Basin Evolution and Coal Geology of the Donets Basin (Ukraine, Russia): Implications for CBM Potential*

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Abstract

The Donets Basin covers an area of 60,000 km². The Carboniferous part of the basin fill hosts about 130 seams (>0.45 m). Coal seams are typically thin (0.6-1.0 m), but have a wide lateral distribution. Total coal thickness is about 60 m. Economic coal seams occur in Serpukhovian to Moscovian strata. Today there are 205 active mines, most of them with workings more than 1000 m deep.

Serpukhovian coals are found along the SW basin margin. The coal is rich in inertinite and liptinite and often very poor in ash and moderate in sulfur. Bashkirian and Moscovian seams have a significantly wider areal extent, with some seams covering the entire Donets Basin. These seams usually contain vitrinite-rich coal with high ash yields and high sulphur contents.

The coal is generally of meta-anthracite rank. Low-rank coals are restricted to the western and northern basin margins. The rank of the coal is controlled by temperatures during maximum (Permian) burial. The resulting coalification pattern was overprinted by a Permo-Triassic heating event, most probably caused by magmatic intrusions. Fission track data suggest a complex uplift history with late Permian and late Cretaceous cooling episodes.

Coal mines in the Donets Basin are among the gassiest in the world. The average methane content is 14.7 m³/t, but some seams even contain more than 100 m³/t mined coal. The high methane content presents a severe mine safety problem, but also represents a high potential for CBM projects. The isotopic and chemical composition indicate the thermogenic origin of methane. Methane occurs within the coal seam, but also within sandstone reservoirs. There is a clear depth dependency of the gas composition. Within the uppermost few hundred meters CH_4 is often missing and N, and CO, are prevailing (gas weathering zone). Below this zone follows a

transition zone and the methane zone with more than 70% CH_4. The thickness of the gas weathering zone is probably related to the present day stress field.

There are large areas with high rank coals within the Donets Basin where no methane, but significant amounts of CO_2 occur (up to 35 m^3/t coal). Perhaps the lack of methane is due to demethanization during major uplift and the occupation of the free space by CO_2. The Donets Basin thus may serve as a natural laboratory for CO_2 sequestration in coal seams.

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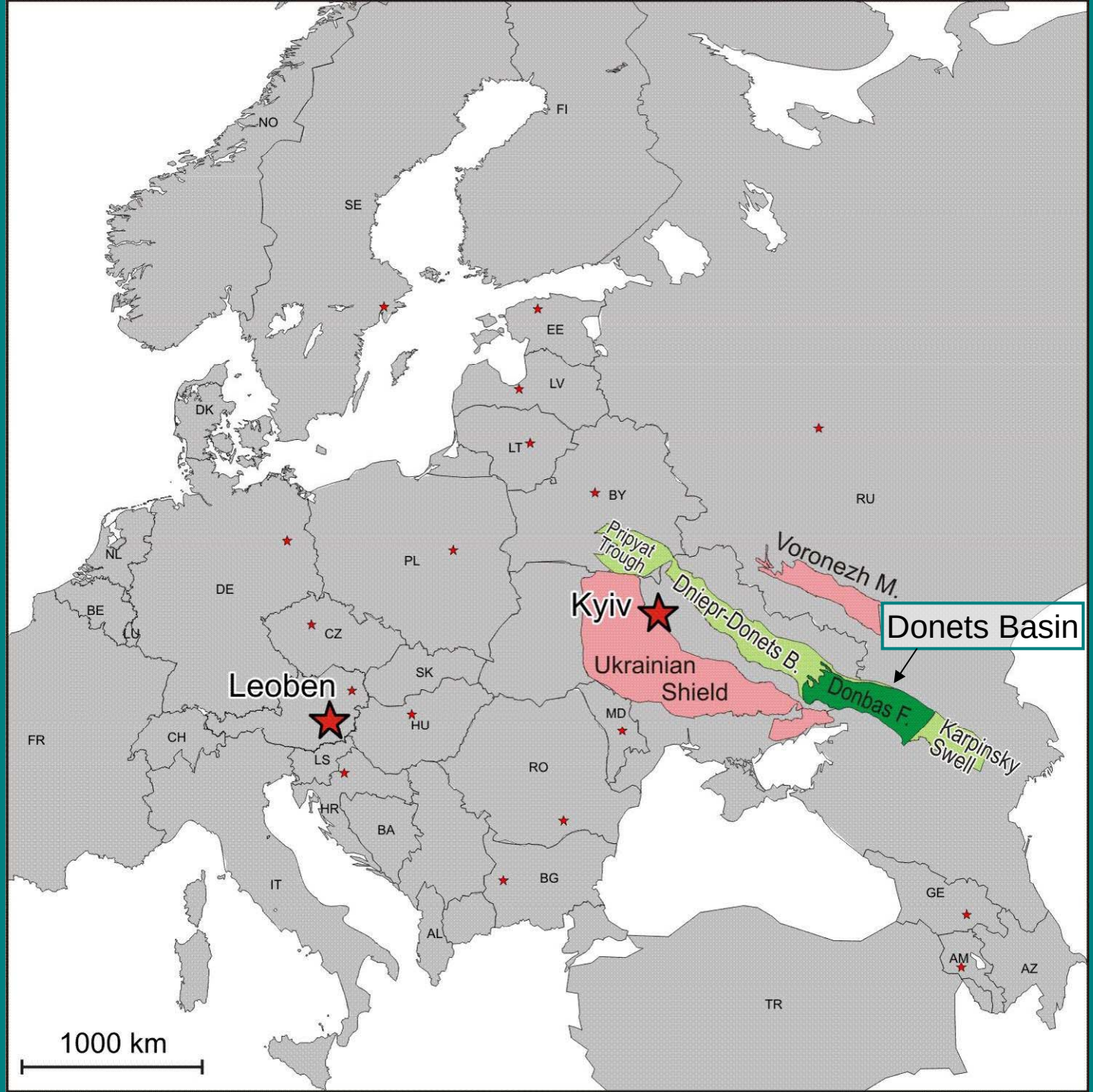
Donetsk National Technical University, Ukraine


NO
FI
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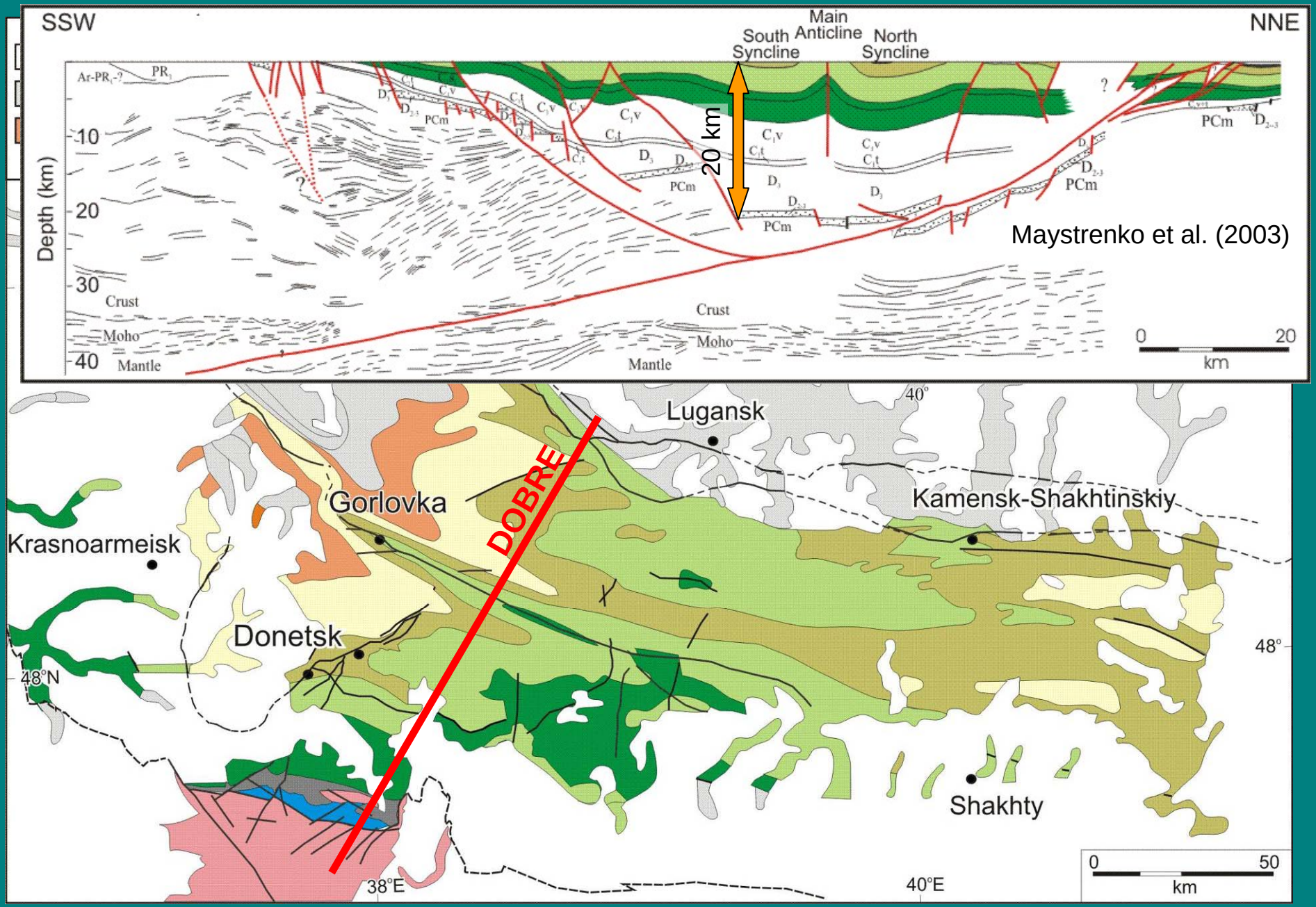
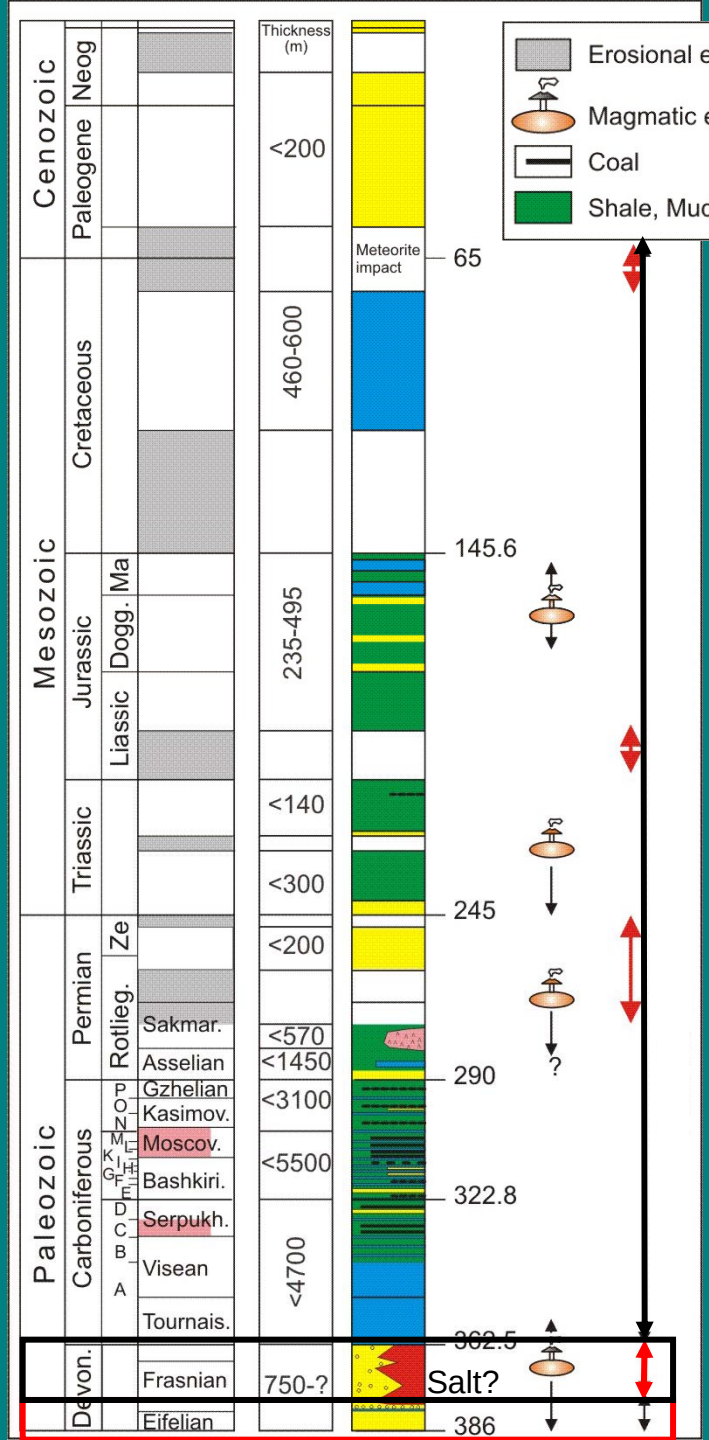
DE
BE
LU
CZ
SK
FR
CH
HU
MD
LS
RO
HR
BA
IT
BG
AL
GE
AM
AZ
TR
Pripyat Trough
Dniepr-Donets B.
Voronezh M.
Kyiv
Donets Basin
Ukrainian Shield
Donbas F.
Karpinsky Swell
Leoben
1000 km


SSW
NNE
Main Anticline
South Syncline
North Syncline
Depth (km)
10
20
30
40
20 km
Crust
Moho
Mantle
PCm
0
20
km
Maystrenko et al. (2003)
Lugansk
40°
Gorlovka
DOBRE
Kamensk-Shakhtinskiy
Krasnoarmeisk
Donetsk
48°N
48°
Shakhty
38°E
40°E
0
50
km

Contents

- Basin Evolution
- Carboniferous Basin Fill
- Coal Seams
- Maturity / Thermal History
- Basin Uplift
- Gas in Coal (Methane, CO_2)
- Summary



Erosional event
Magmatic event
Coal
Shale, Mudstone
Sandstone/Congl.
Carbonate
Salt/Anhydrite
Volcanic rocks

Uplift/erosion
Basin inversion

Cimmerian
Compression

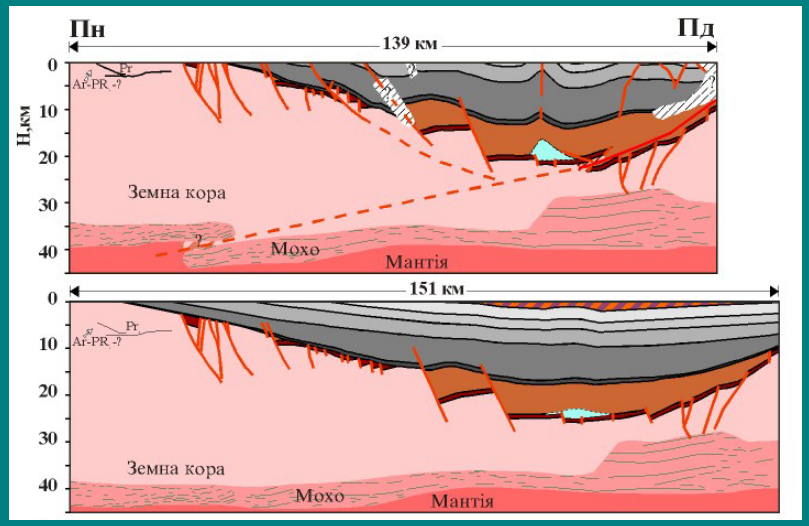
Uplift/erosion
(Basin inversion /
Transtension?)

