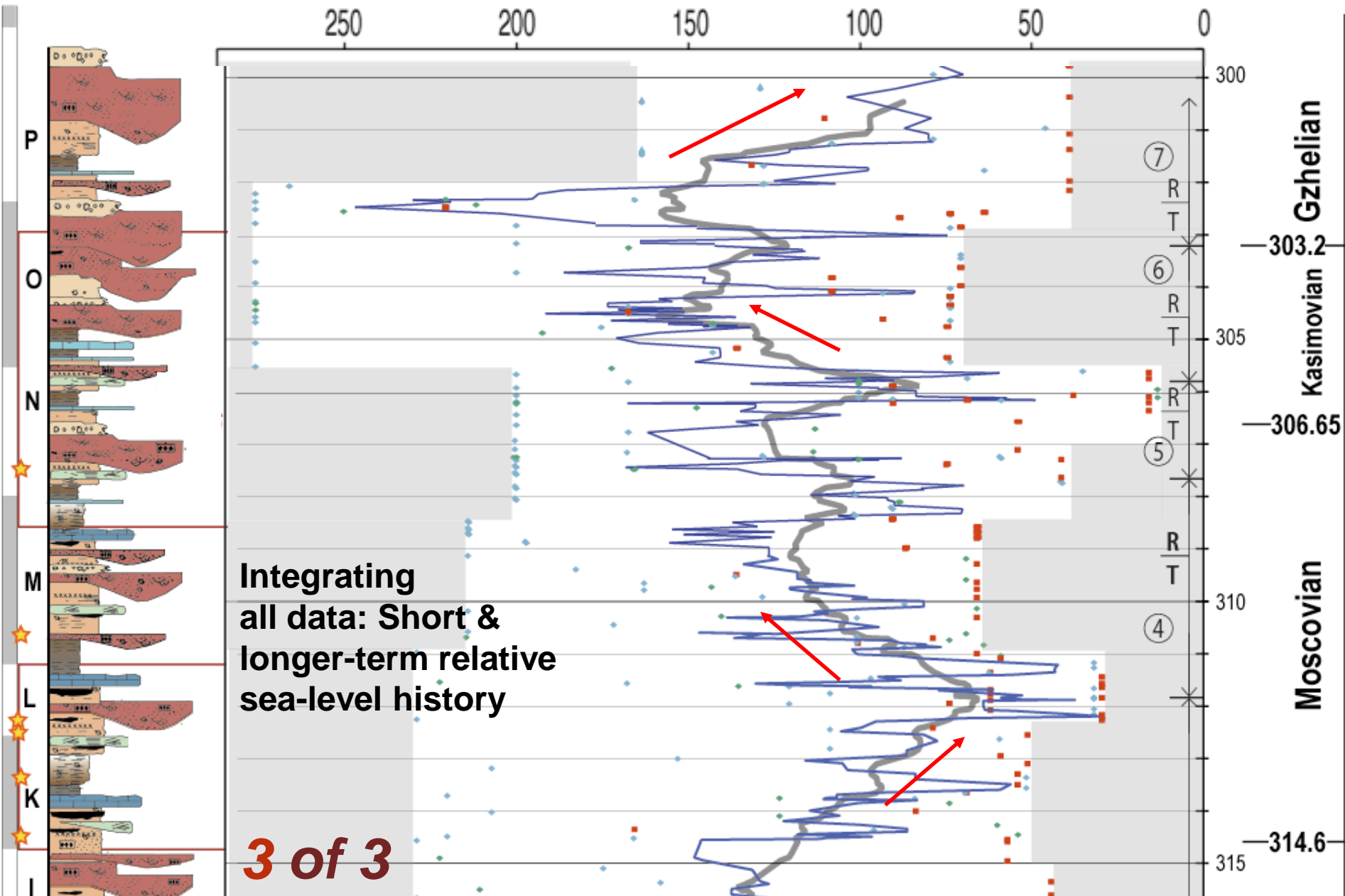
Bashkirian

—322.8



Donets
Basin
Generalized
Lithology

Long-term Relative Sea Level
Onlap-Offlap Record



