The Danube River – Danube Delta – Coastal Zone – Black Sea System

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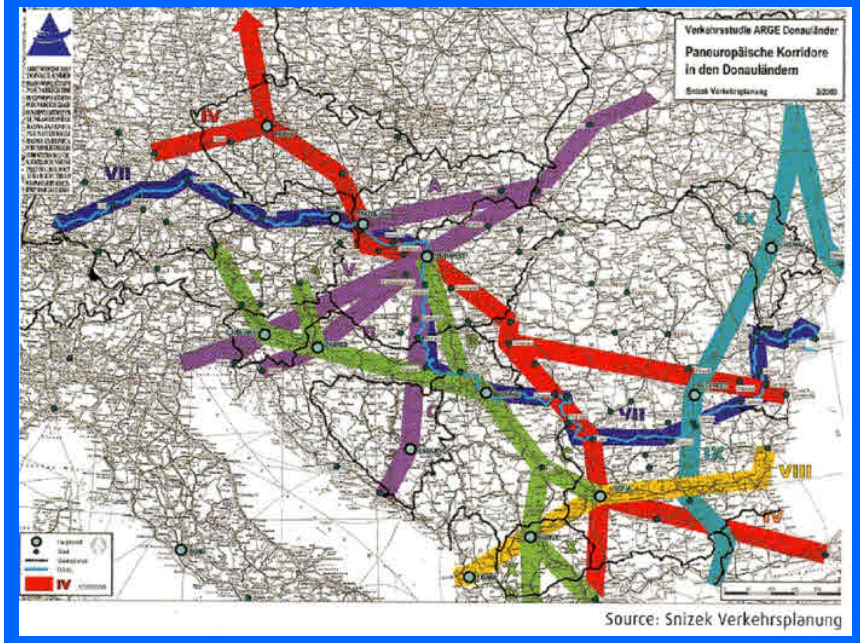
River Danube drainage basin

Total Length of the Danube River 2 860 km

Total area of the Danube Drainage Basin 817,000 km^2

The Danube River

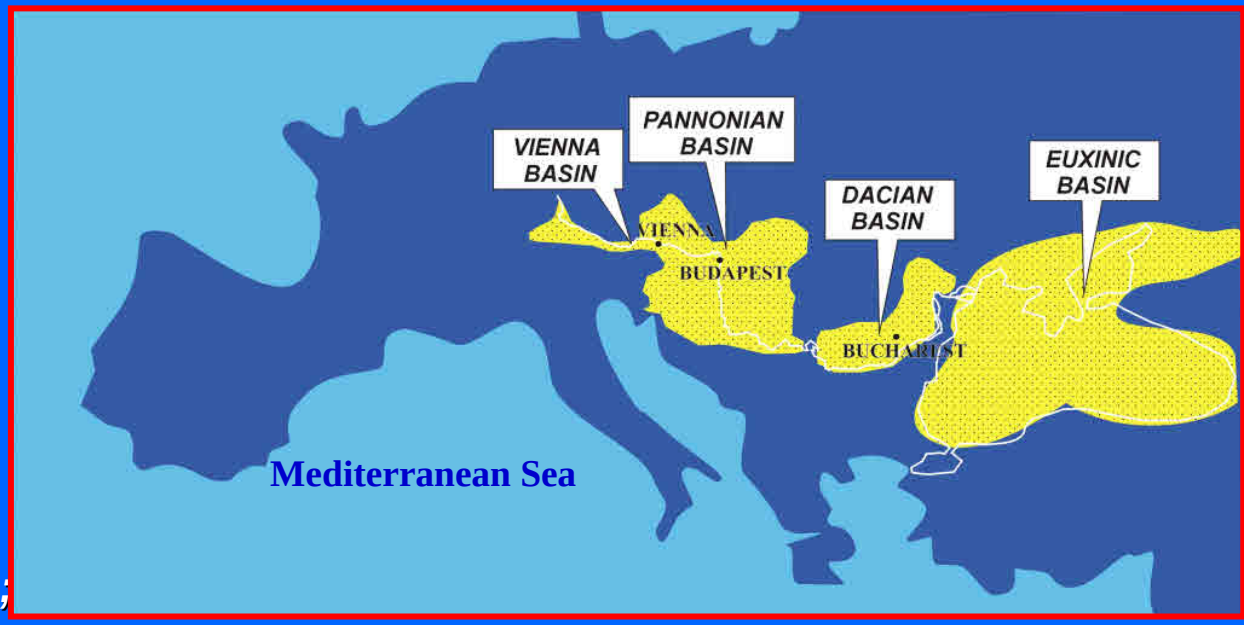
one of the most important European Connection Corridors



PARATETHYS BASINS
IN THE CENTRAL AND EASTERN EUROPE
WHERE THE RIVER DANUBE WAS BORN

- *Before 16 Ma, connections between the Mediterranean Sea and the Paratethys were unobstructed and faunal exchanges have currently occurred;*

- *From 12 Ma, the Paratethys evolved into restricted marine environments and the complete isolation of the Pannonian Basin (Western Paratethys) took place in the early Tortonian;*

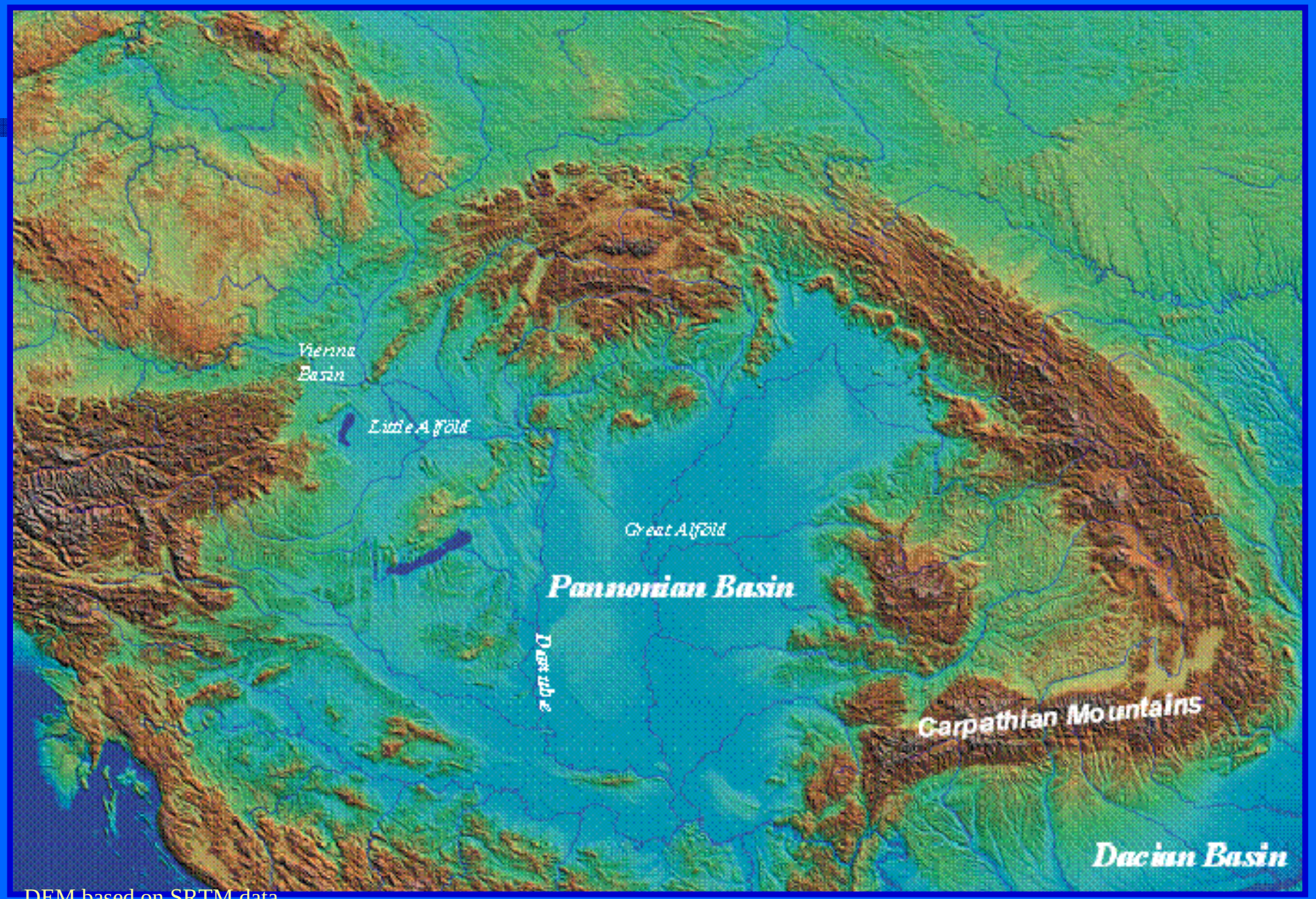


- *Then, the Paratethys became a succession of more or less separated brackish to freshwater basins. Normal connections between the Mediterranean Sea and the Paratethys ended in the Late Miocene;*

- *Nevertheless, Paratethys seems to have had strong influences on the Mediterranean Region during the so-called Lago Mare event of the Messinian salinity crisis (5.96 - 5.33 Ma);*

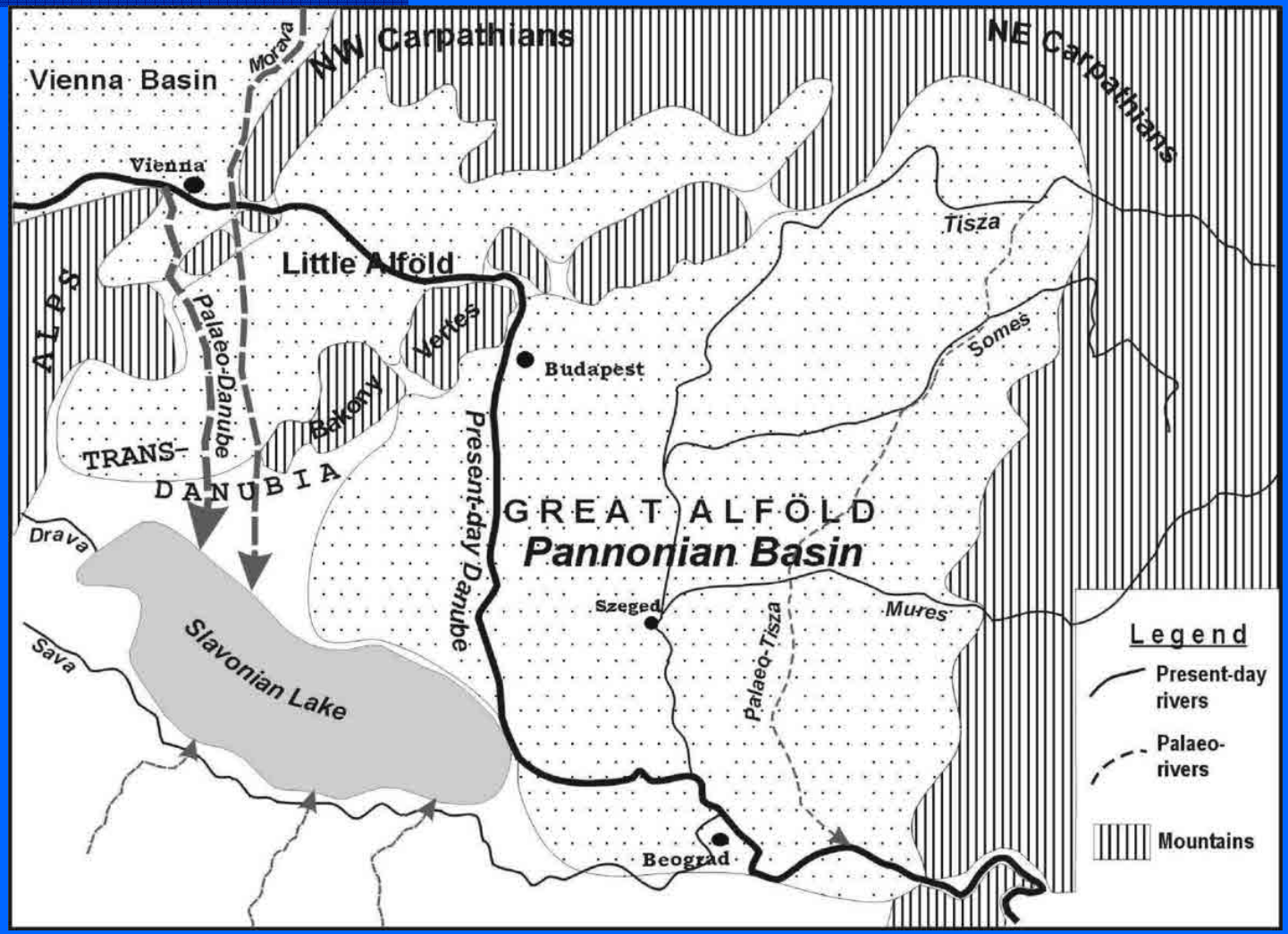
- *The Danube River flows along the succession of former Paratethys basins.*