Post-Rift

Syn-Rift

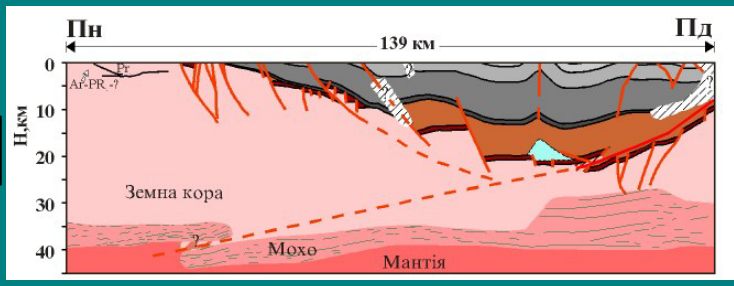
Pre-Rift

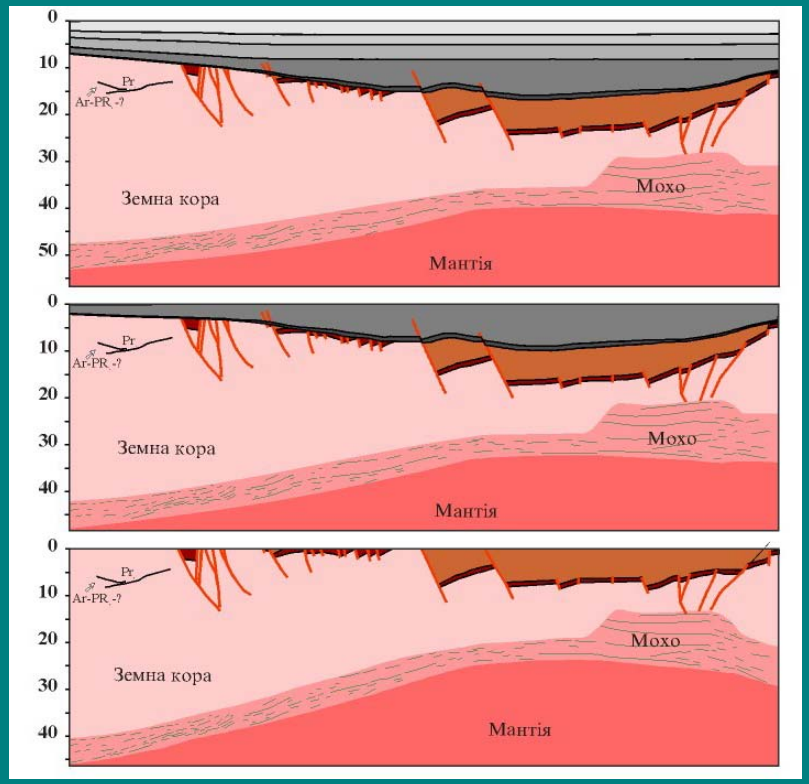
S N



Cret./Tertiary

Upper Permian





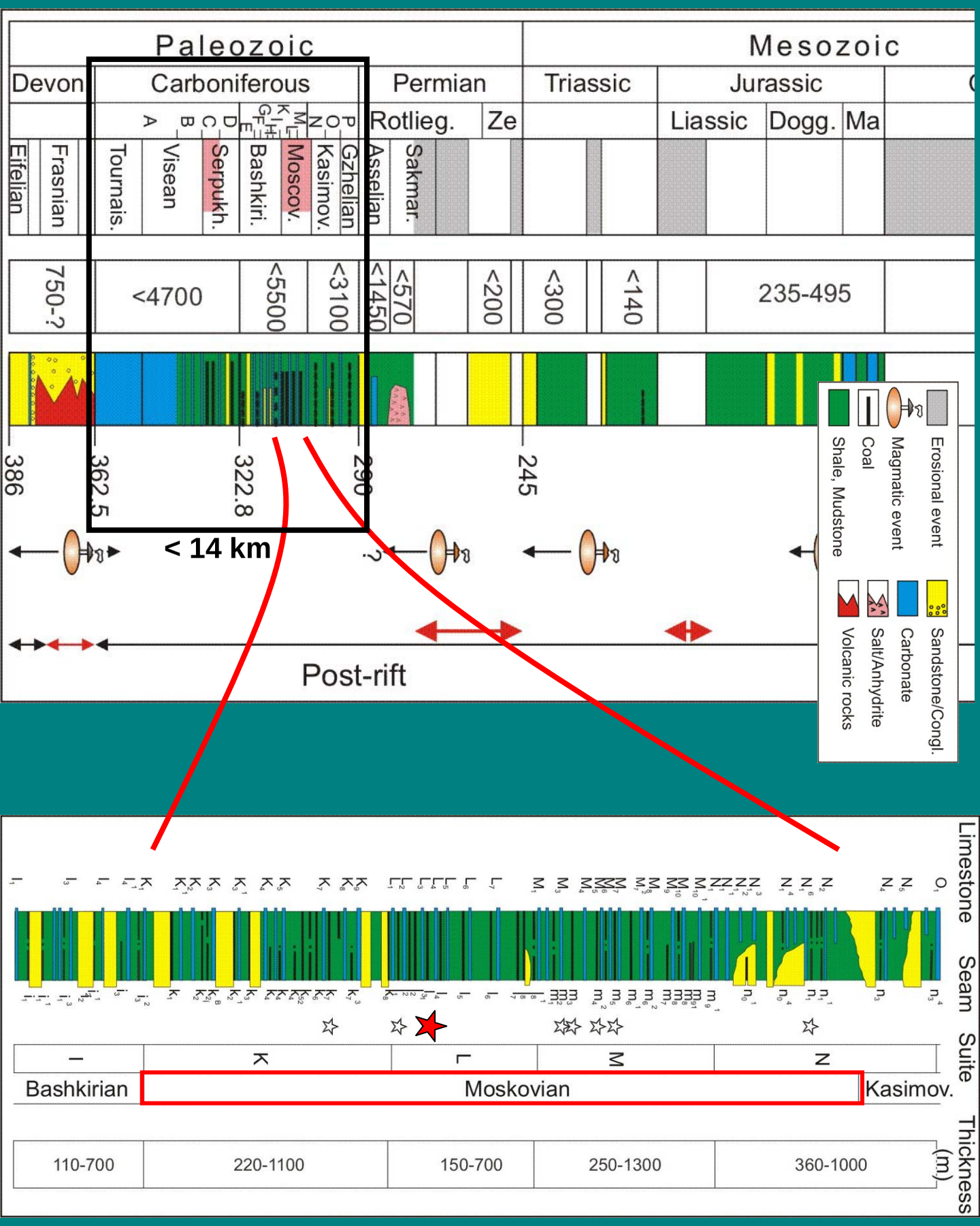
Up.-Carb.

Lower Carboniferous

Devonian

Stovba et al., 2003

Carboniferous Basin Fill



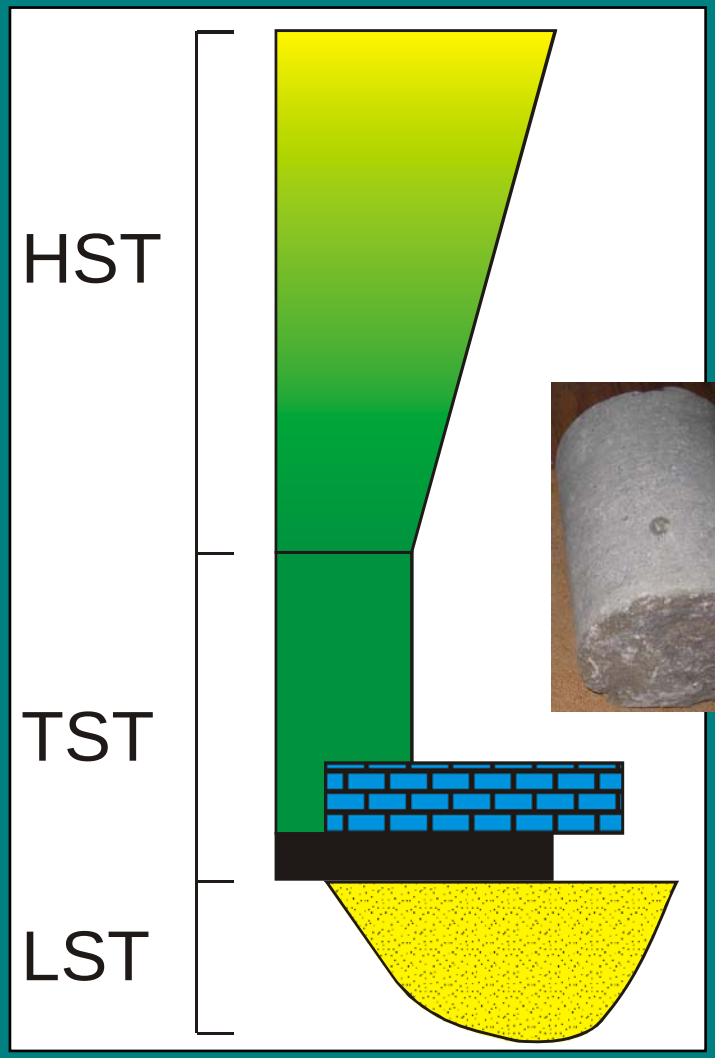
Levenshtein et al. (1991)

High Frequency Cycle

Delta deposits

Marine shale

Coal



MS 598/599

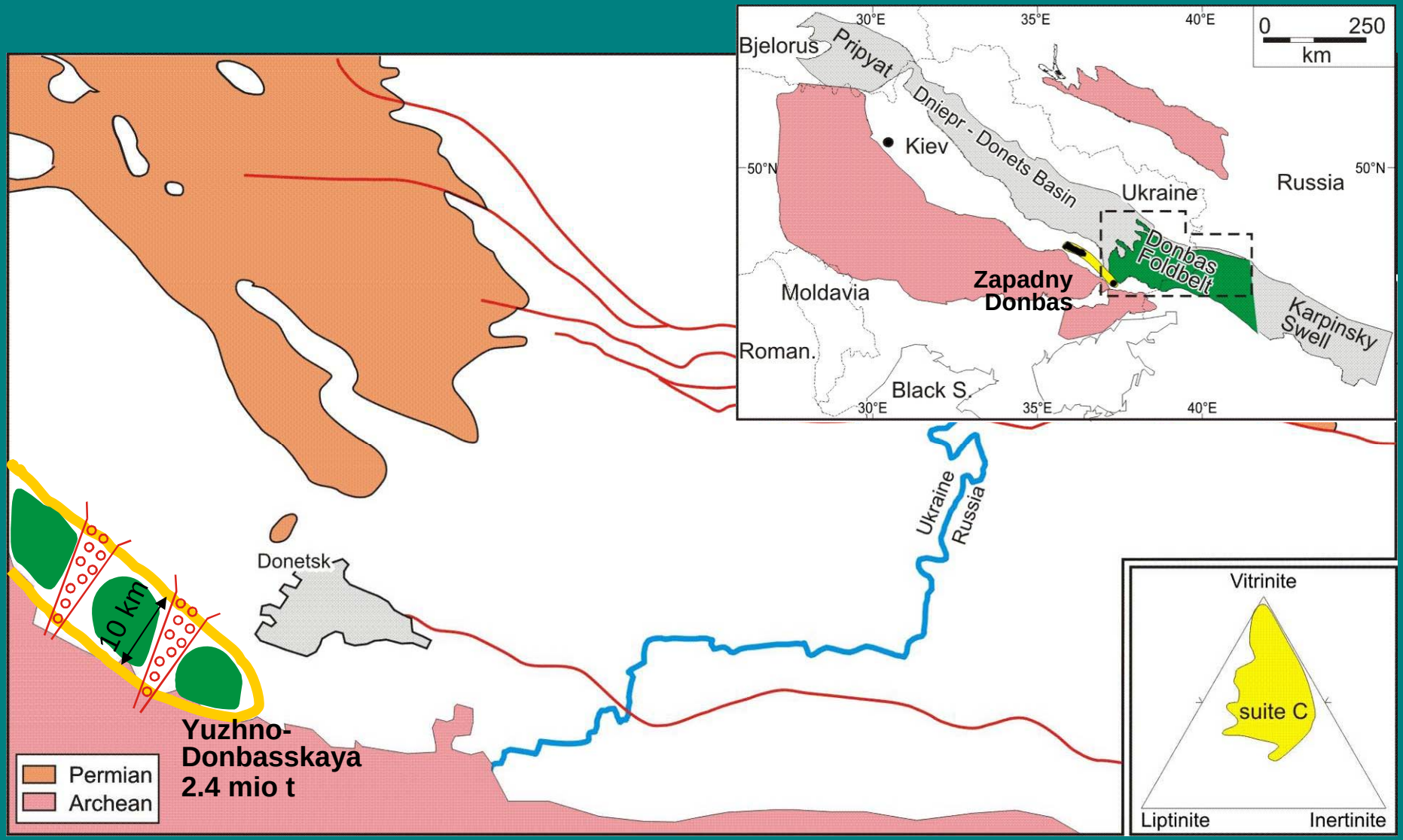
Marine limestone

Fluvial channel

Coal Seams

- 300 seams and layers are known.
- 106 seams are > 0.5 m thick
- 12 seams are > 1.0 m thick
- Seams > 2.0 m are exceptional