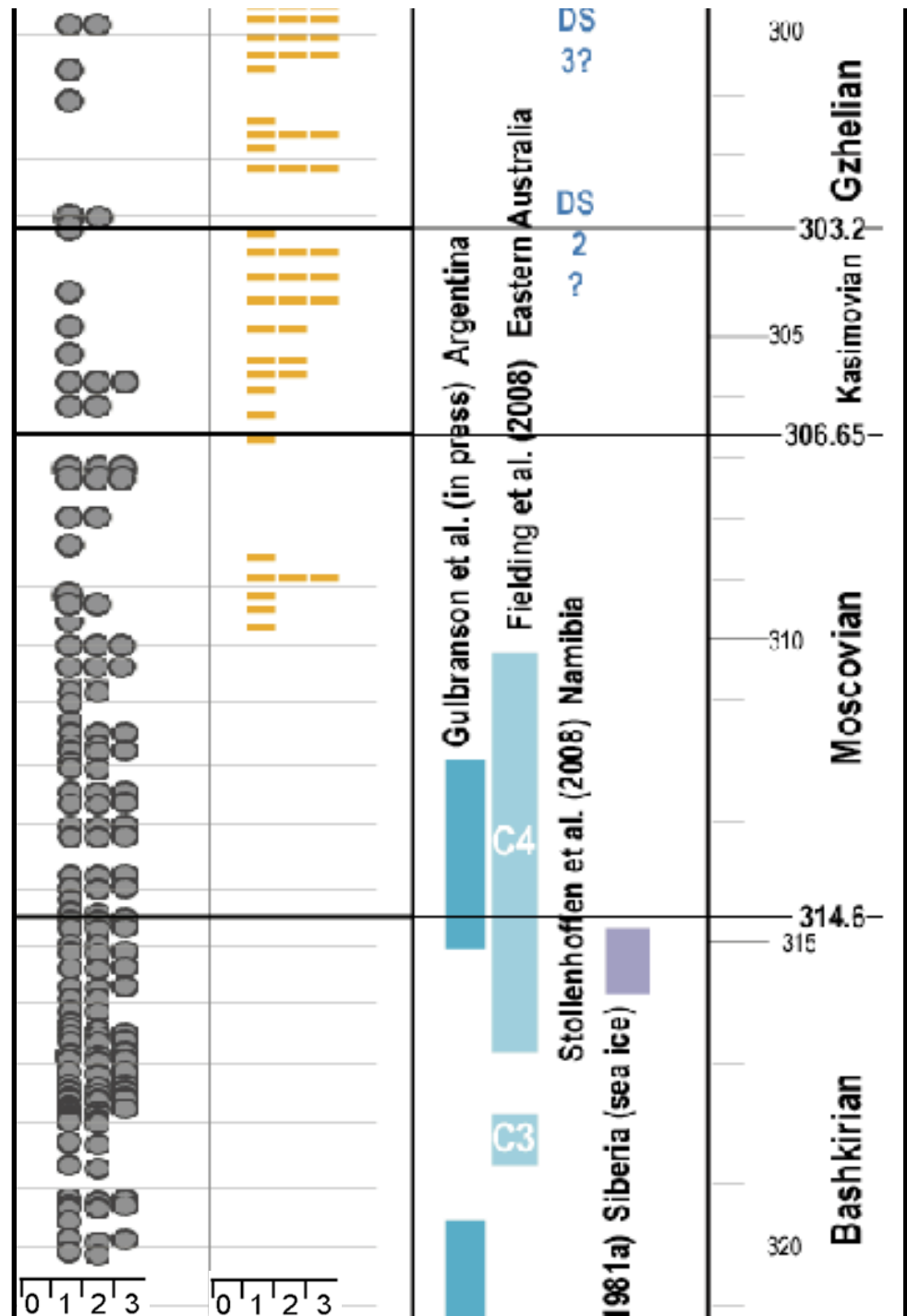


Regional aridity
In late Pennsylvanian:

Earlier than previously
estimated; agrees with
recent work across
Pangea

Relative abundance:

----- Evaporites
●●● Coals

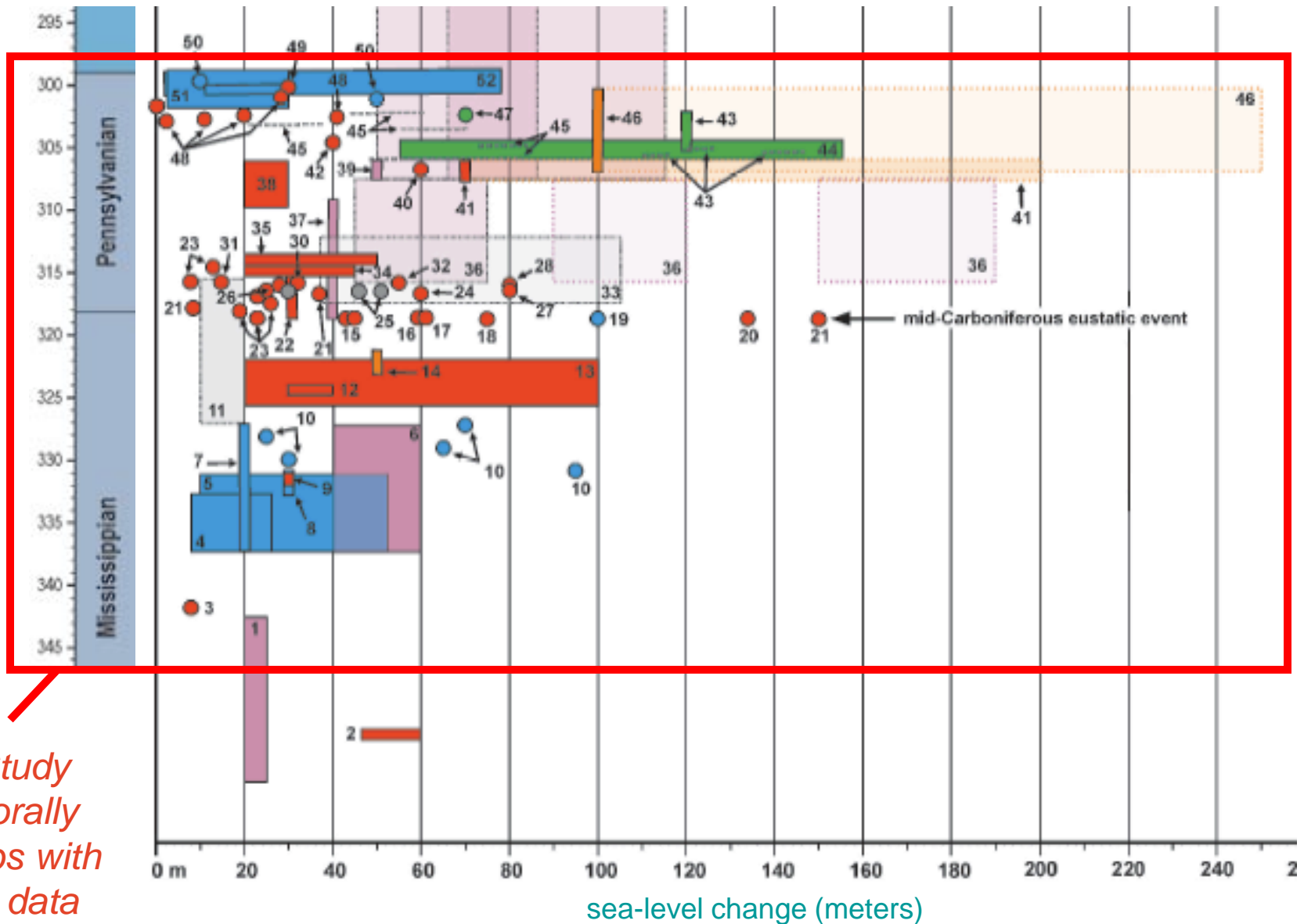


Conclusions:

- The Donets records a hierarchy of relative sea-level changes including multiple 1-4 Myr duration lowstands
- Marked episodes of longer-term sea level fall correlate with recent high latitude records of glaciation
- First U-Pb dated far-field cyclothem record to confirm the dynamic nature of the LPIA
- Newly documented periods of widespread aridity and a prolonged period of highstand in the Late Pennsylvanian

Single phase late Paleozoic Ice Age?

Rygel et al. (2008)



Major Sequence boundaries and marine deposits correlate with pinning point movement on the platform