The Danube River Course through the Pannonian and Dacian basins

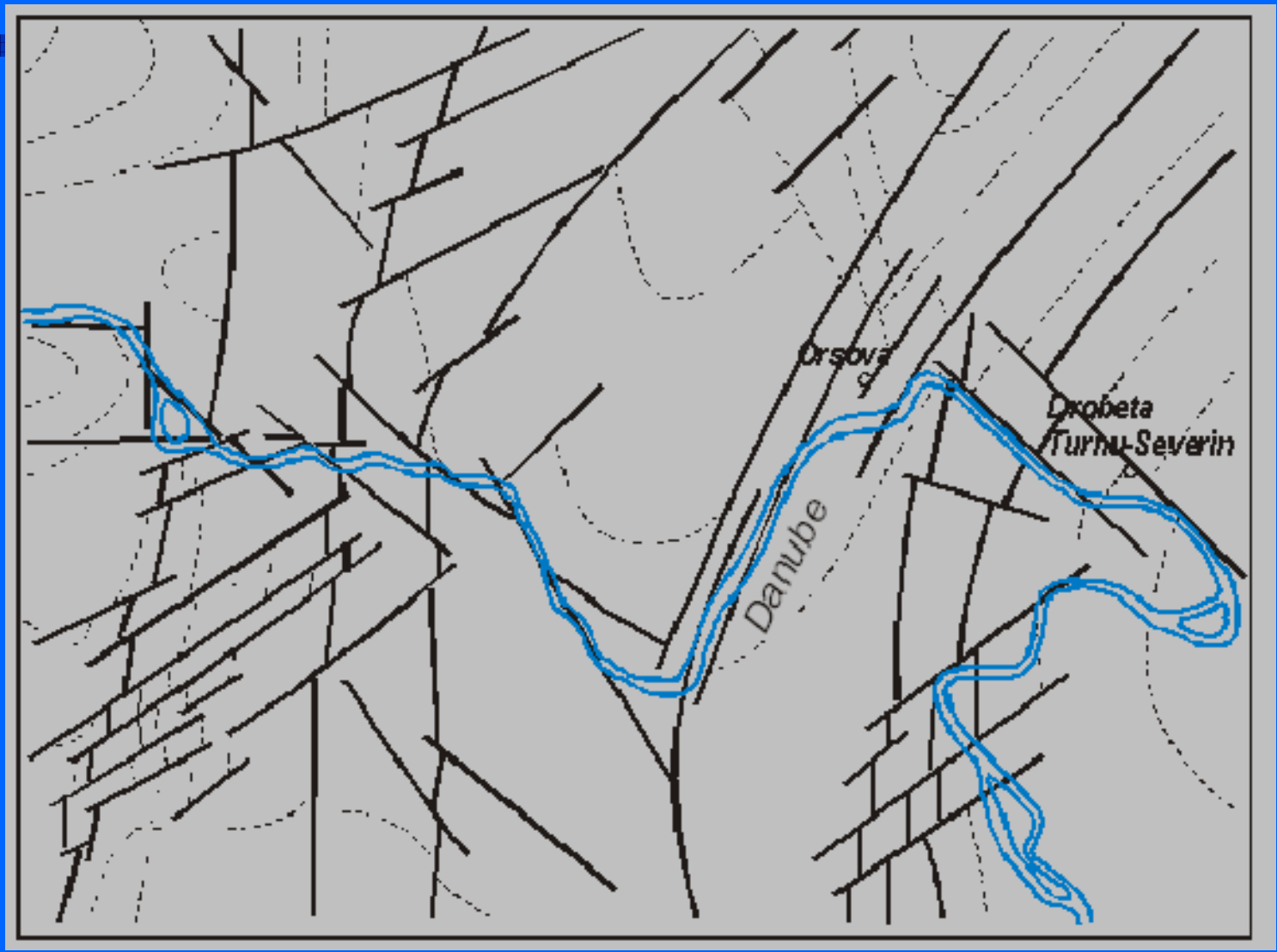


DEM based on SRTM data

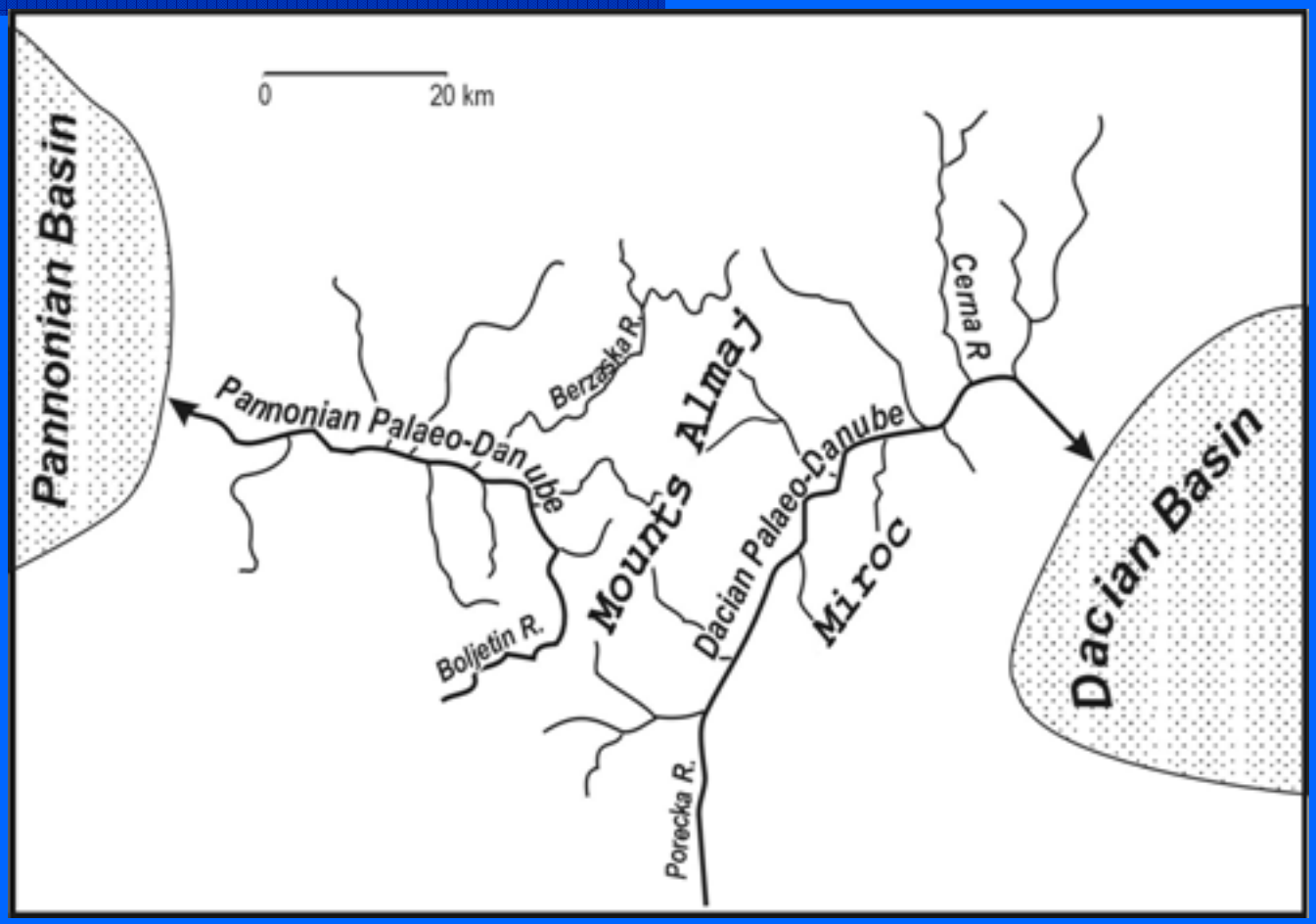
Evolution of the Middle Section of the River Danube (after Gábris G., 1994)



Faults control of the River Danube course break-through at the Iron Gates



The palaeo-hydrography at the crossing of Carpathian Mountains



(After Marović et al., 1997 and Posea, 1964)

The "Dacian palaeo-Danube" with a larger water discharge, lower base level (for the Dacian basin the water level was directly depending of the Black Sea level) and consequently stronger regressive erosional force captured the "Pannonian palaeo-Danube".

In the prevailing opinion, the capture was realised at the end of Pliocene – beginning of Quaternary, some 1.6 million years ago.

Thereafter, the River Danube began to cut its gorge-like channel which was shaped by a combined action of mountain up-lifting and base level lowering.