Serpukhovian coal (Suite C)

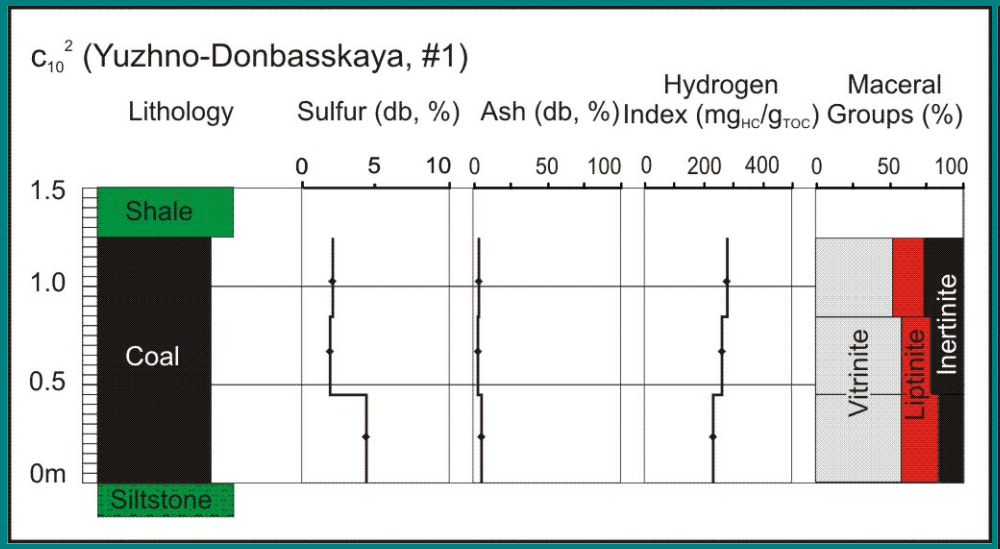


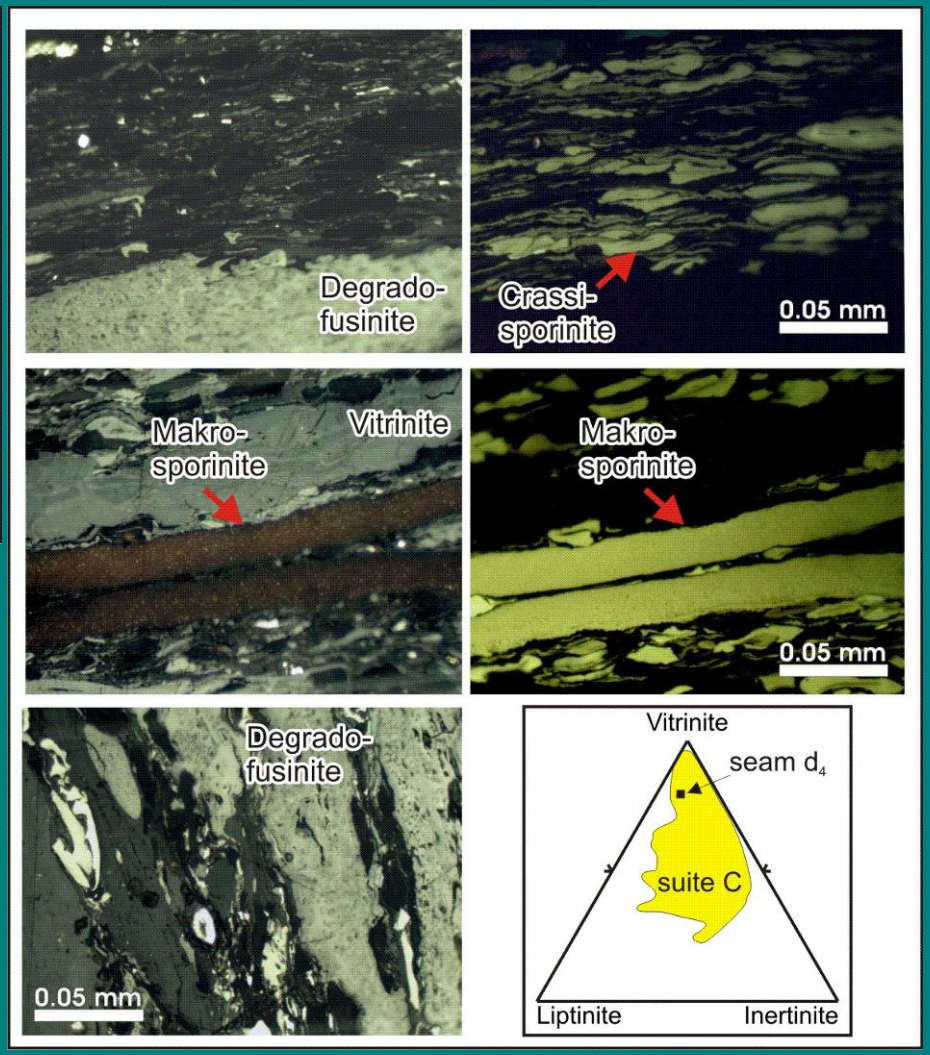
Lagoonal floor/roof rocks
Rapid subsidence (Shulga, 1981)

Privalov et al. (2004)

Reflected white light

Fluorescence mode

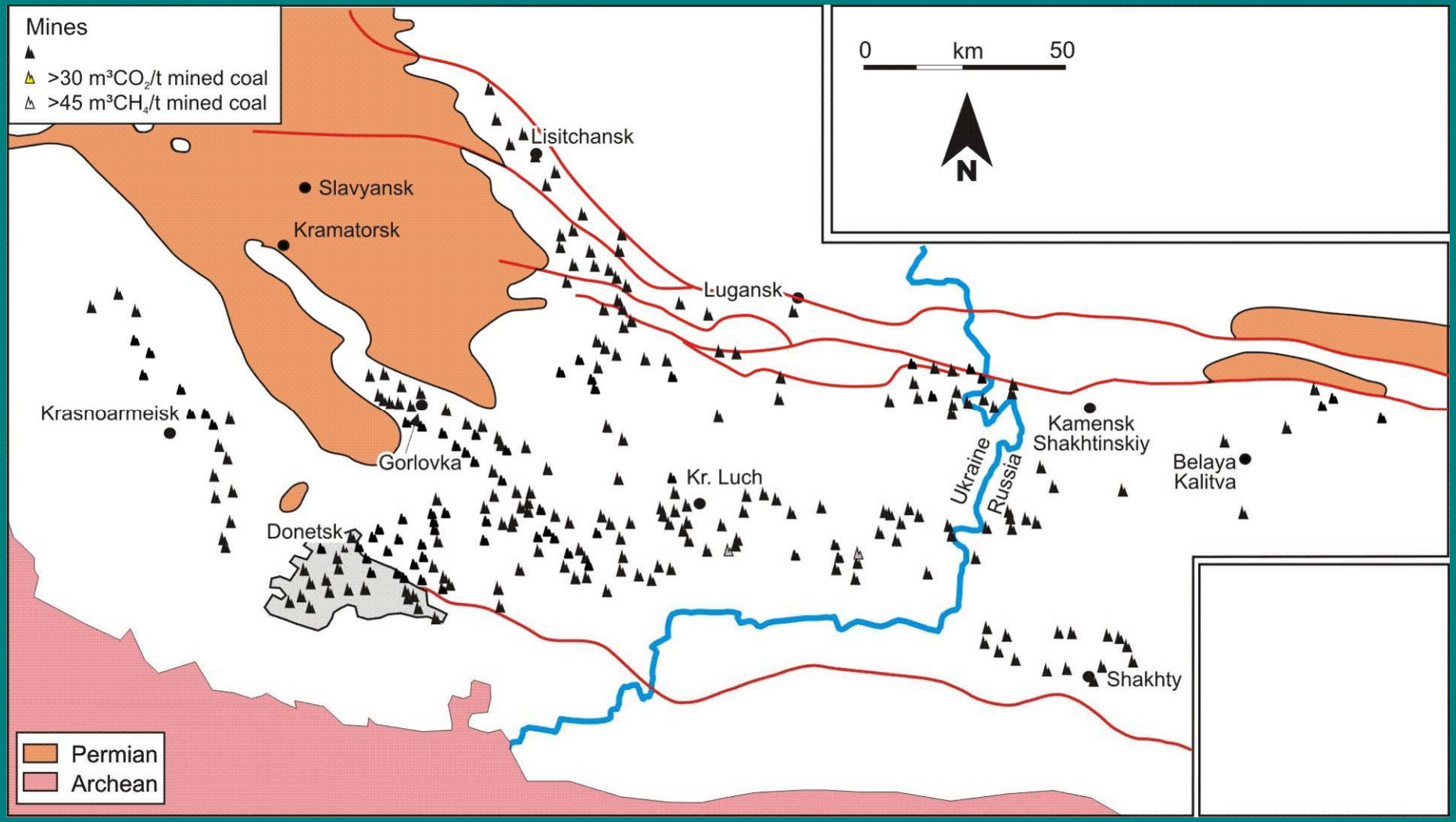




Serpukhovian Coal

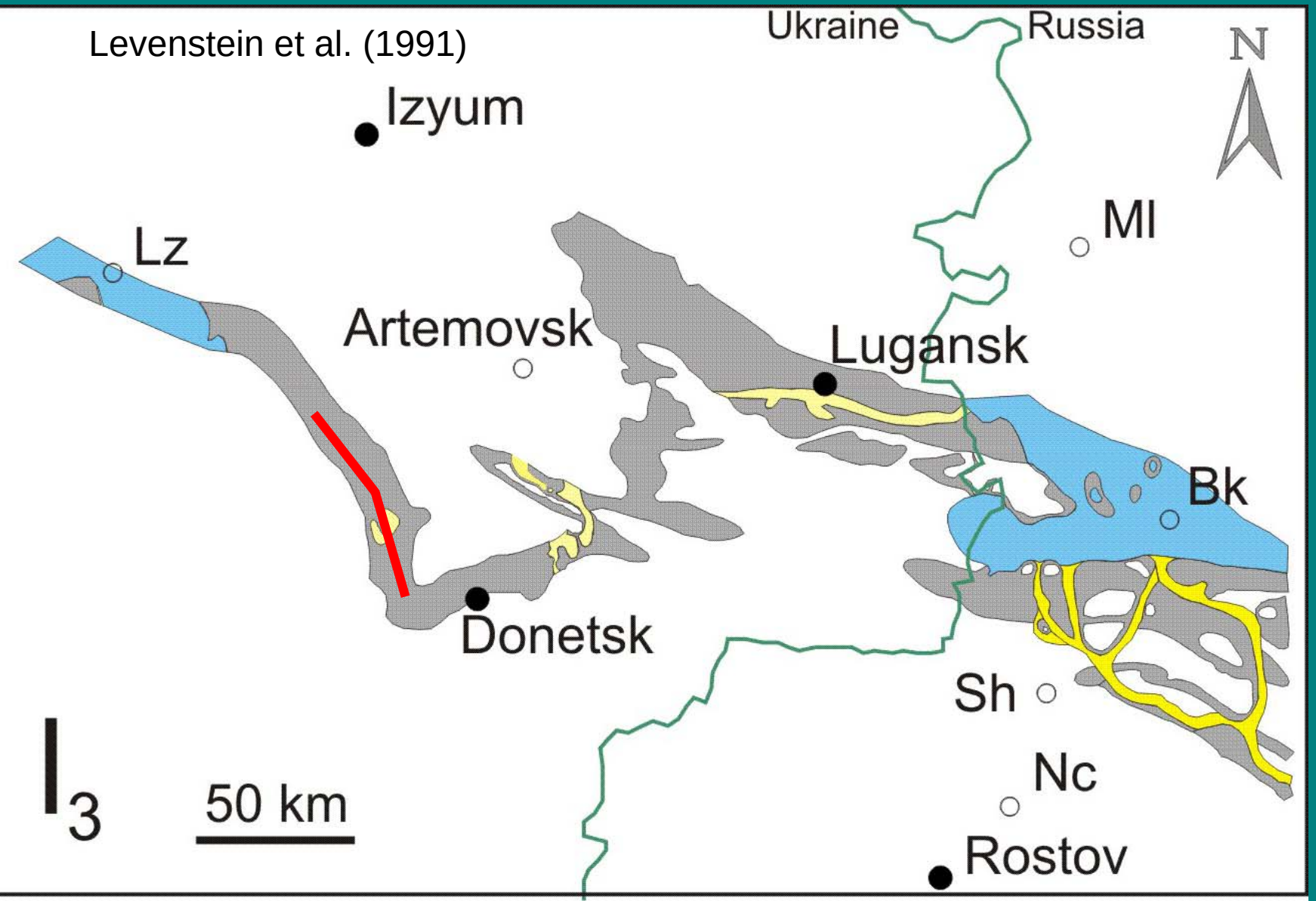
- H-rich
- oil prone

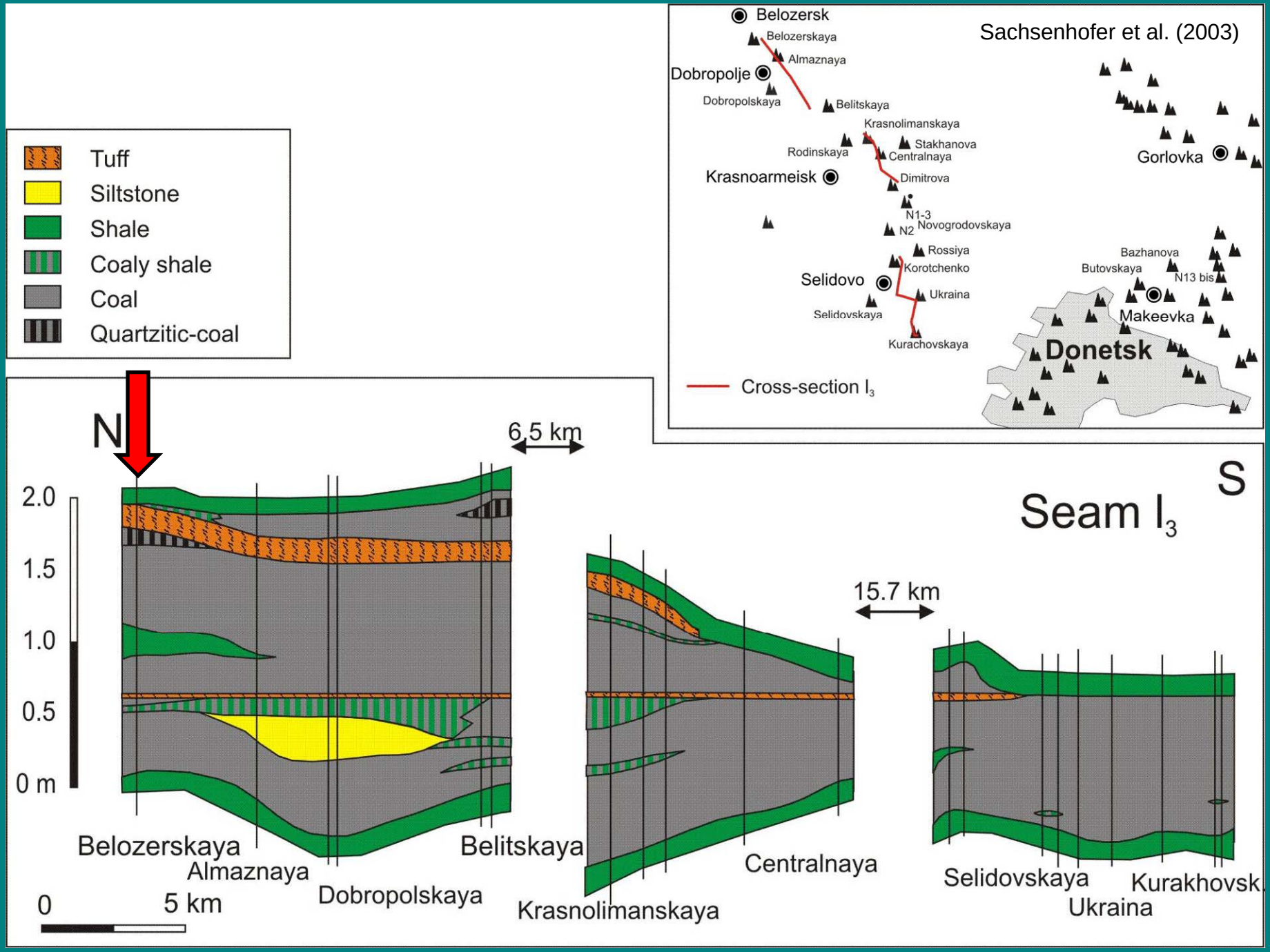
Bashkirian/Moscovian coal (Suite E-N)

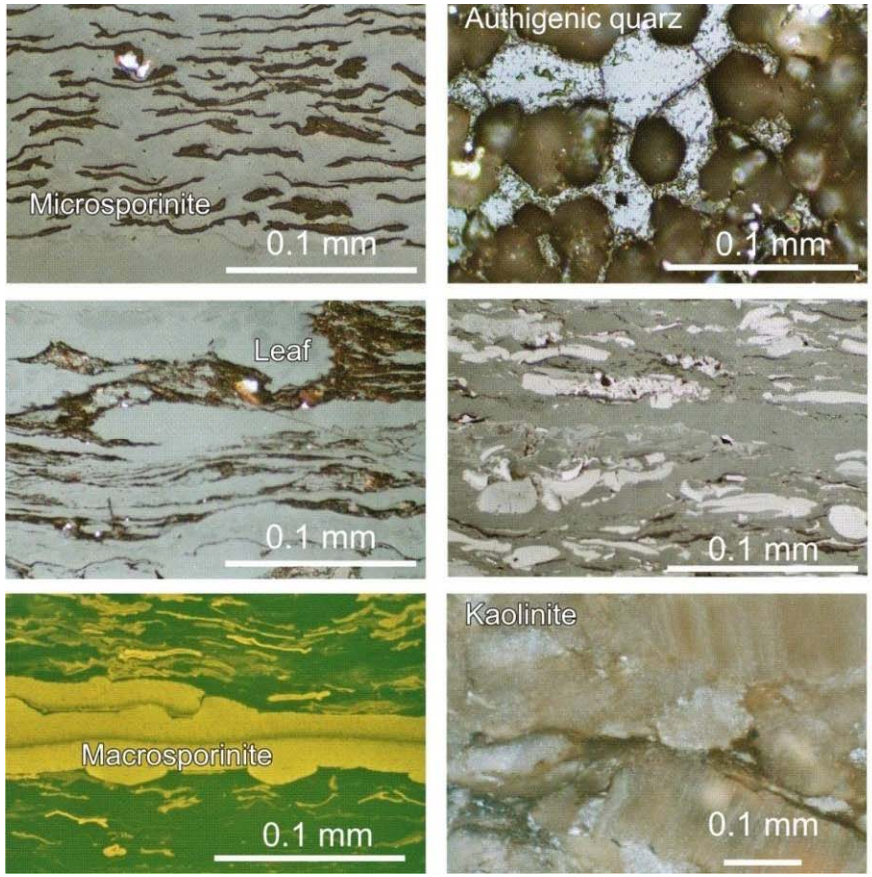


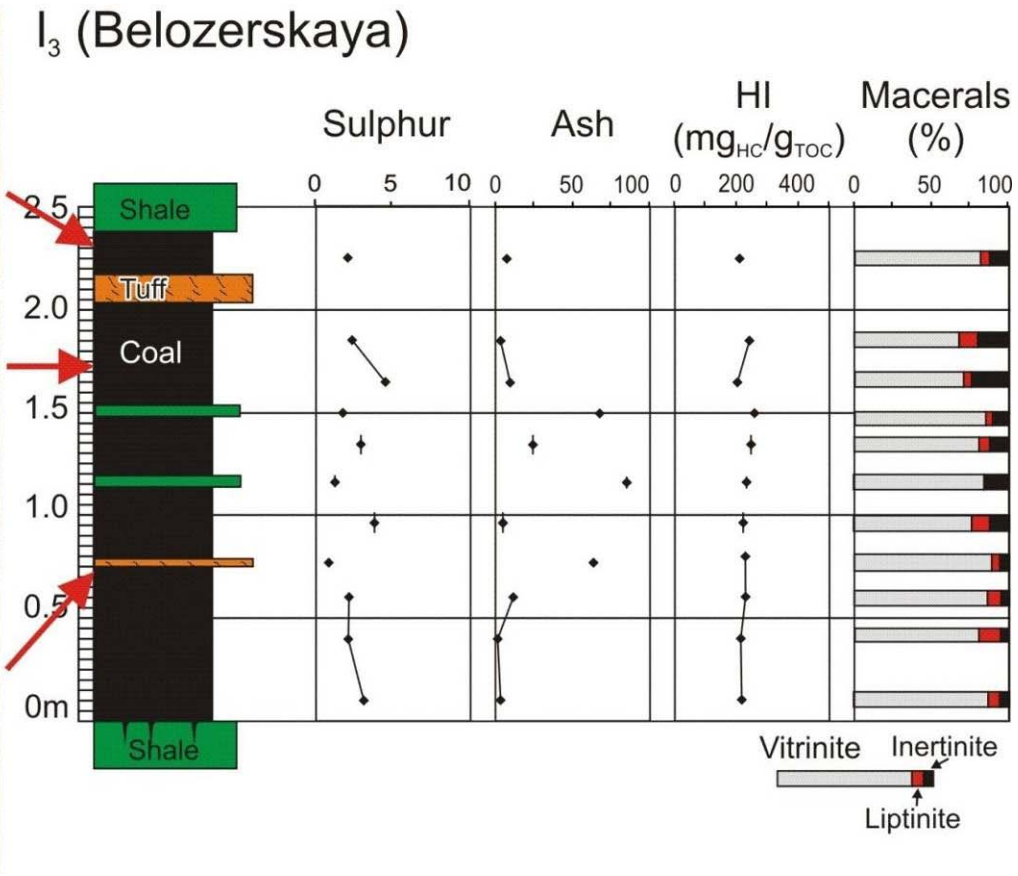
Distribution of seam l_3 (0 - 2 km depth)

- exploited in 48 mines




Sachsenhofer et al. (2003)
Tuff
Siltstone
Shale
Coaly shale
Coal
Quartzitic-coal
Belozersk
Belozerskaya
Almaznaya
Dobropolje
Dobropolskaya
Belitskaya
Krasnolimanskaya
Stakhanova
Rodinskaya
Centralnaya
Krasnoarmeisk
Dimitrova
N1-3
N2
Novogrodovskaya
Rossiya
Korotchenko
Selidovo
Ukraina
Selidovskaya
Kurachovskaya
Gorlovka
Bazhanova
Butovskaya
N13 bis
Makeevka
Donetsk
Cross-section l3
N
S
6.5 km
15.7 km
Seam l3
2.0
1.5
1.0
0.5
0 m
0
5 km
Belozerskaya
Almaznaya
Dobropolskaya
Belitskaya
Krasnolimanskaya
Centralnaya
Selidovskaya
Ukraina
Kurakhovsk



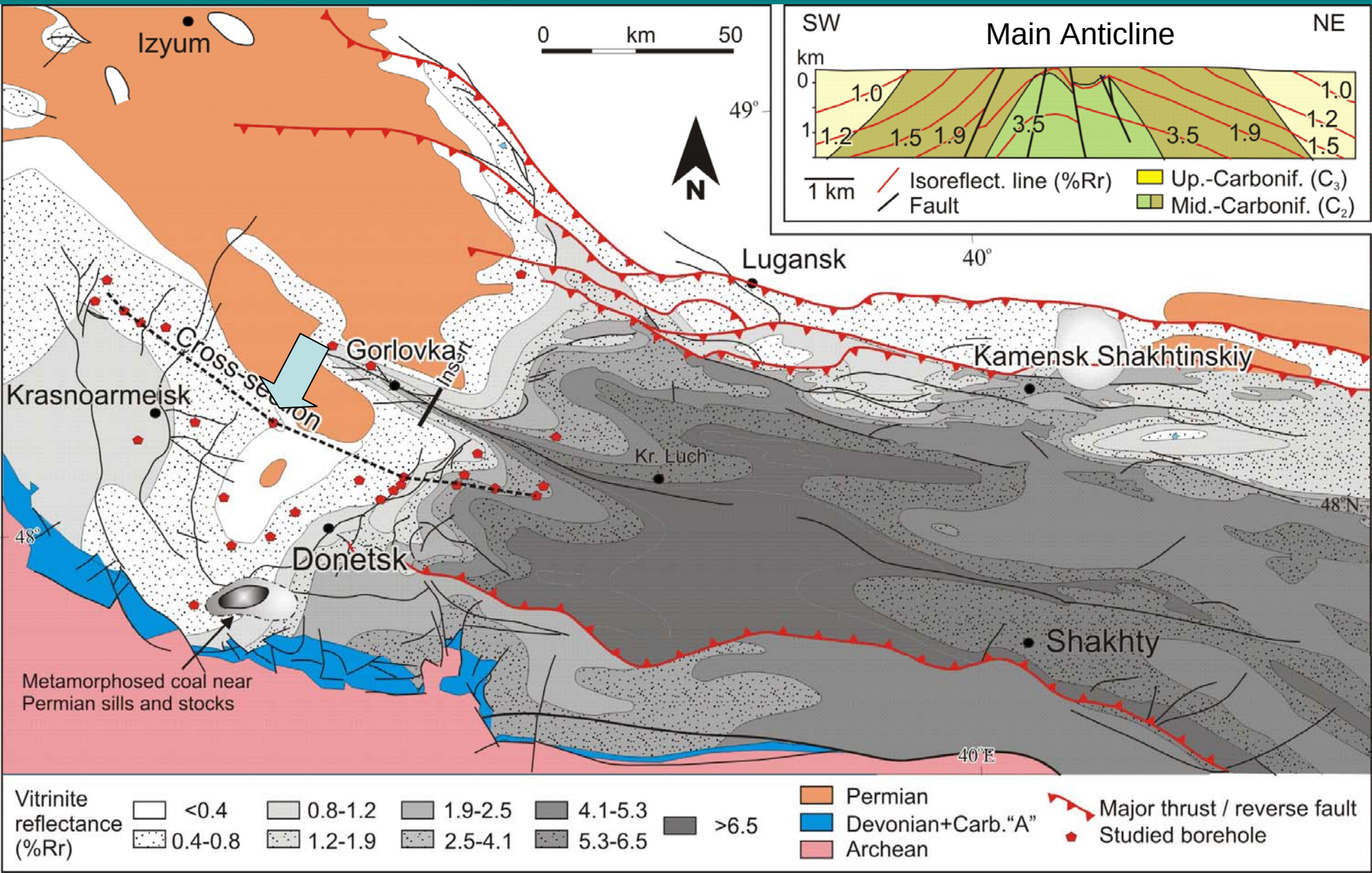


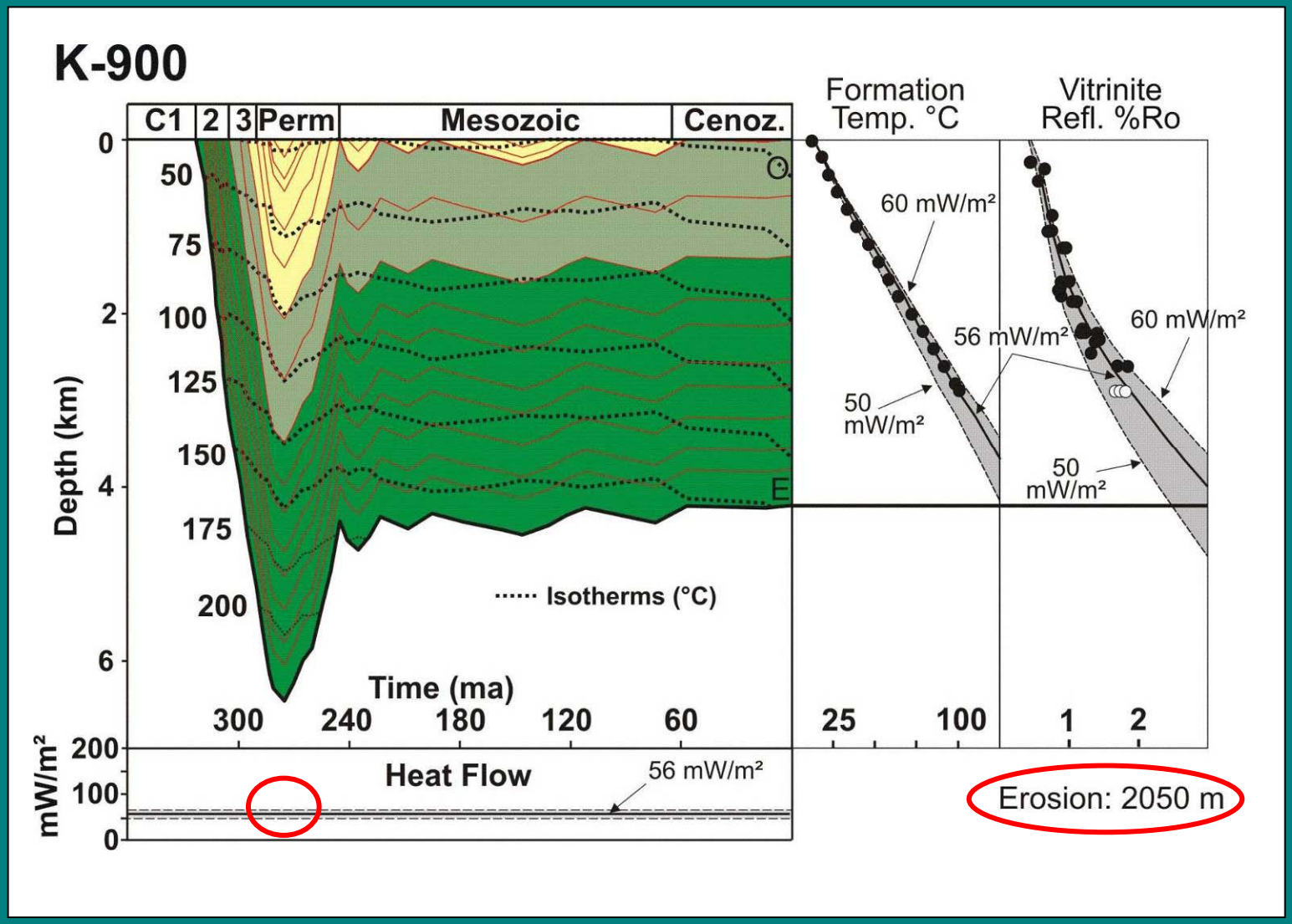
(Sachsenhofer et al., 2003)