Mean Multiannual Water Discharges in different Cross-sections

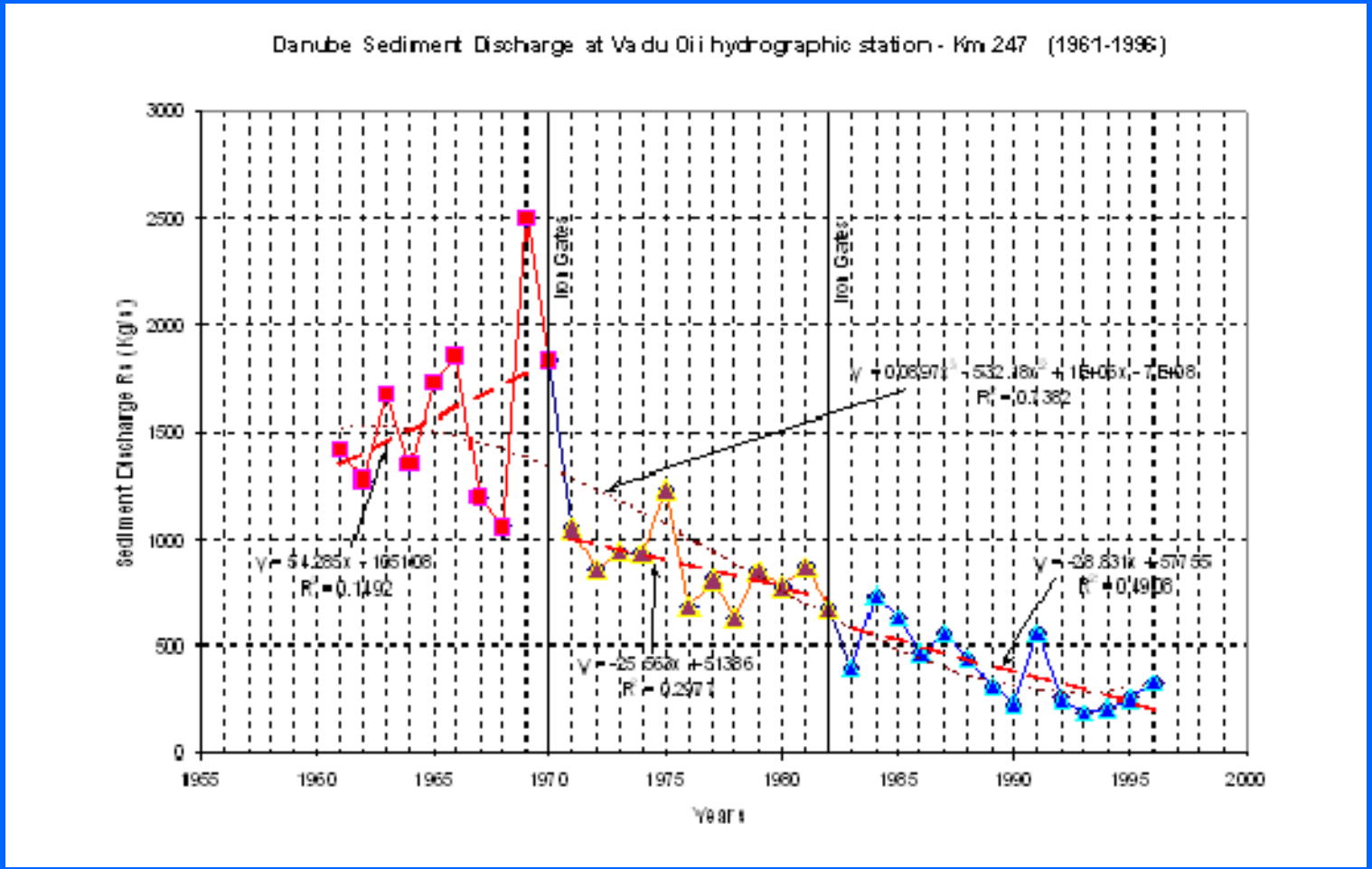
Hydrometric cross-sections	Time intervals (m³/s)		
	1931-1970	1971-1984	1985-2000
1. Bazias, km 1072.	5579	5599	5175
2. Orsova, km 957.	5694	5628	5160
3. Turnu Severin, km 931.	5682	5628	5163
4. Gruia, km 858.	5695	5628	5183
5. Chiciu-Calarasi, km 378.	6242	6169	5812
6. Braila, km 167.	6144	6374	5882
7. Ceatal Ismail, km 80.	6469	6743	6193

(after Bondar, 2003)

Mean multiannual suspended sediment discharges of the Danube River in different cross-sections in 1931 – 2000 period (after Bondar, 2003)

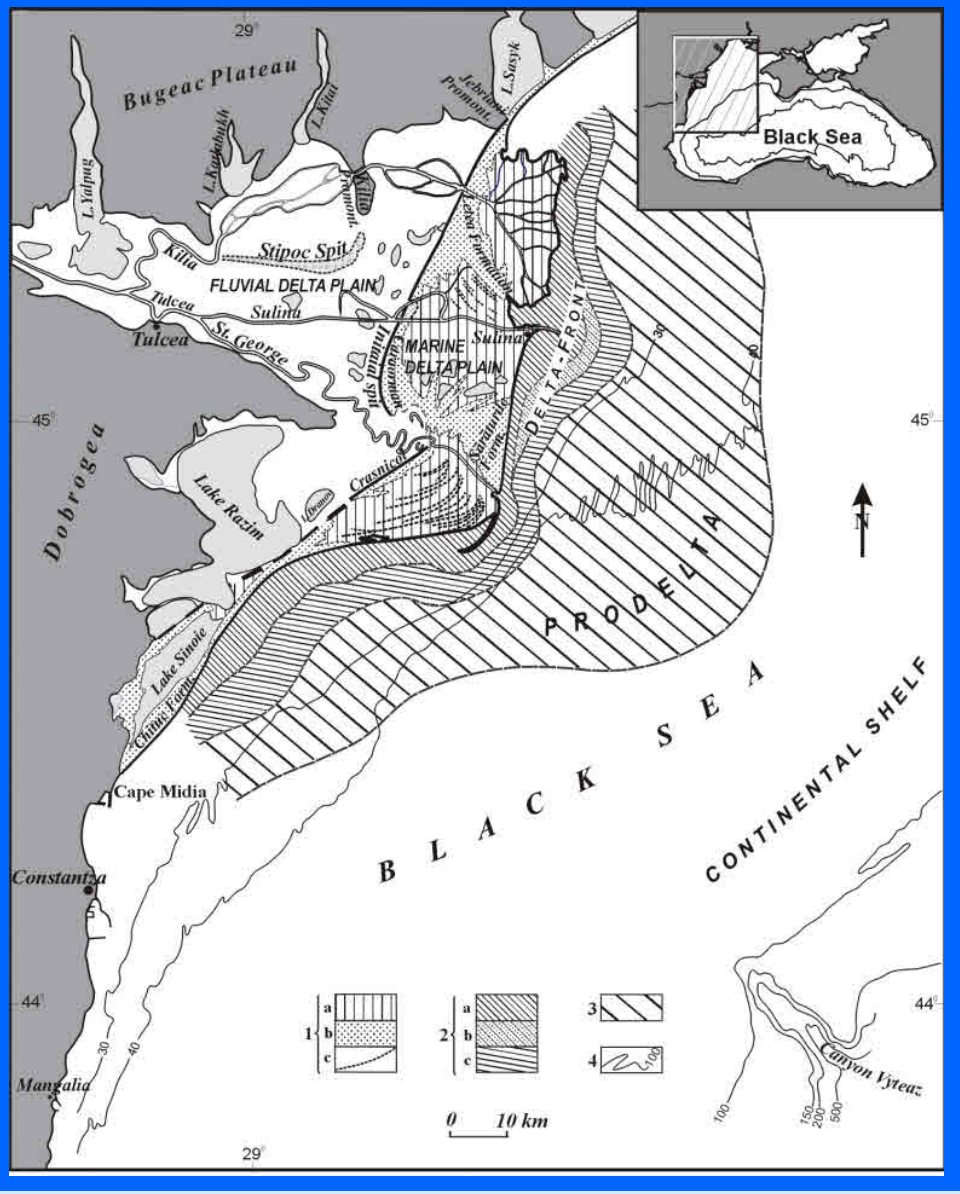
Hydrometric cross-sections	*Time Intervals kg/s*		
	1931-1970	*1971-1984*	*1985-2000*
1. Bazias, km 1072.	1062	650	121
2. Orsova, km 957.	1062	404	102
3. Turnu Severin, km 931.	1118	417	116
4. Gruia, km 858.	1170	484	85.4
5. Chiciu-Calarasi, km 378.	1684	728	440
6. Braila, km 167.	1639	966	395
7. Ceatal Ismail, km 80.	1657	1280	678

Decreasing of the River Danube sediment discharge after damming



The Danube Delta

Satellite image



- The Danube Delta plain area: about 5800 km^2, of which the marine delta plain represents 1800 km^2;
- The delta front – 1300 km^2; The Prodelta > 6000 km^2;
- The Danube Delta coastal zone length: about 240 km of which 165 km on Romanian territory;