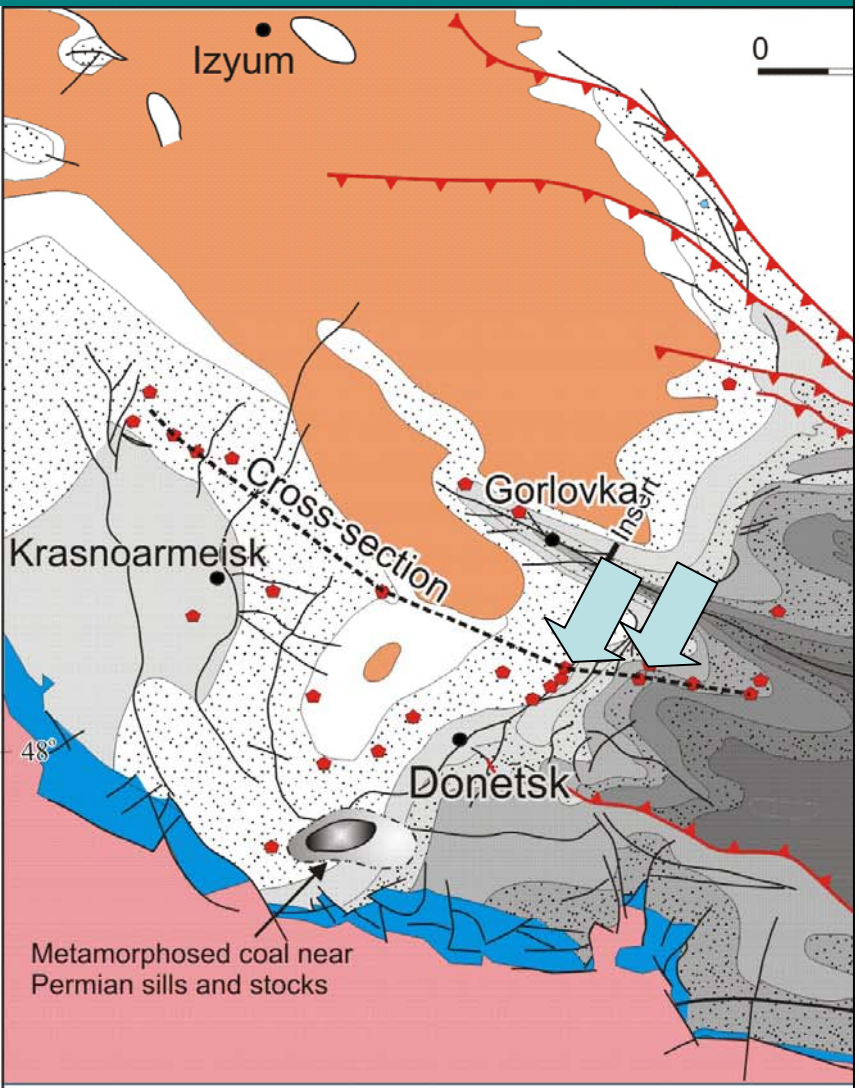
Maturity / Thermal History

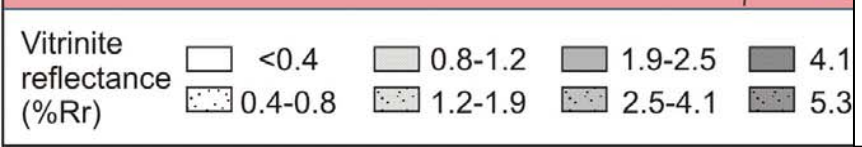
(Levenshtein et al., 1991)

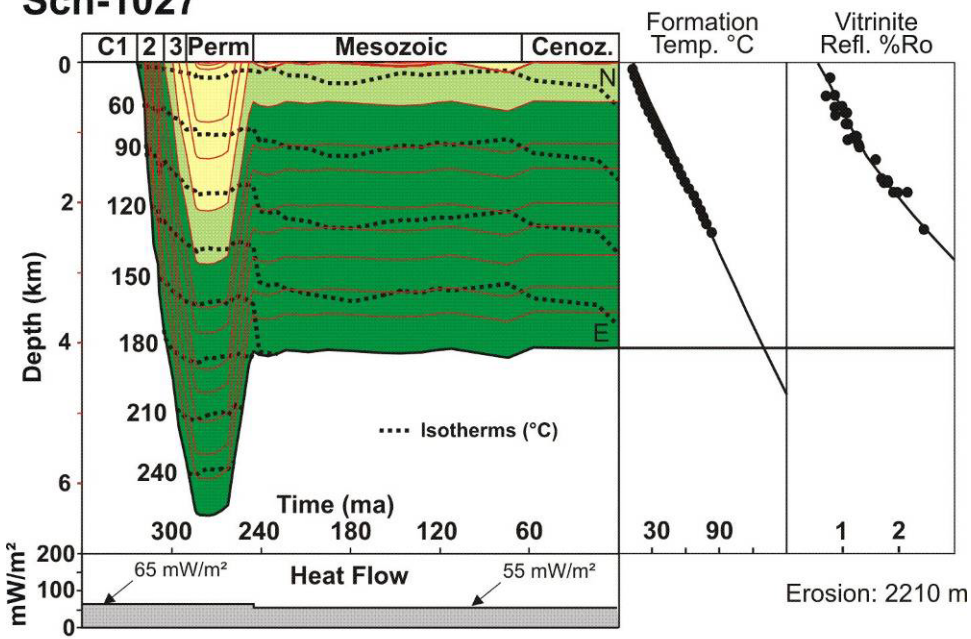
VR at Top Carboniferous

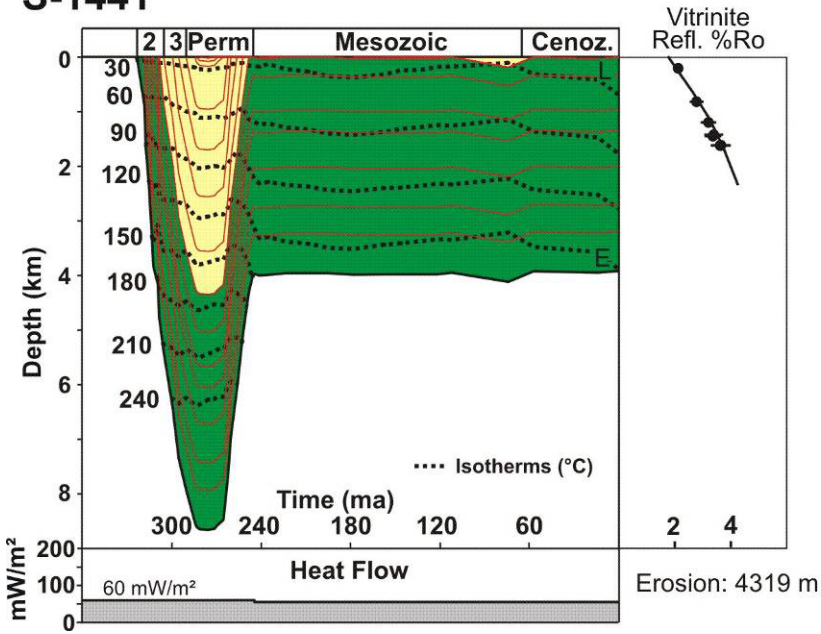


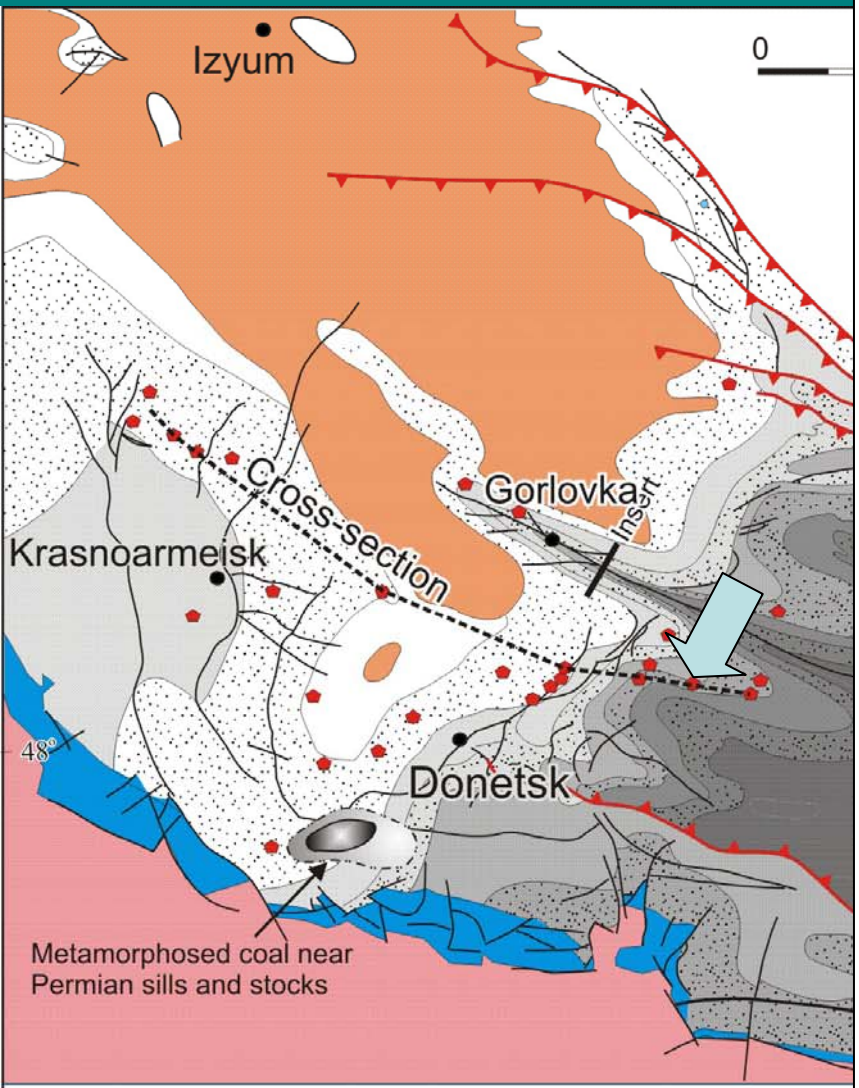

K-900
C1
2
3
Perm
Mesozoic
Cenoz.
Formation Temp. °C
Vitrinite Refl. %Ro
60 mW/m²
56 mW/m²
50 mW/m²
60 mW/m²
50 mW/m²
Depth (km)
0
2
4
6
50
75
100
125
150
175
200
Isotherms (°C)
Time (ma)
300
240
180
120
60
25
100
1
2
mW/m²
200
100
0
Heat Flow
56 mW/m²
Erosion: 2050 m


Izyum
0
Cross-section
Krasnoarmeisk
Gorlovka
Insert
48°
Donetsk
Metamorphosed coal near
Permian sills and stocks


Vitrinite
reflectance
(%Rr)
<0.4
0.4-0.8
0.8-1.2
1.2-1.9
1.9-2.5
2.5-4.1
4.1
5.3

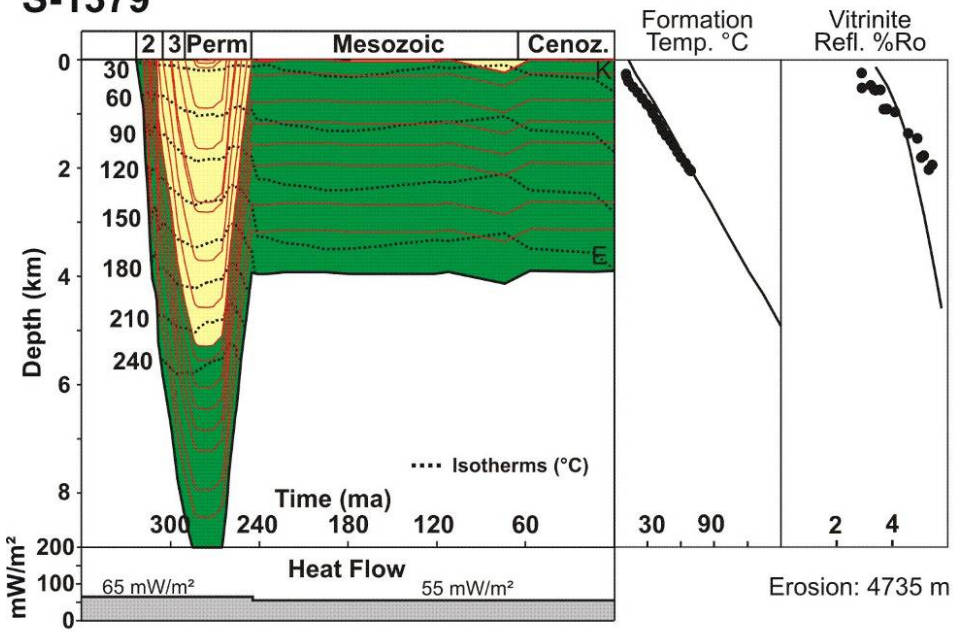

Sch-1027
C1
2
3
Perm
Mesozoic
Cenoz.
Formation
Temp. °C
Vitrinite
Refl. %Ro
N
E
Depth (km)
Isotherms (°C)
Time (ma)
300
240
180
120
60
30
90
1
2
mW/m²
65 mW/m²
Heat Flow
55 mW/m²
Erosion: 2210 m