Danube Delta Geological Setting

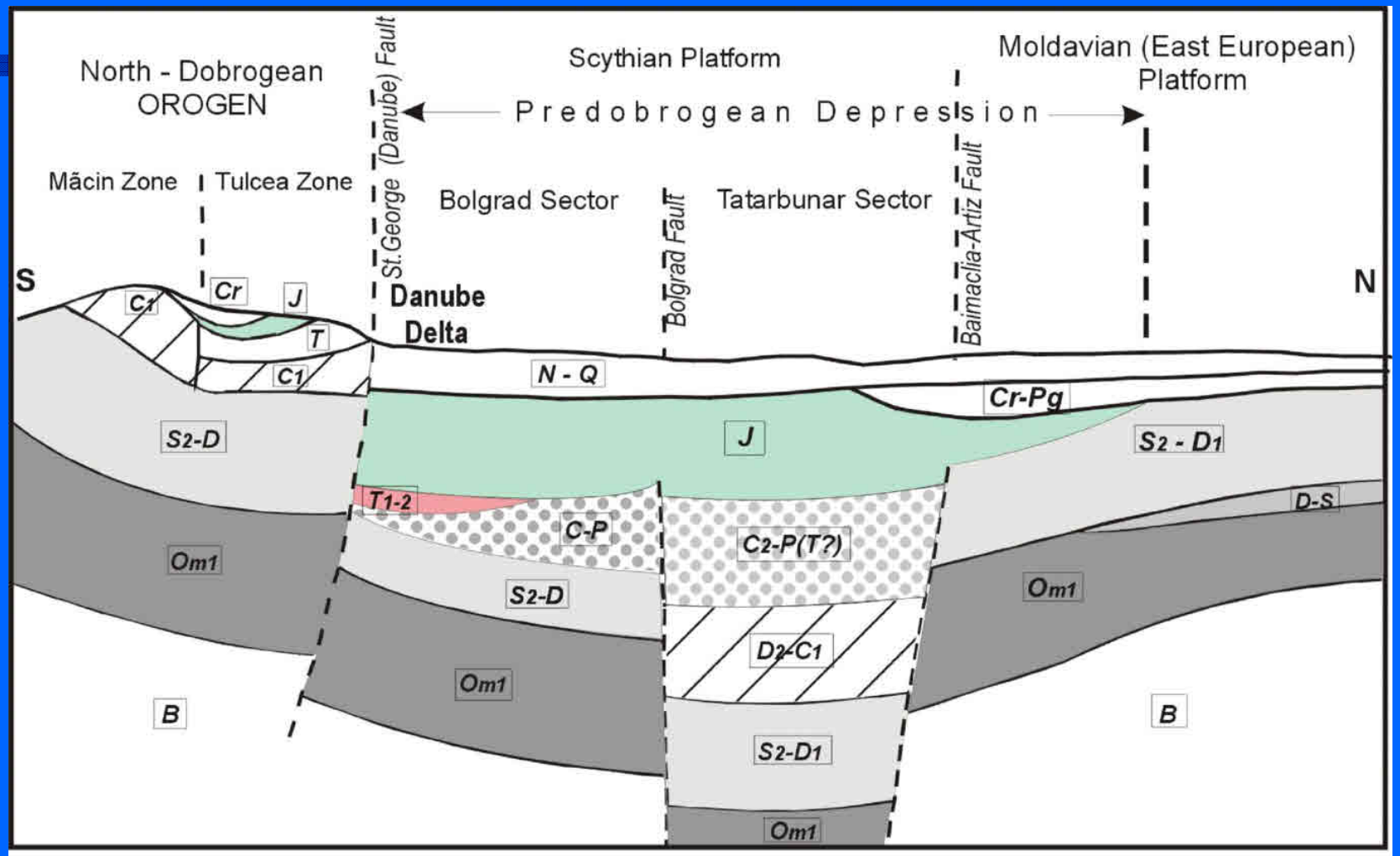
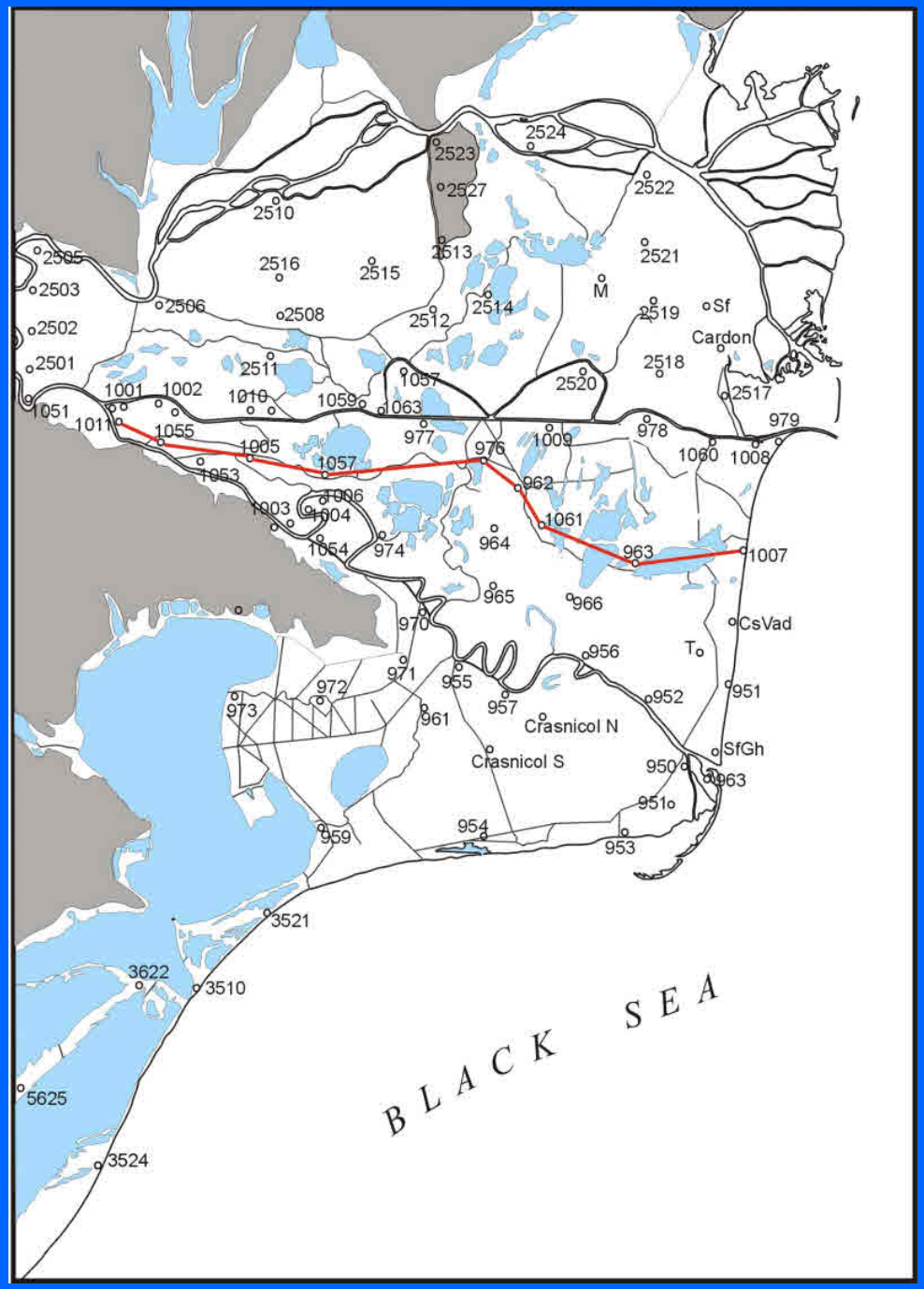
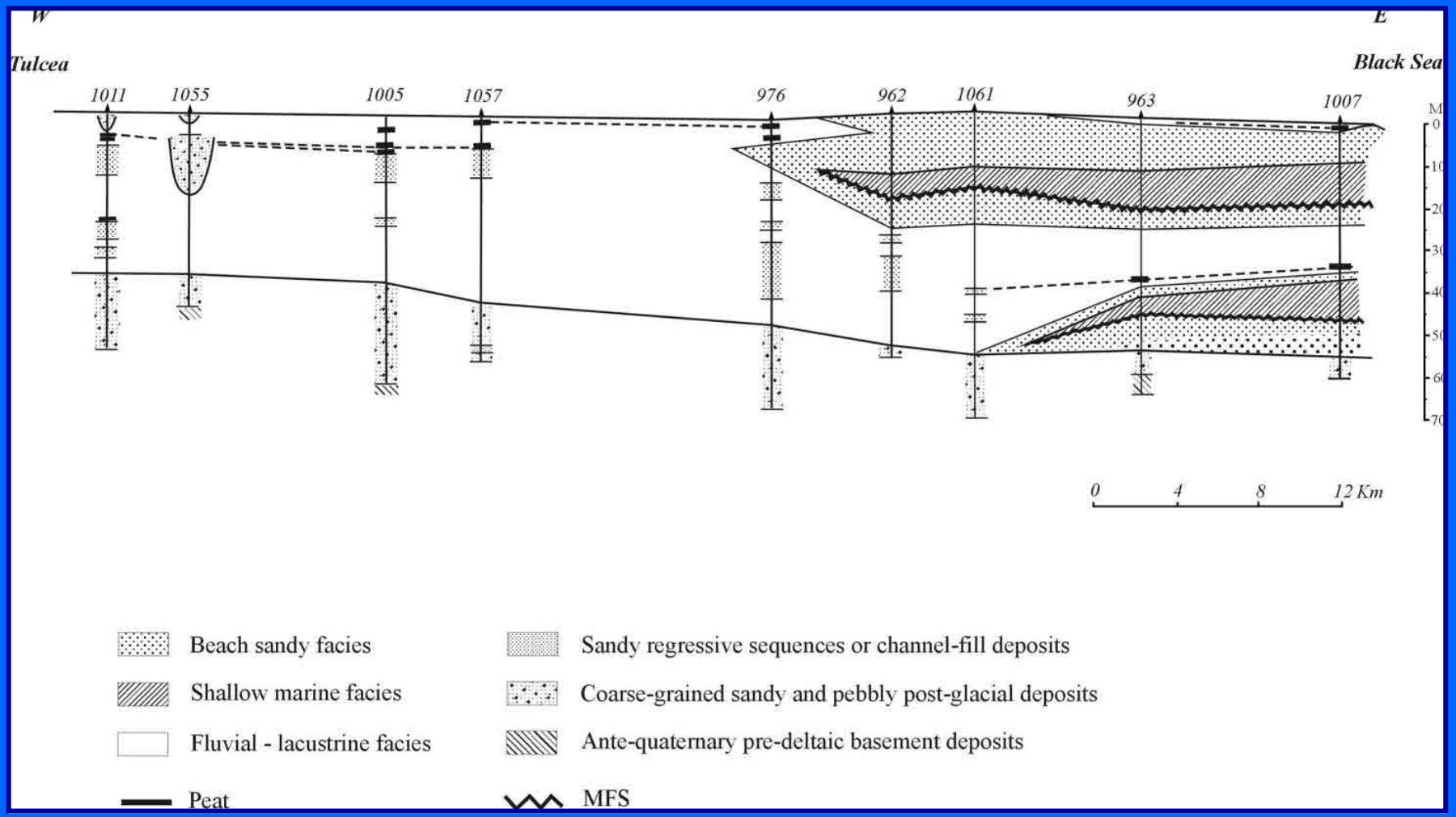


Fig.8

Bore-holes in the Danube Delta

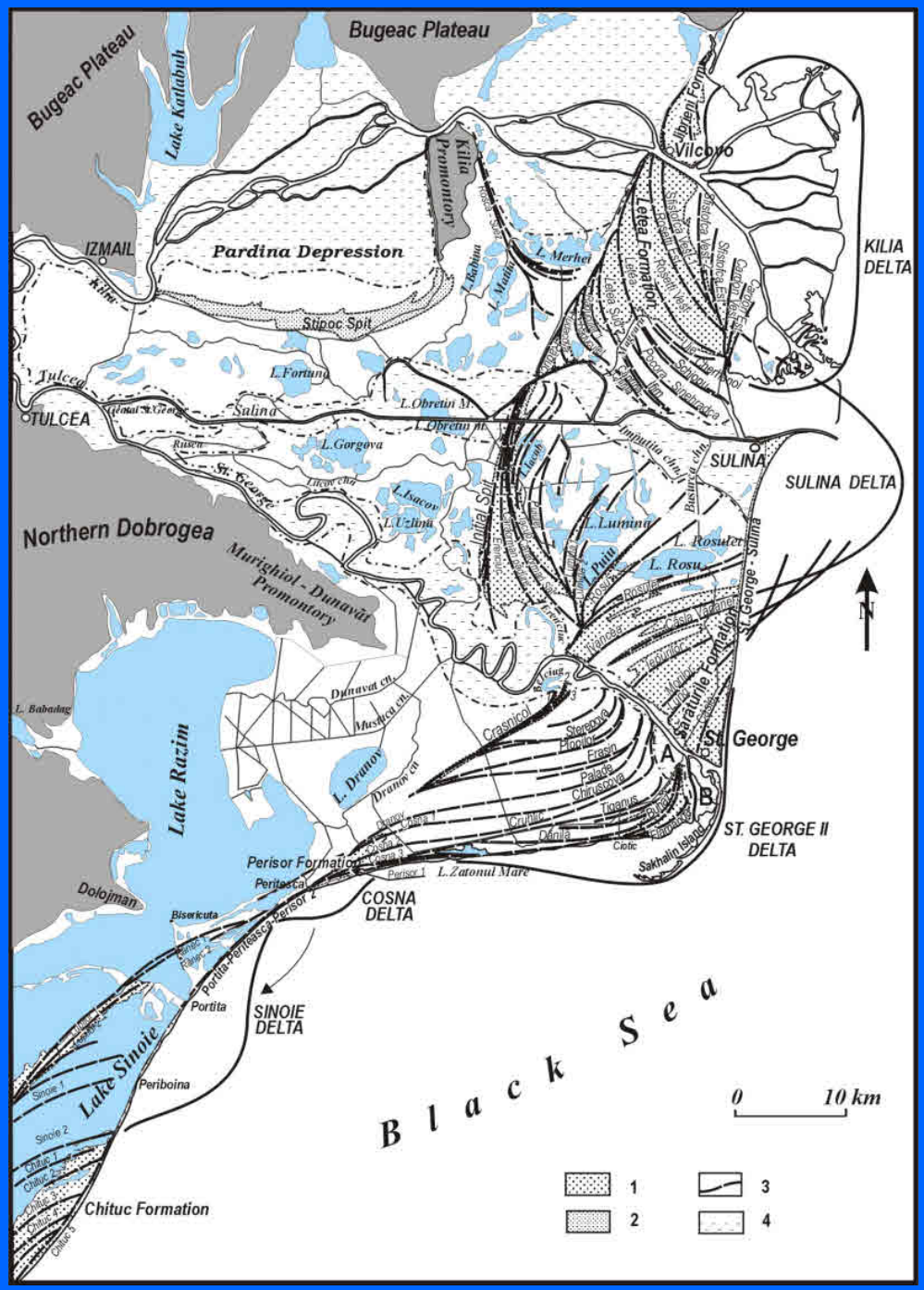


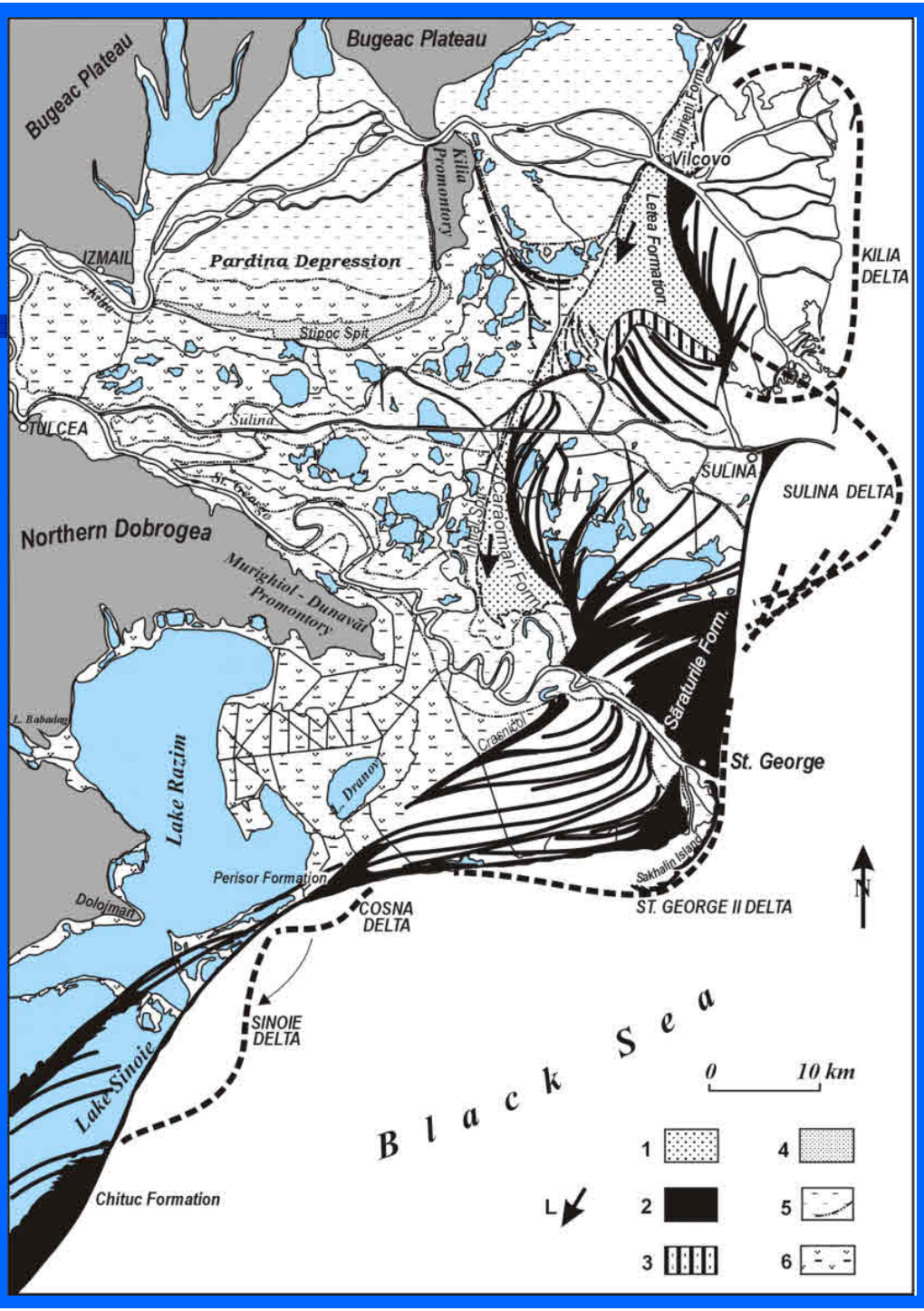
Geological section of the Danube Delta



The Danube Delta geomorphologic – sedimentological structure

1. Marine beach ridges
2. Lacustrine spit
3. Directions of main beach ridges and of beach ridge sets
4. River meandering zone





Areal distribution of the main types of deposits in the Danube Delta

1. Marine littoral deposits:
   a, type “a” - of littoral drift from the Ukrainian rivers;
   b, type “b”- of Danubian origin;
   c, littoral diffusion (mixed “a” and “b” types);
2. Lacustrine littoral deposits;
3. Fluvial deposits:
   a, meander belt deposits;
   b, interdistributary depression deposits;
4. Læss-like deposits;

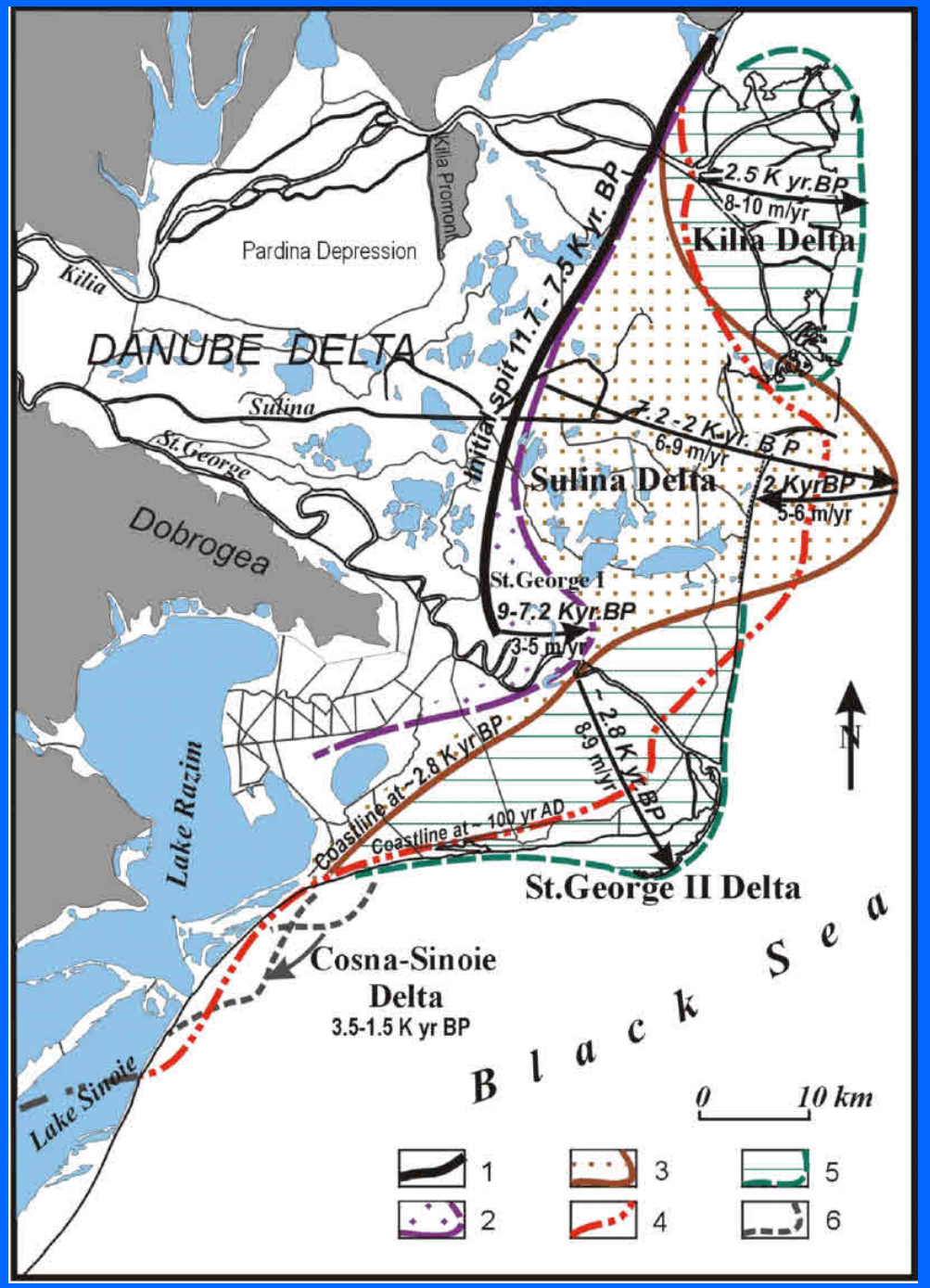
L - longshore sediment drift;

D - main sediment supplies.

The Danube Delta evolution

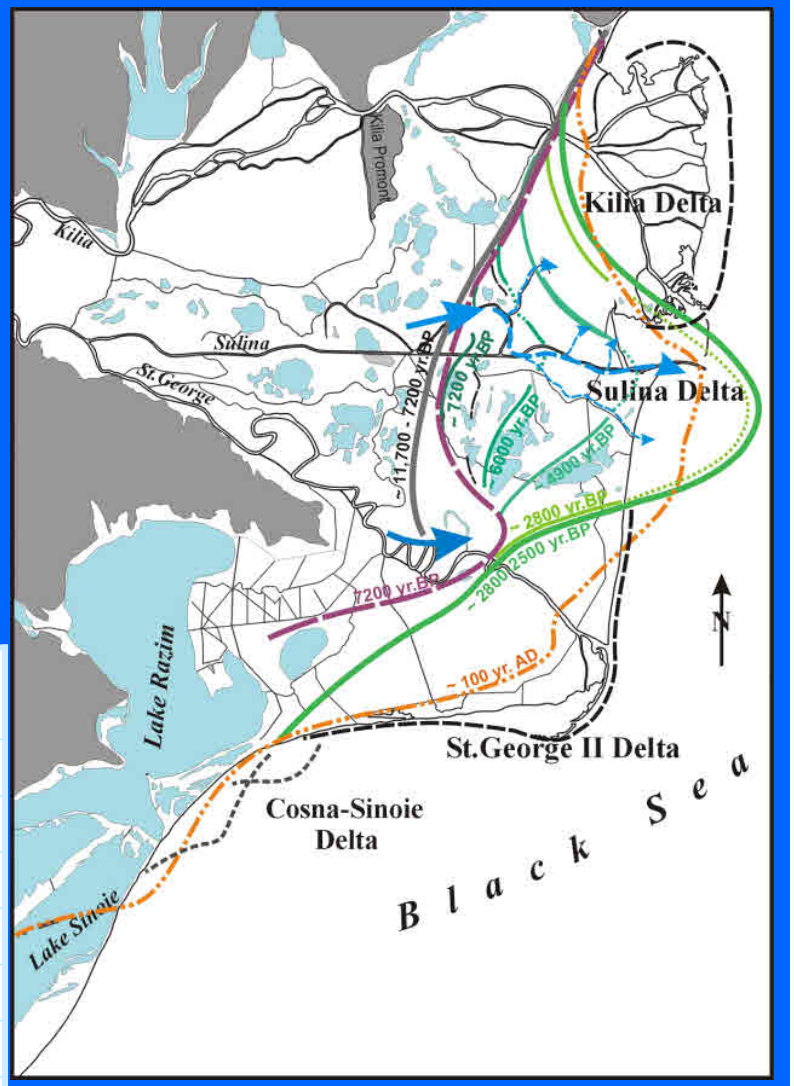
Evolution of the coastline during the last 12,000 years