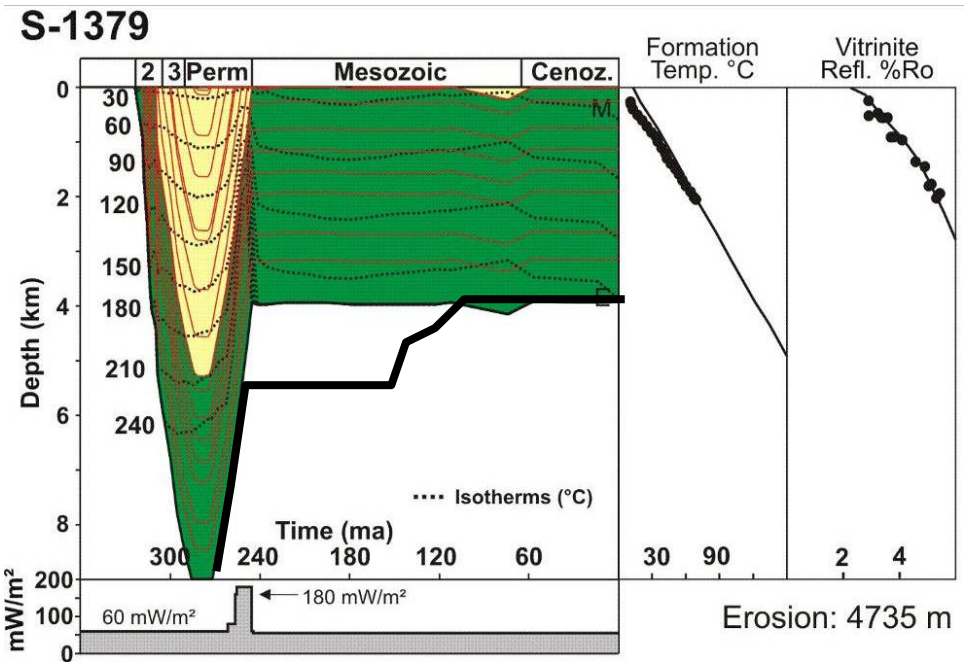

S-1441
2
3
Perm
Mesozoic
Cenoz.
Vitrinite
Refl. %Ro
L
E
Depth (km)
Isotherms (°C)
Time (ma)
300
240
180
120
60
2
4
mW/m²
Heat Flow
60 mW/m²
Erosion: 4319 m

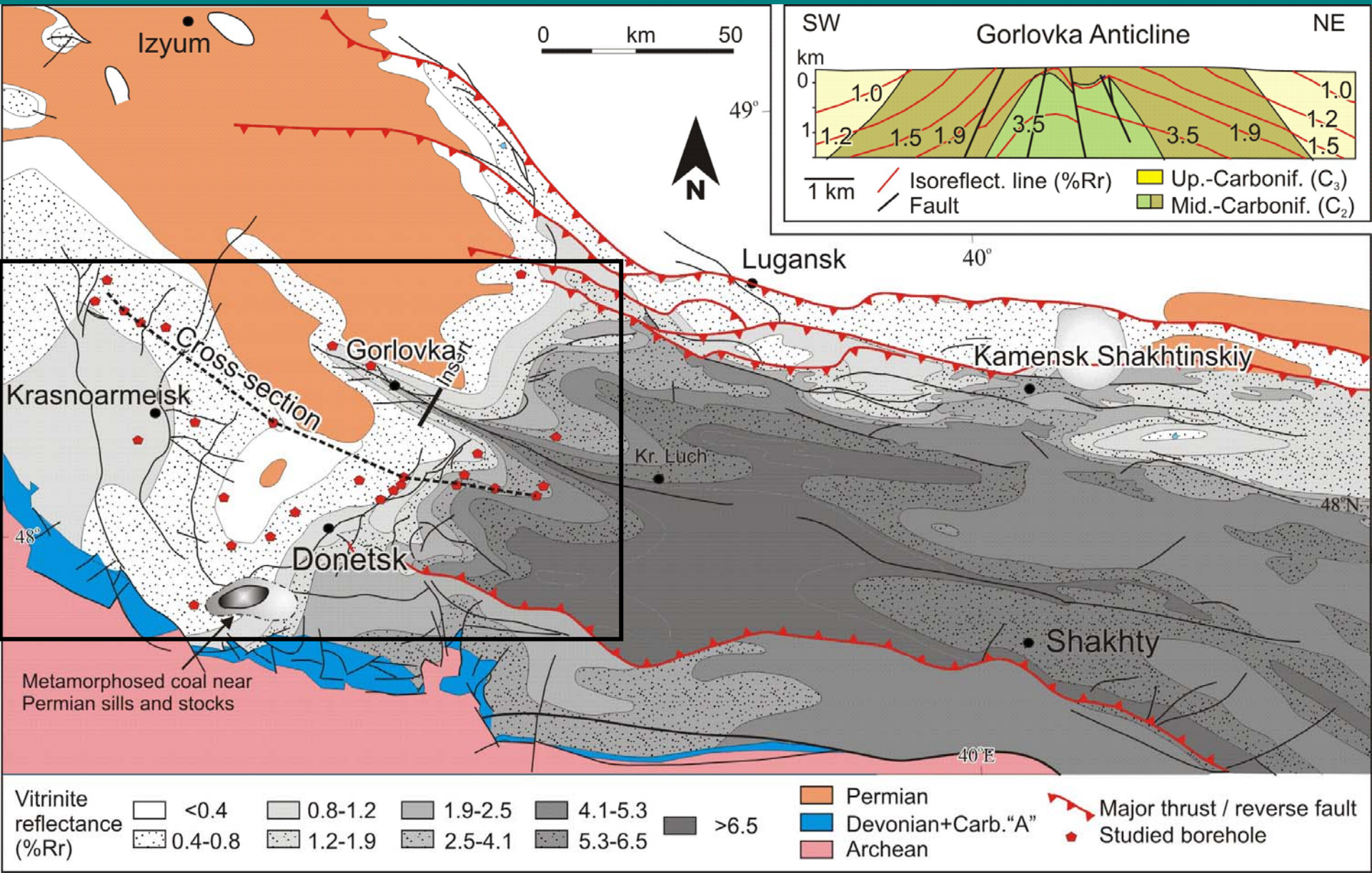


Vitrinite reflectance (%Rr)

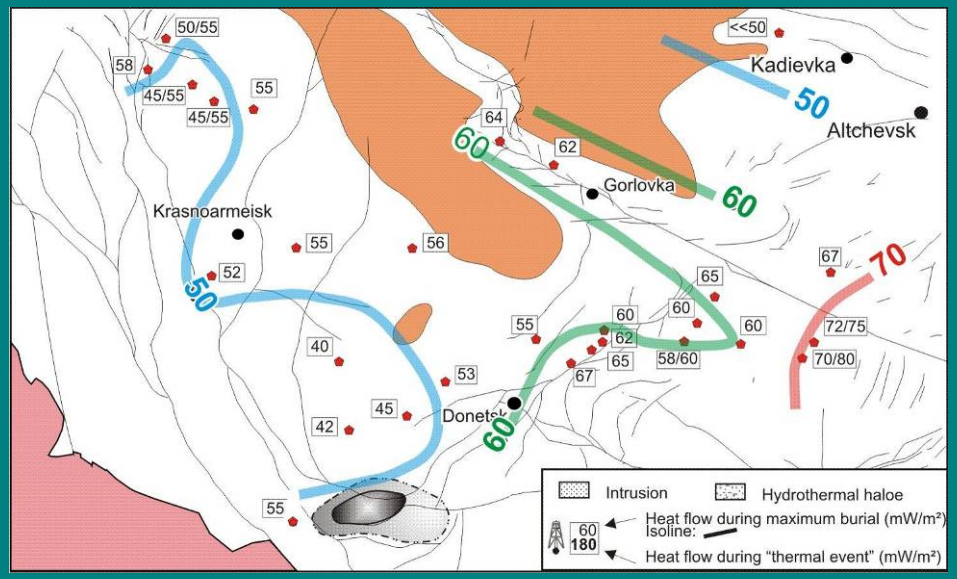
<0.4	0.8-1.2	1.9-2.5	4.1
0.4-0.8	1.2-1.9	2.5-4.1	5.3



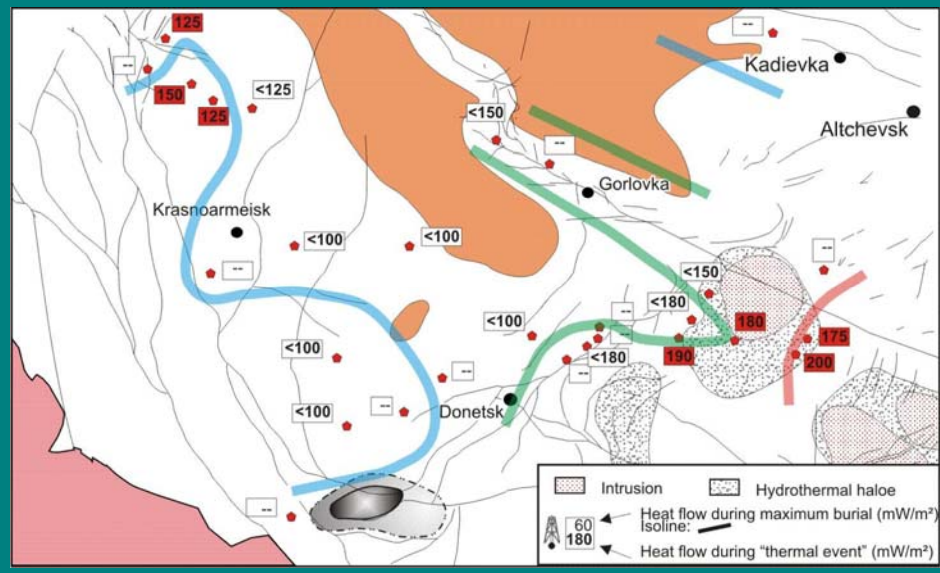



Izyum
0 km 50
49°
N
SW
Gorlovka Anticline
NE
km
0
1
1.0
1.2
1.5
1.9
3.5
3.5
1.9
1.0
1.2
1.5
1 km
Isoreflect. line (%Rr)
Fault
Up.-Carbonif. (C3)
Mid.-Carbonif. (C2)
Lugansk
40°
Cross-section
Gorlovka
Insert
Krasnoarmeisk
Kamensk Shakhtinskiy
Kr. Luch
48°N
48°
Donetsk
Shakhty
Metamorphosed coal near
Permian sills and stocks
40°E
Vitrinite reflectance (%Rr)
<0.4
0.4-0.8
0.8-1.2
1.2-1.9
1.9-2.5
2.5-4.1
4.1-5.3
5.3-6.5
>6.5
Permian
Devonian+Carb."A"
Archean
Major thrust / reverse fault
Studied borehole

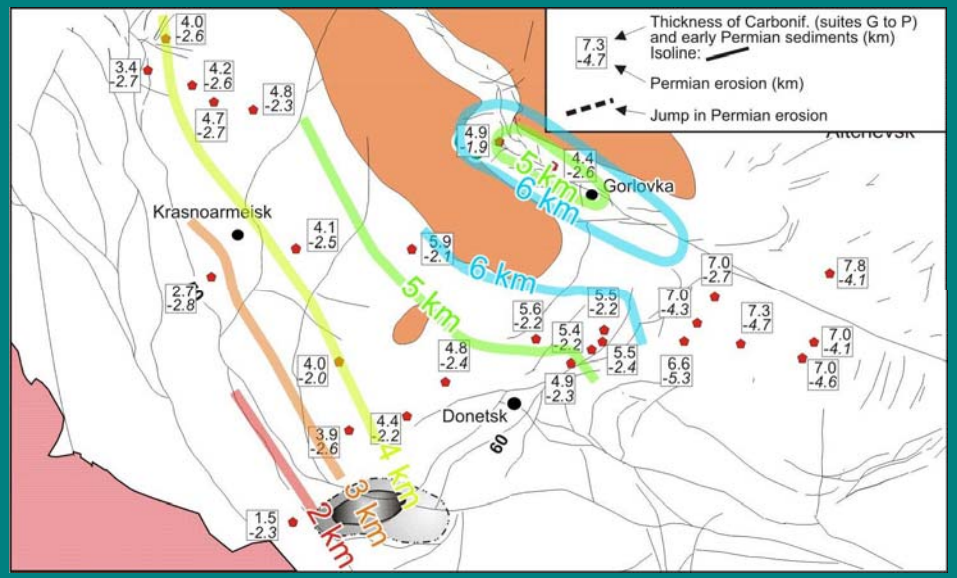
Heat Flow during maximum Permian burial



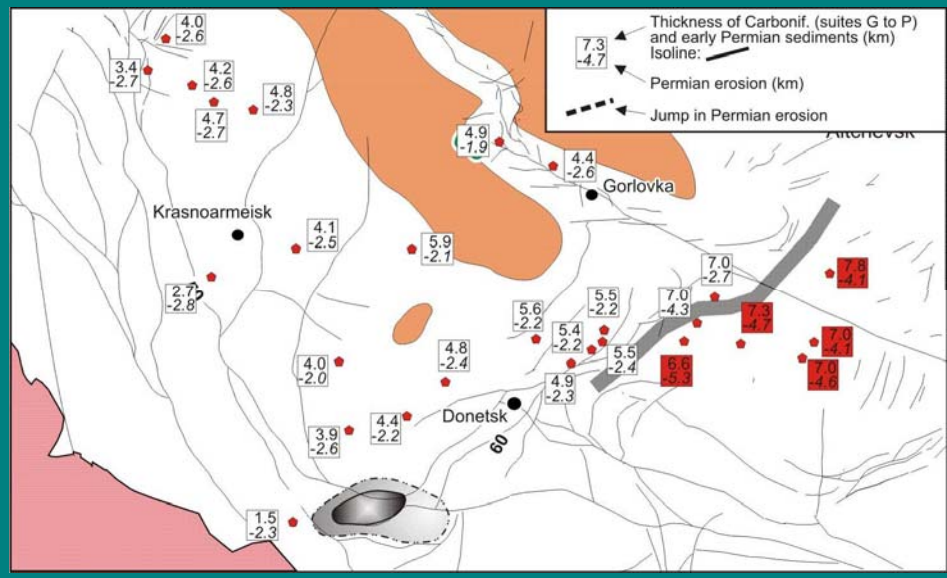
Heat Flow during Permo-Triassic HF event