1. Initial spit: 11.7 – 7.5 K yr. BP
2. St. George I Delta: 9.0 – 7.2 K yr. BP
3. Sulina Delta: 7.2 – 2.0 K yr. BP
4. Coastline position at ~ 100 yr. AD
5. St. George II Delta and Kilia Delta: 2.8 K yr.BP – Present
6. Cosna – Sinoie Delta: 3.5 – 1.5 K yr. BP



The Danube Delta lobe chronology and characteristics

Main lobe name	*Absolute dating years BP*	*Number channels*	*Prograd. Speed*
Initial Spit	**11,700 - 7200**	**1**	
Blocked Delta	**11,700 – 7200**	**2-3**	
St.George I Delta	**~9000 – 7200**	**1**	**3-5 m/yr**
Sulina	**~7200 - 2 000**	**1 – 5**	**6-9 m/yr**
Sulina Delta - phase 1	***7200***	***1***	
Sulina Delta - phase 2	***~ 6000***	***3***	
Sulina Delta - phase 3	***~ 4900***	***5***	
Sulina Delta - phase 4	***~ 2800 – 2000***	***2***	
Cosna - Sinoie Delta	**3500 – 1500**	**1**	
Kilia Delta	**2500 - present**	**1 to 19**	**8-10 m/yr**
St. George II Delta	**~ 2800 - present**	**1 to 3**	**8-9 m/yr**



Danube Delta Lobes Volumes

Lobe name/time of development	Total volume of deposits (m^3)	Rate of deposition Danubian sedim. (m^3/yr)
St.George I/ 2200 yr.	2,105,342,923	383,063
Sulina/ 4500 yr.	9,236,857,413	1,653,150
St. George II/ 2800 yr.	5,294,475,401	1,436,884
Kilia/ 2500 yr.	3,982,737,489	1,593,095
Total, without Cosna-Sinoie	20,619,413,226	

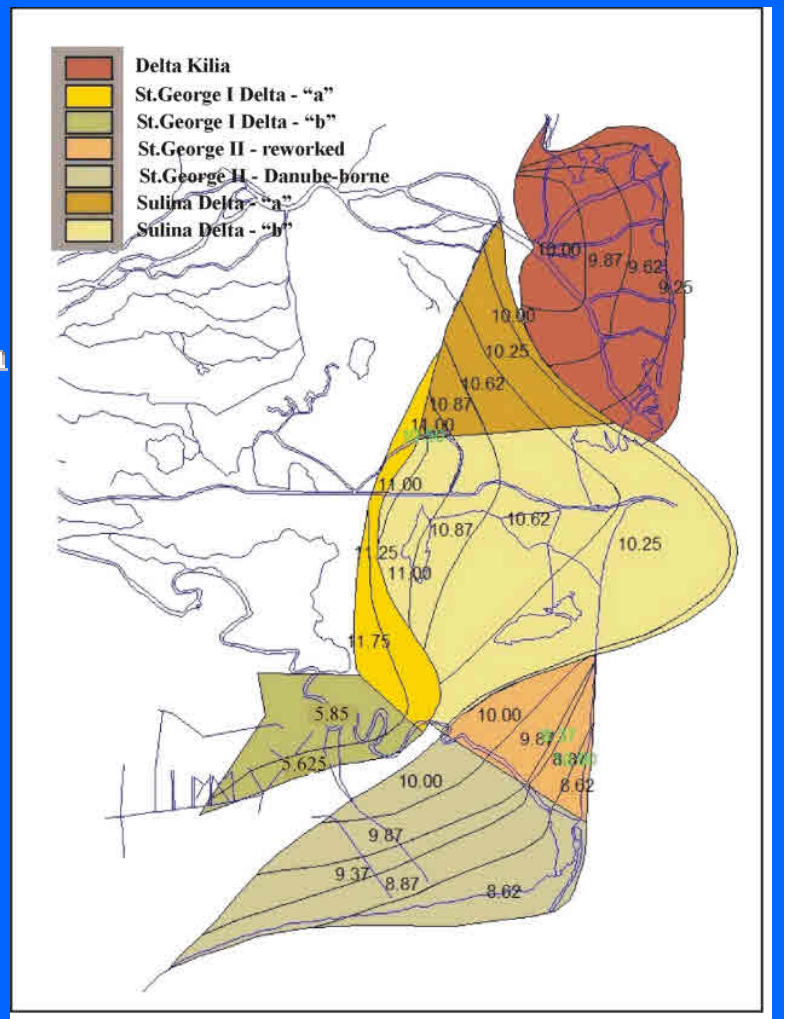
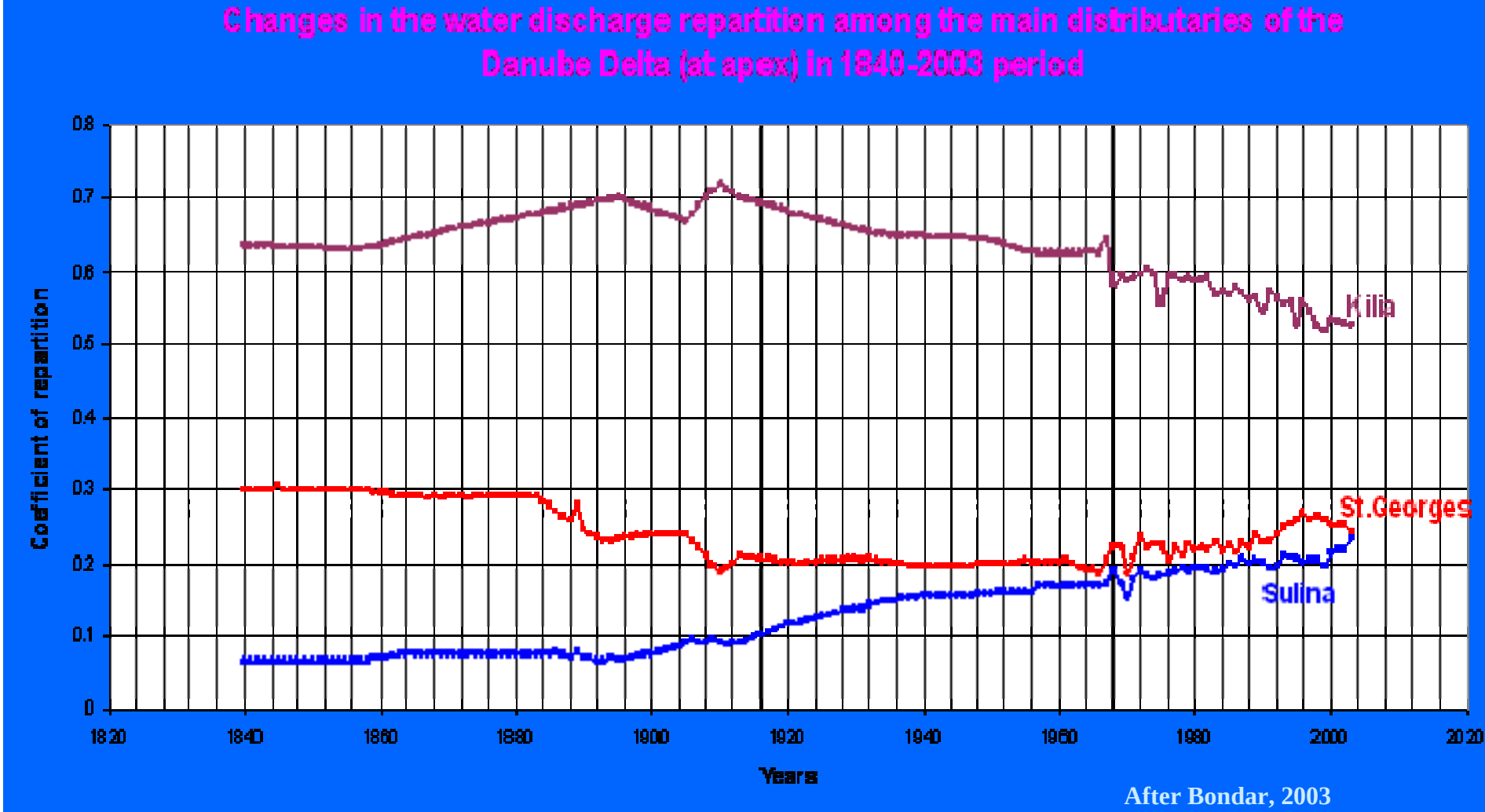


Fig. 5 - Area and thickness for different delta lobes

Water Discharge Distribution among the Danube Delta main Distributaries (%)



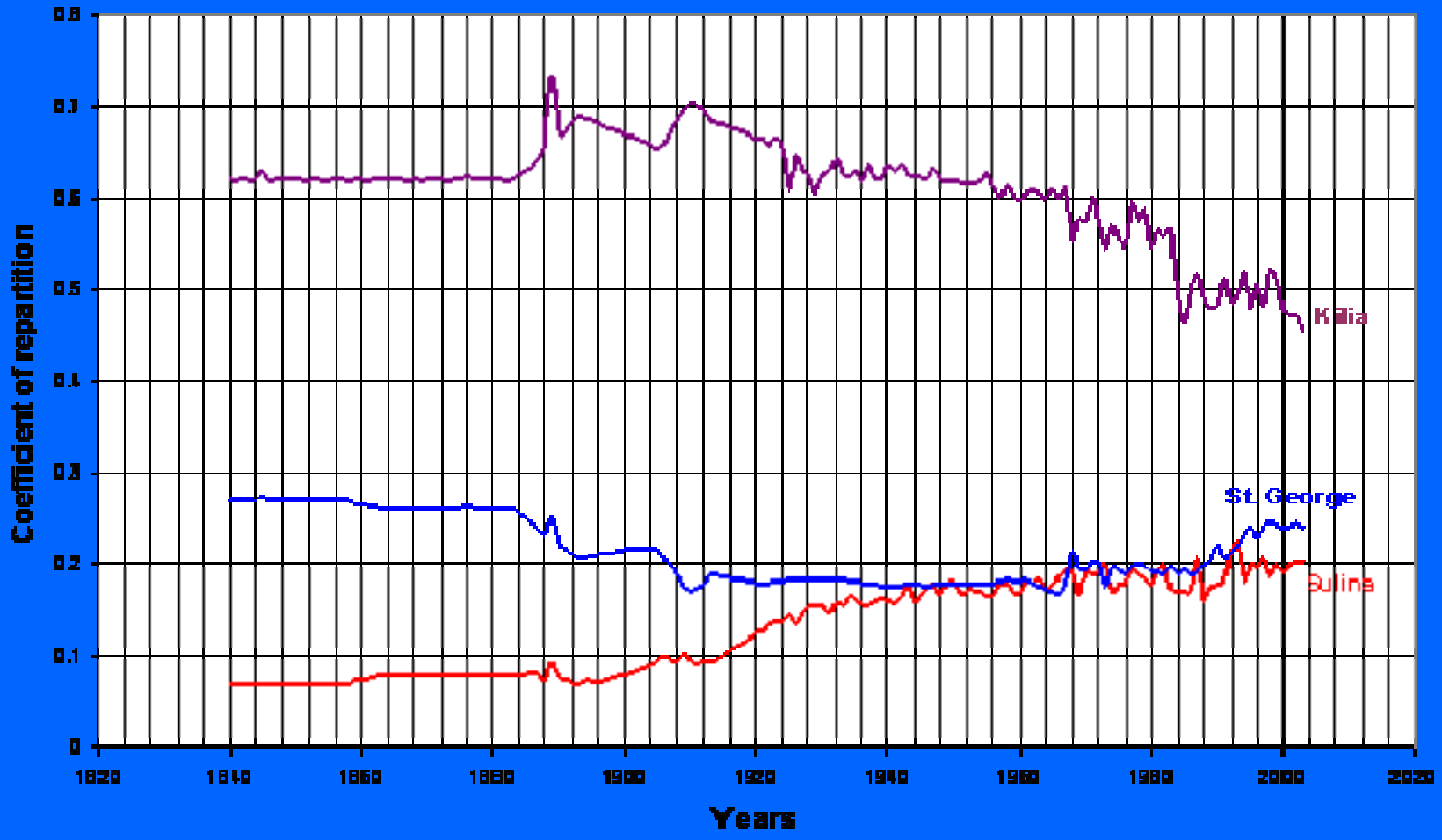
After Bondar, 2003

Sediment Discharge Distribution among the Danube Delta main Distributaries (%)