Thickness of Upper Carboniferous Rocks



Amount of total erosion

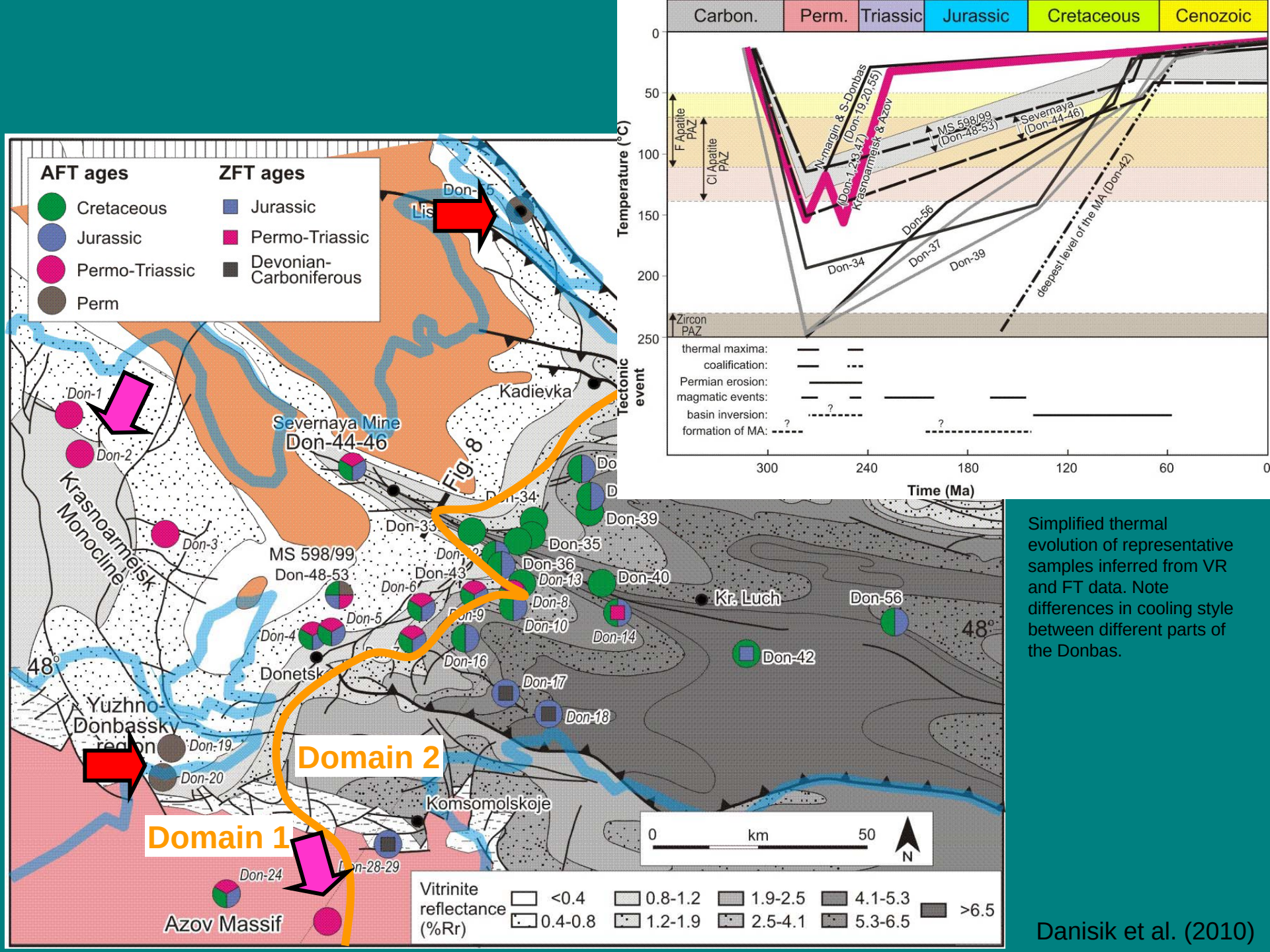


Basin Uplift

Fission track dating

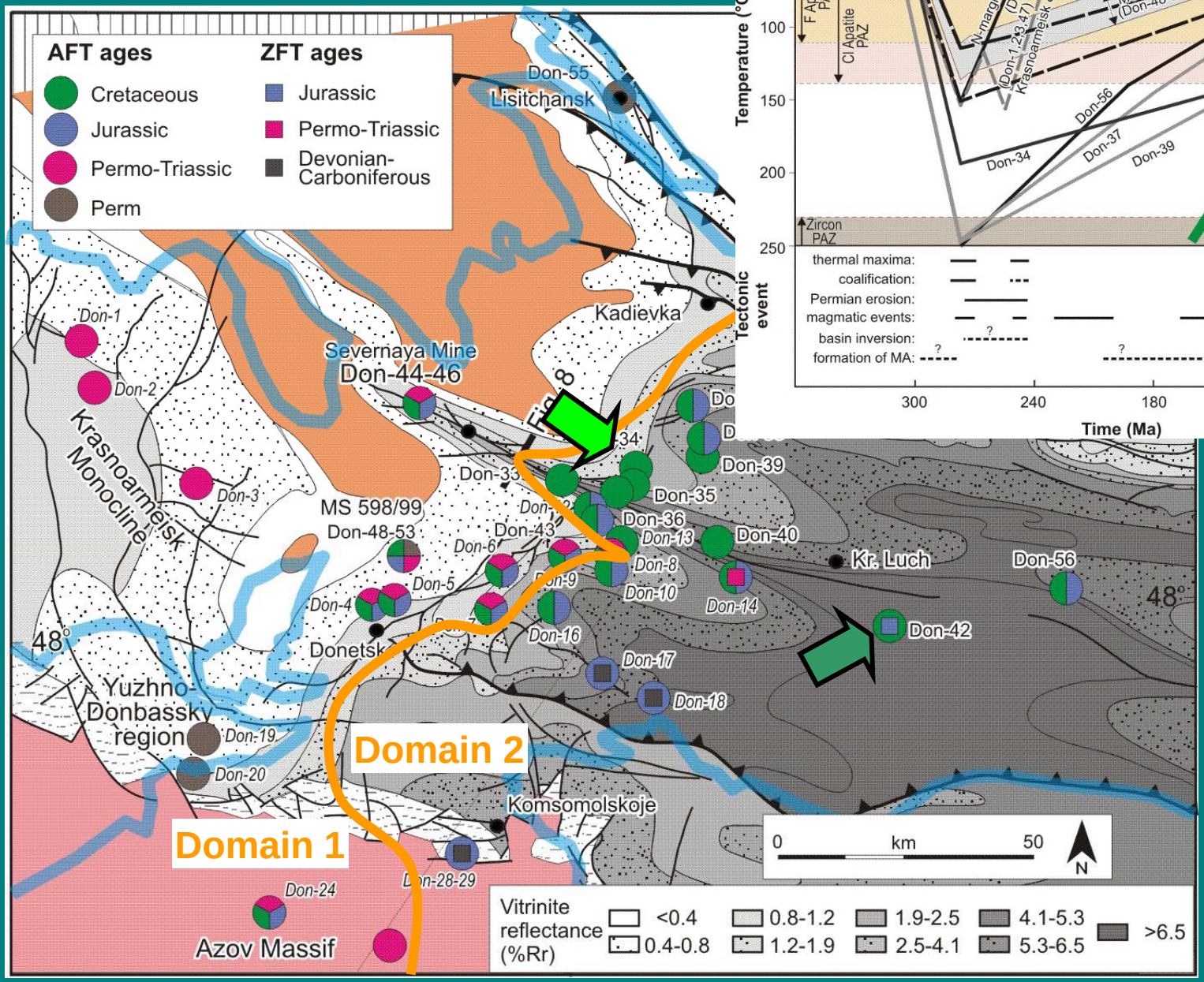
„Tübingen group“ (C. Spiegel, M. Danisik)

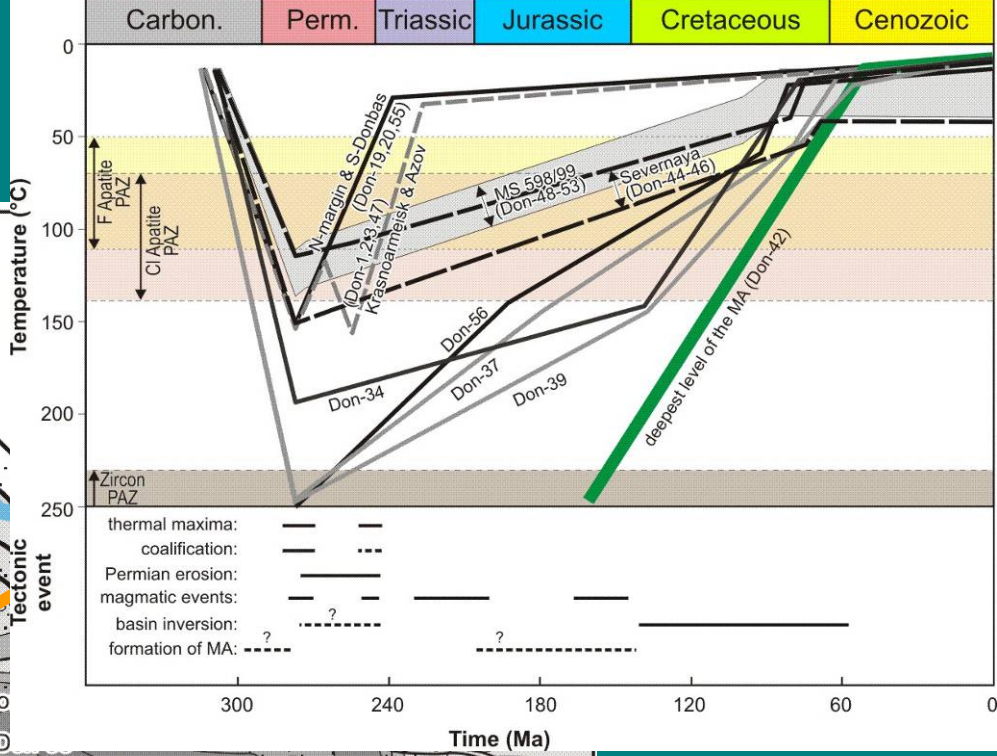
	Closure Temp.
F-rich apatite:	110°C
Cl-rich apatite:	140°C
Zircon:	240°C



Simplified thermal evolution of representative samples inferred from VR and FT data. Note differences in cooling style between different parts of the Donbas.

Danisik et al. (2010)