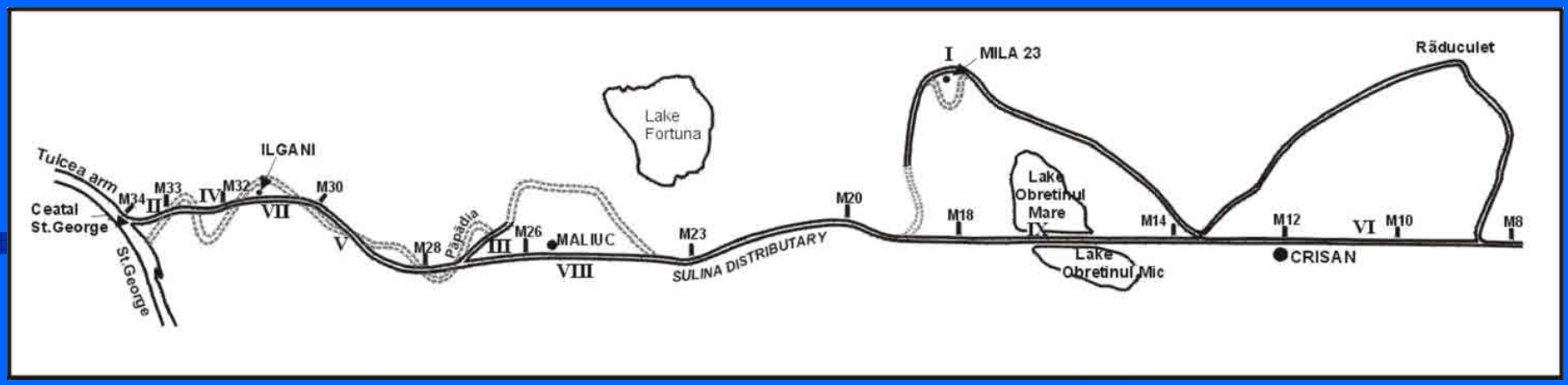
Danube Distributary – Hydrometric cross-sections	*Time Intervals*			
	1931-1970	1971-1984	1985-2000	*2003*
Kilia, km 115.	63.6	58.7	55.8	*~50.0*
Tulcea, km 63.	35.9	40.8	44.0	
Sulina, km 62.4.	15.9	18.8	20.1	*~20.0*
St. George, km 108	20.0	22.0	24.2	*~30.0*

After Bondar, 2003

Changes in the suspended load distribution among the main Danube Delta distributaries at the mouth zones for the 1840-2003 period



After Bondar, 2003



The Sulina distributary meander belts cut-offs (EDC, 1868 – 1902)

Order of digging channels	Period	Length of cut-off channel (Km)	Channel location
I	1868 - 1869	0.6	The “Little M" meander bend, "Mila 23"
II	1880 - 1882	1.0	Ceatal St. George
III	1883 - 1884	0.9	The "Pãpãdia" meander bend
IV	1885 - 1886	2.0	Miles 32 – 33
V	1886 - 1889	2.1	Miles 28 – 30
VI	1890 - 1893	9.7	Downstream half of the "Big M" meander
VII	1894 - 1897	5.5	The "Maliuc" meander bend
VIII	1897 - 1898	1.7	The "Ilgani" meander bend
IX	1898 - 1902	9.2	Upstream half of the"Big M" meander

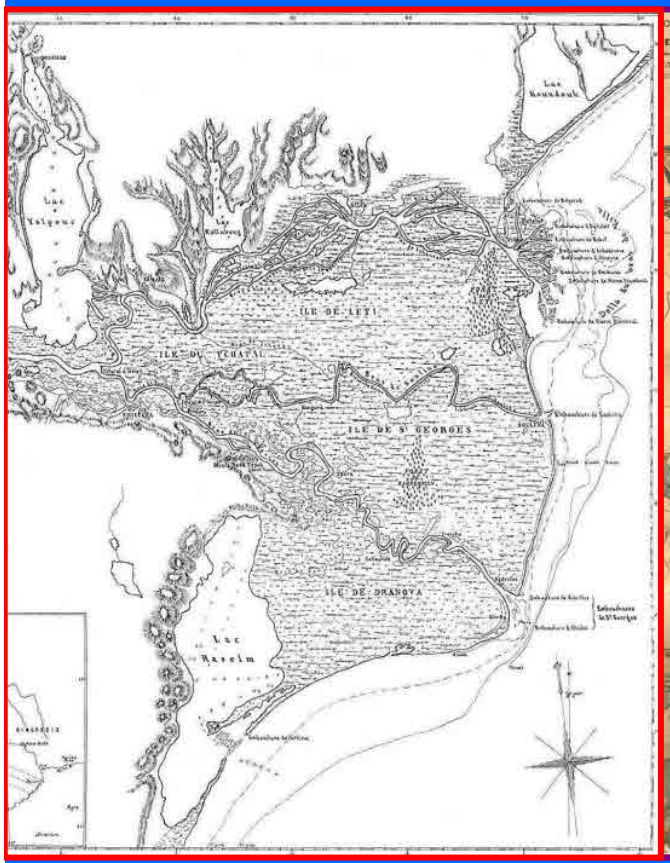
St.George cut-off channels (Dunavat meander belt)

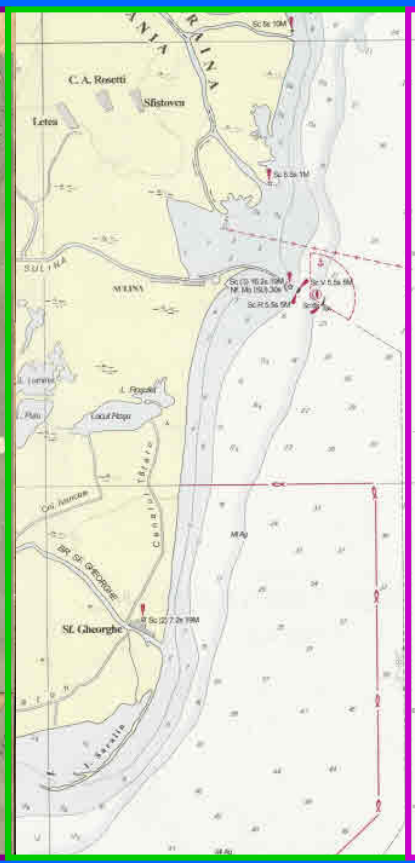
Air image of the Sulina – St.George interdistributary depression

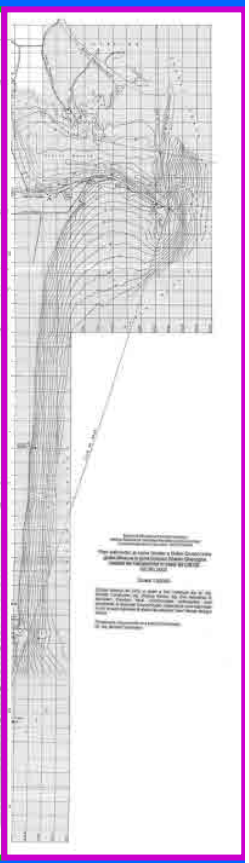
Geomorphologic changes in the Danube Delta Coastal Zone

- Historic cartographic documents consisting of 15 hydrographic and bathymetric maps of Danube Commission and of the Romanian Service for Navigation have been assessed.
- The map of 1857 was taken as reference document.

1857 1909 1994 2003







Romanian Black Sea coastal zone

Longshore sediment transport model

(after Giosan et al., 1997)

Sediment drift (arrows) and transport rates in thousand of cubic meters per year (figures by the arrows). Circled + and - represent advancing and retreating sections respectively

The Danube Delta Coastal Zone – a very dynamic environment

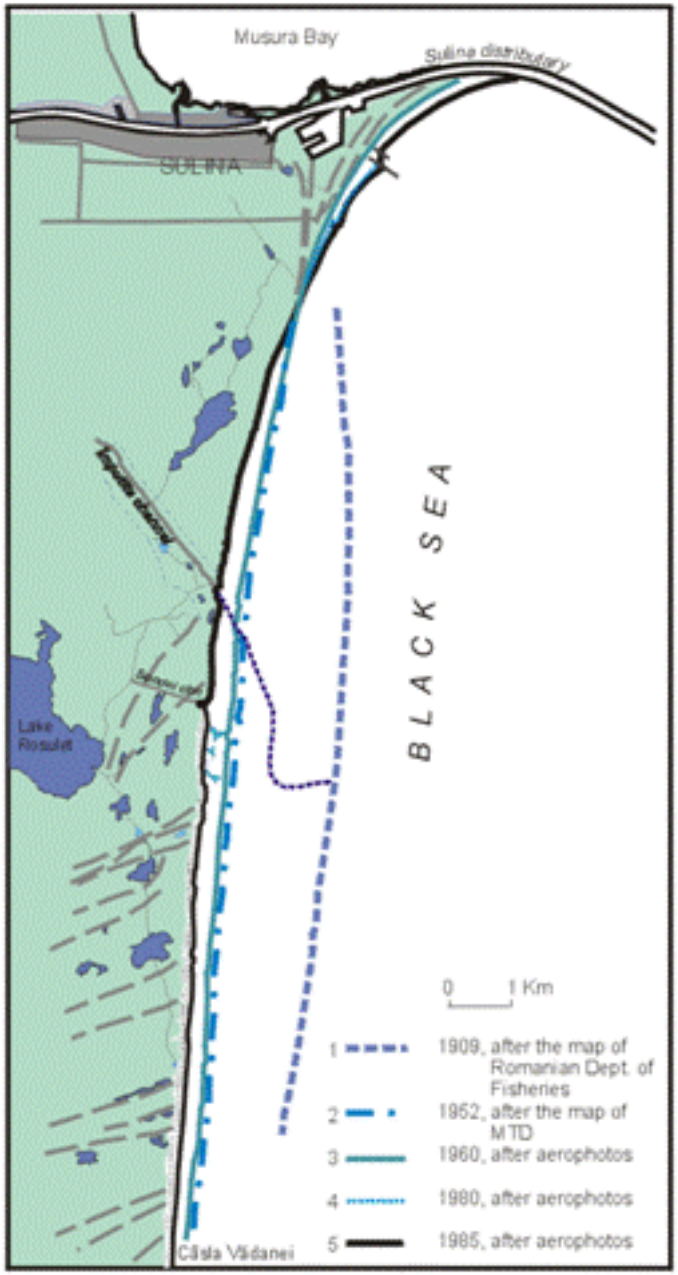
At the mouth of the main distributaries still active accumulation of sediments occures:

- At the Stambulul Vechi distributary mouth (Kilia Delta), northward Sulina, a lateral mouth bar is developing. This bar almost closes the Musura bay, which is gradually transformed into a lagoon.