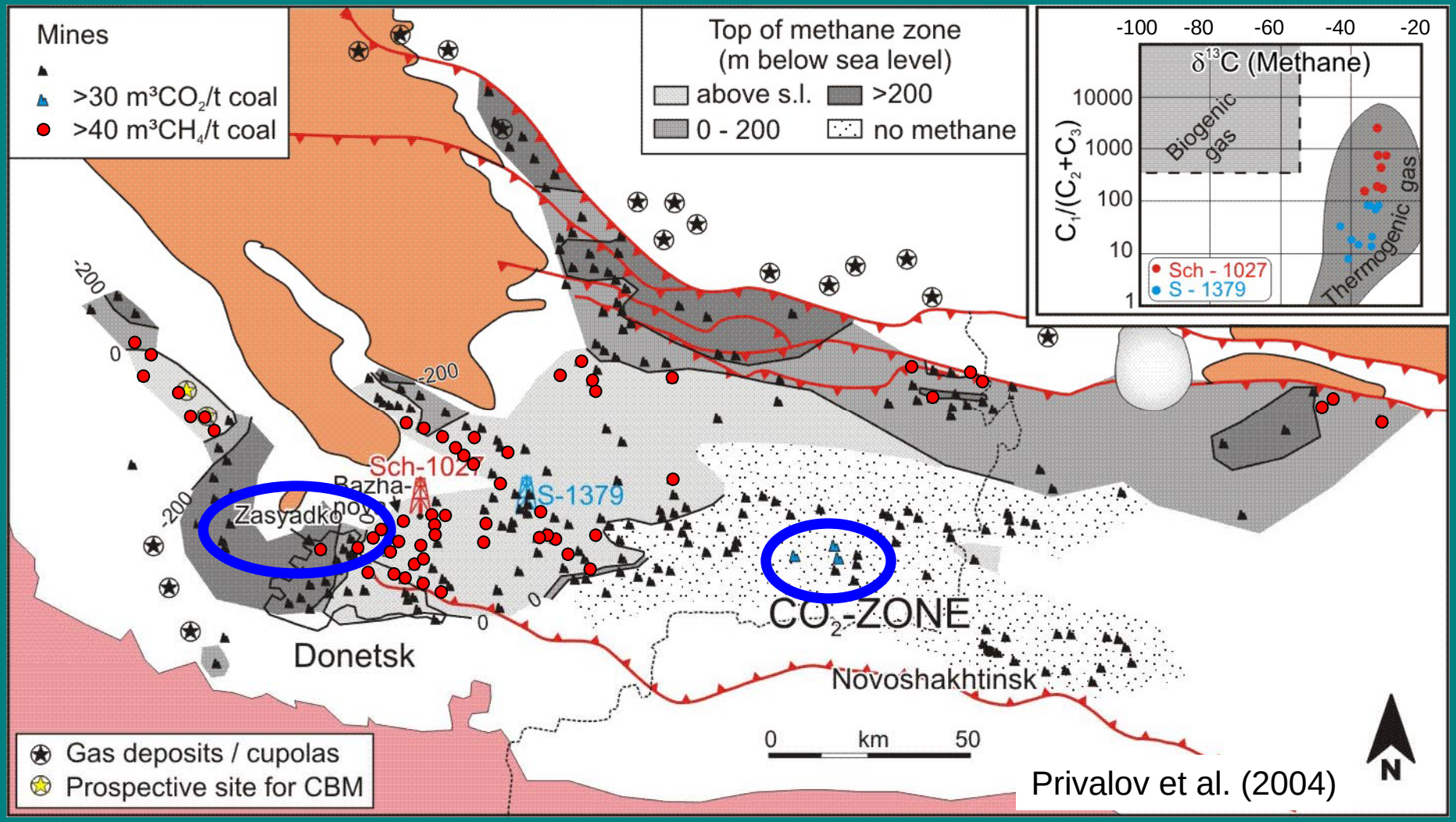




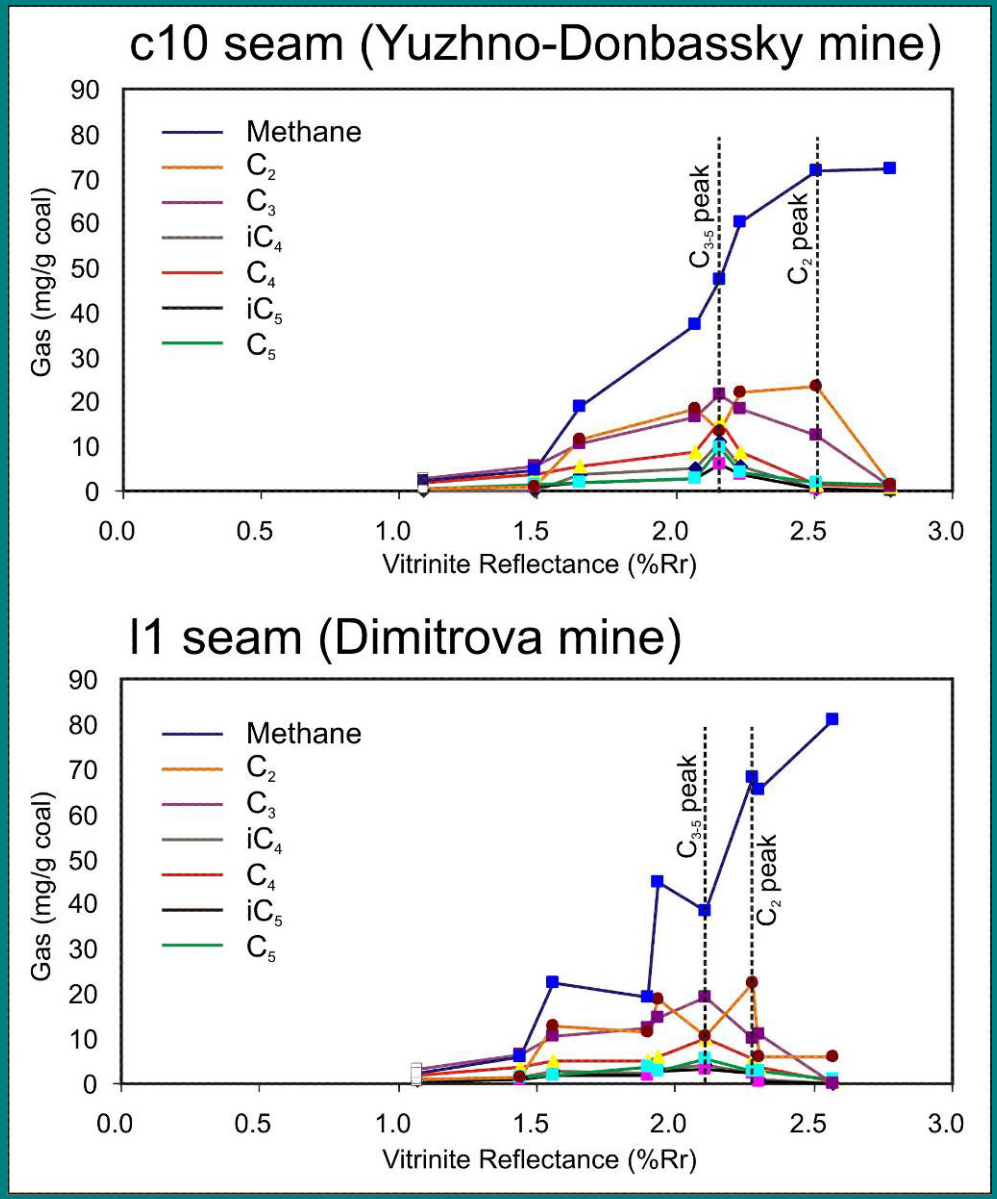
Simplified thermal evolution of representative samples inferred from VR and FT data. Note differences in cooling style between different parts of the Donbas.

Danisik et al. (2010)

Gas / Methane-potential



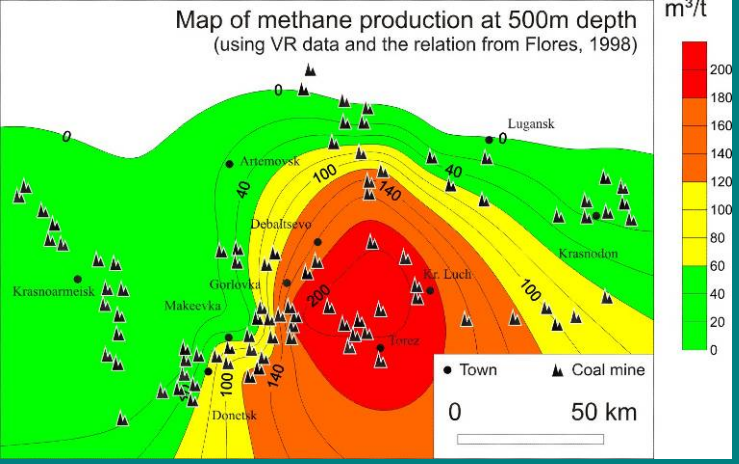
Quantification of HC gases produced during artifical maturation

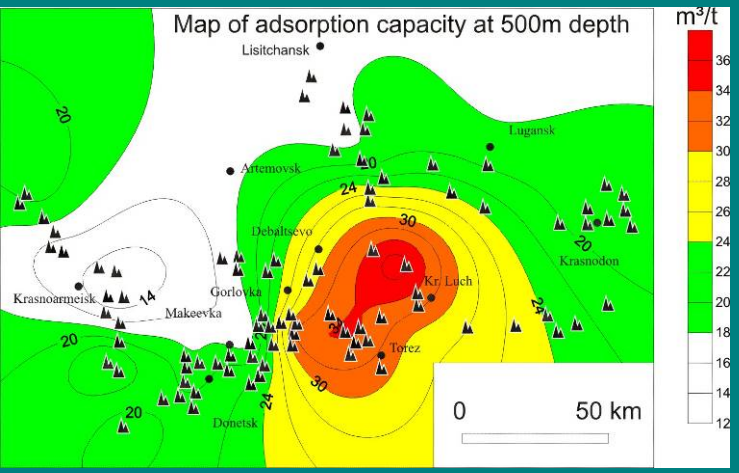


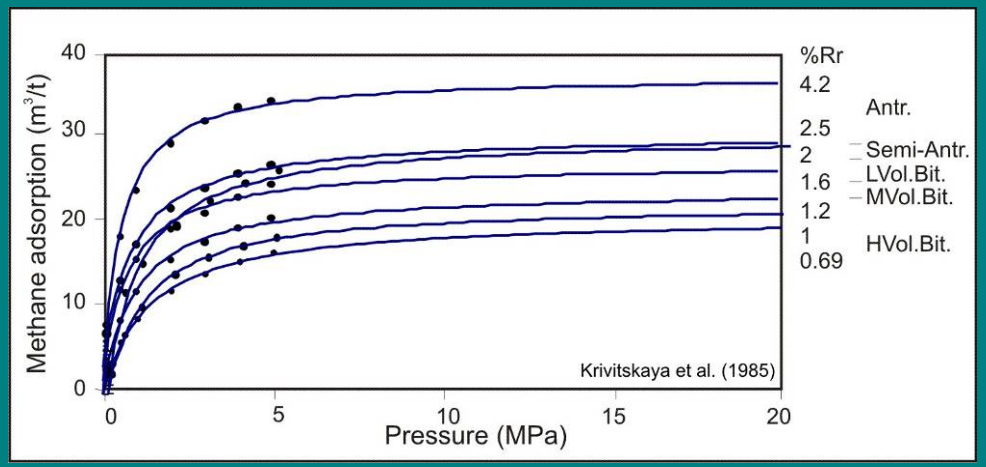
Alsaab et al. (2008)

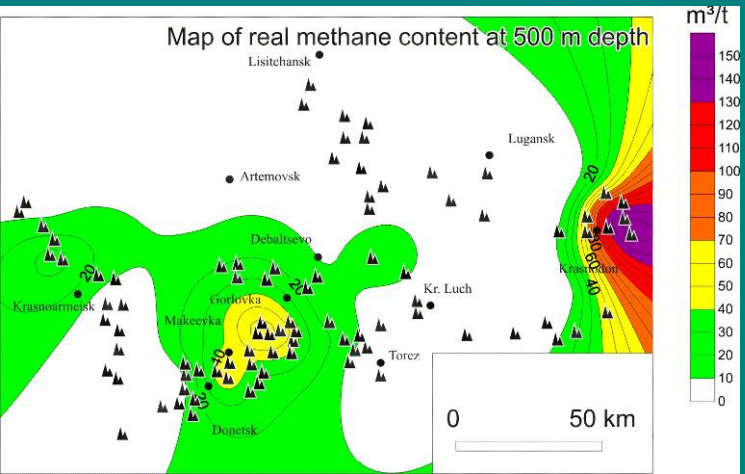
Nancy University

confined-pyrolysis experiments



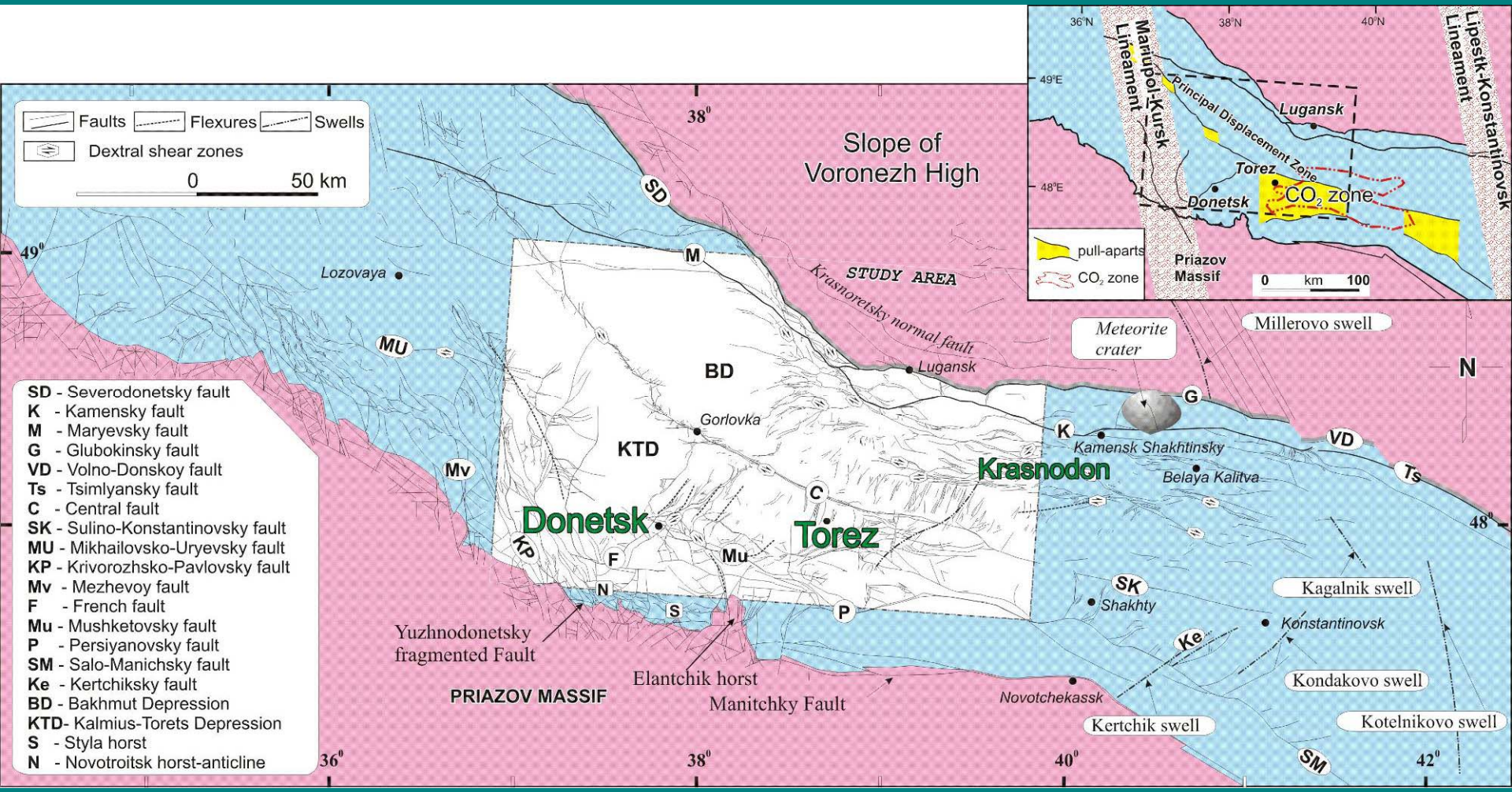






Alsaab et al. (2009)

Tectonic Map of Donets Basin



Privalov

Summary

- Coal seams are thin, but have a wide lateral distribution
- Serpukhovian coals are restricted to a narrow shore-zone dissected by rivers.
- Bashkirian / Moscovian coals have a wider lateral extent.
- The coal is generally of meta-anthracite rank. Low rank coals are restricted to the W and N basin margins.
- Rank is controlled by depth, lateral heat flow variations during max. burial, and a Permo-Triassic heat flow event
- Mesozoic uplift has been underestimated.
- Coal mines are among the gasiest in the world
- Large areas contain significant amounts of CO_2
- Distribution of gas is controlled by faults