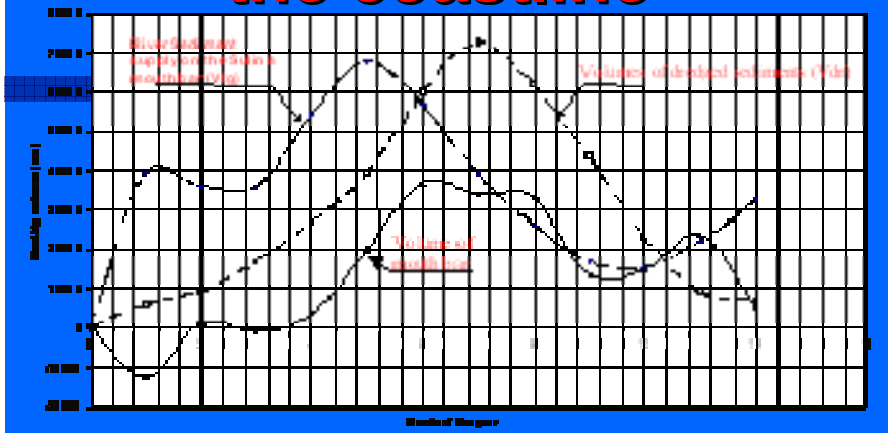
- At the St. George distributary mouth there is a secondary delta and a lateral arcuate lateral bar Sakhalin with a very active development

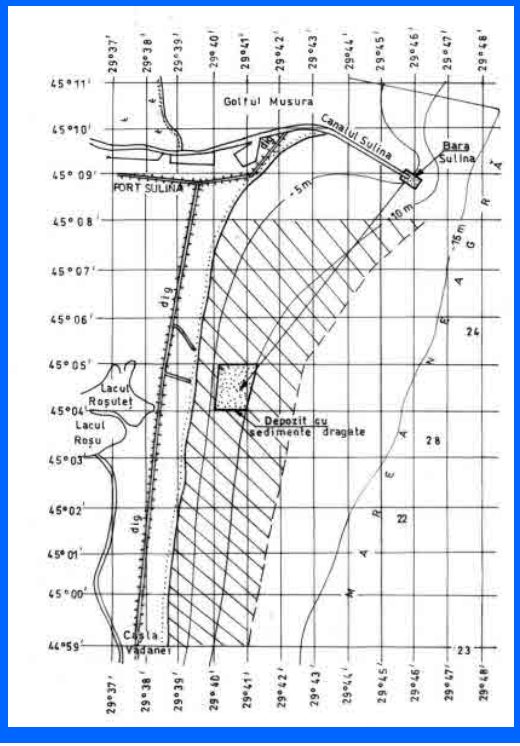
The delta coastline between the distributary mouth zones is very severely eroded

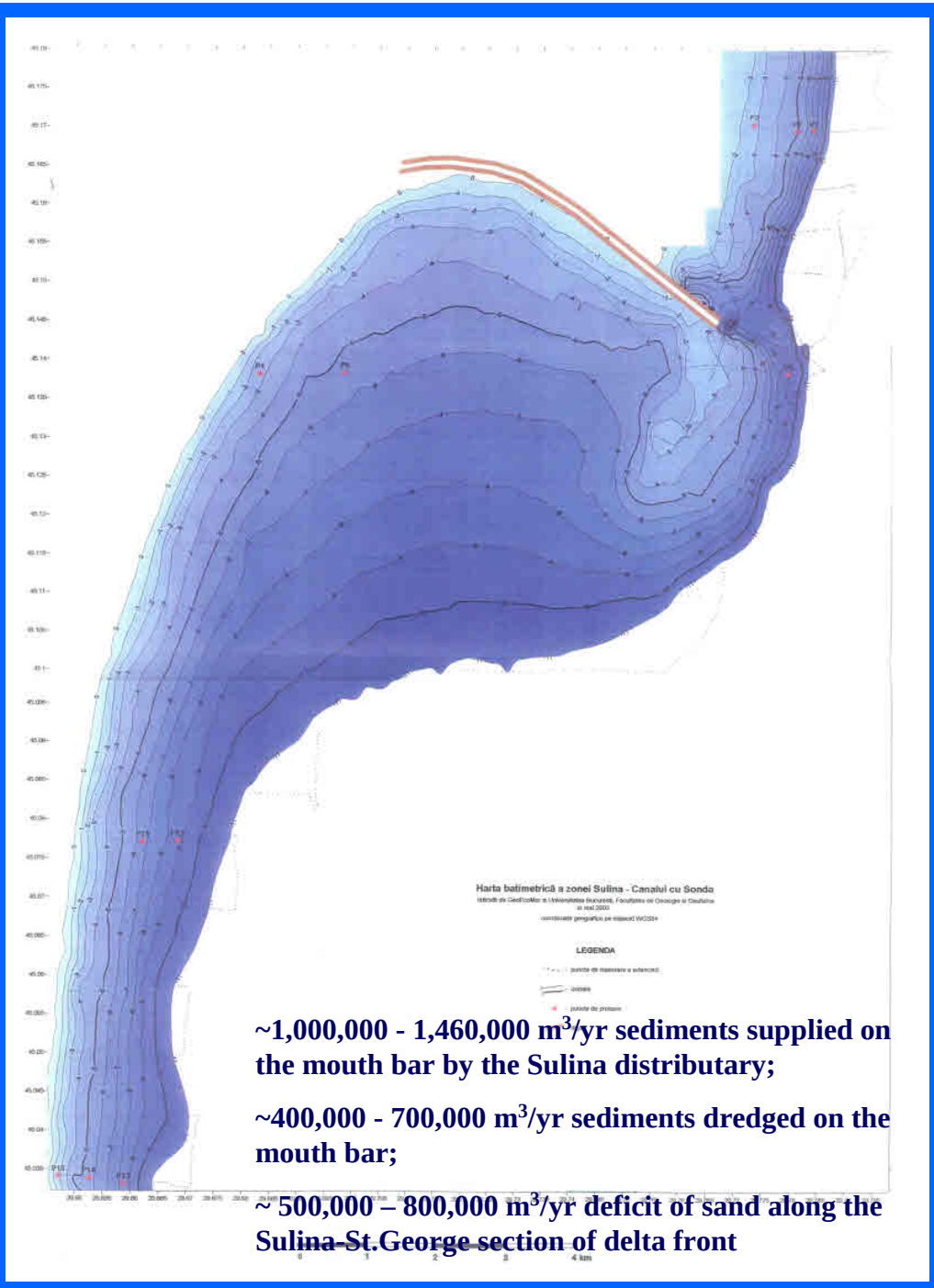
The Danube Delta coastline erosion in the 20-th century



Sulina mouth zone, solutions for protecting the coastline







~1,000,000 - 1,460,000 m^3/yr sediments supplied on the mouth bar by the Sulina distributary;

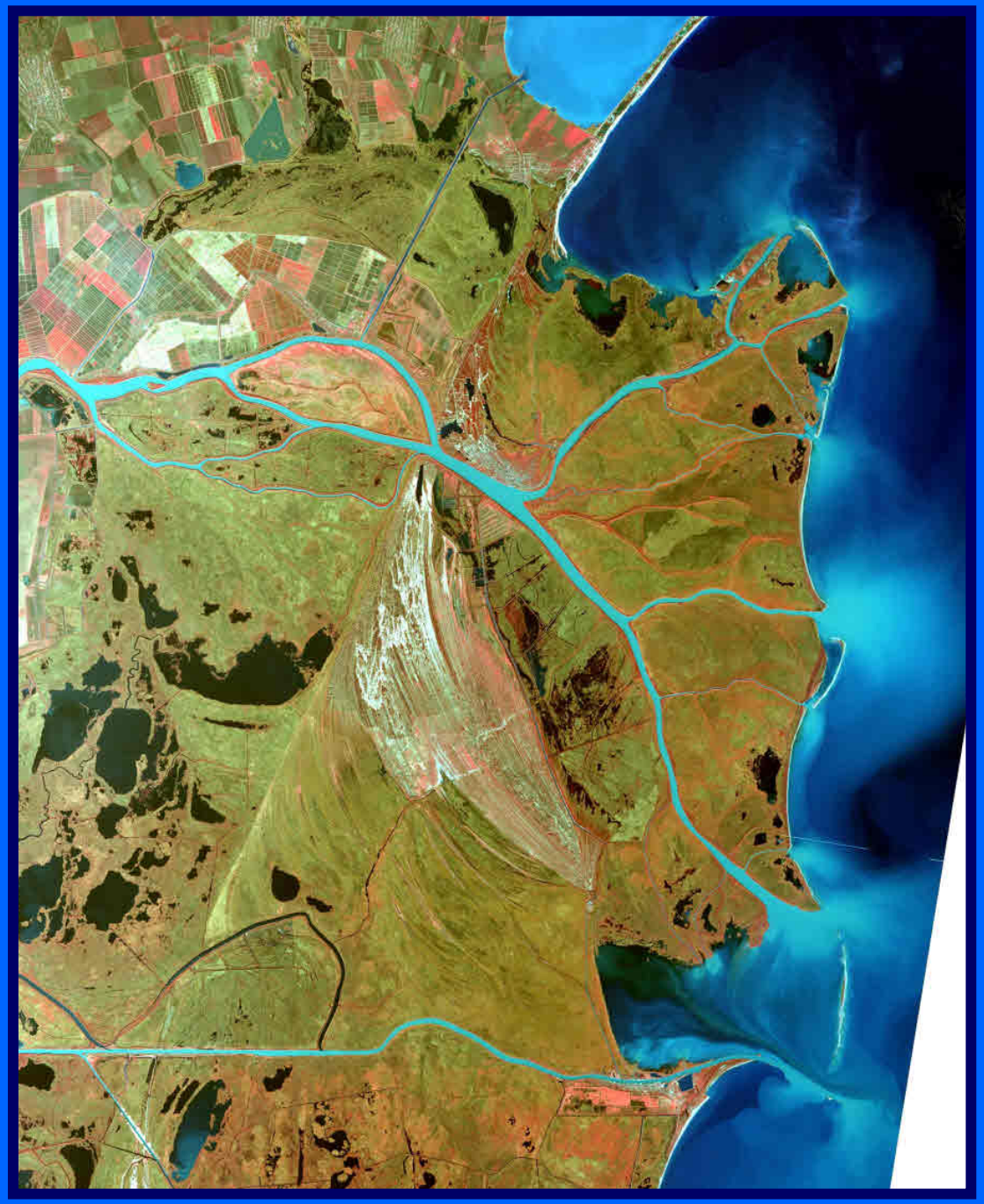
~400,000 - 700,000 m^3/yr sediments dredged on the mouth bar;

~ 500,000 – 800,000 m^3/yr deficit of sand along the Sulina-St.George section of delta front

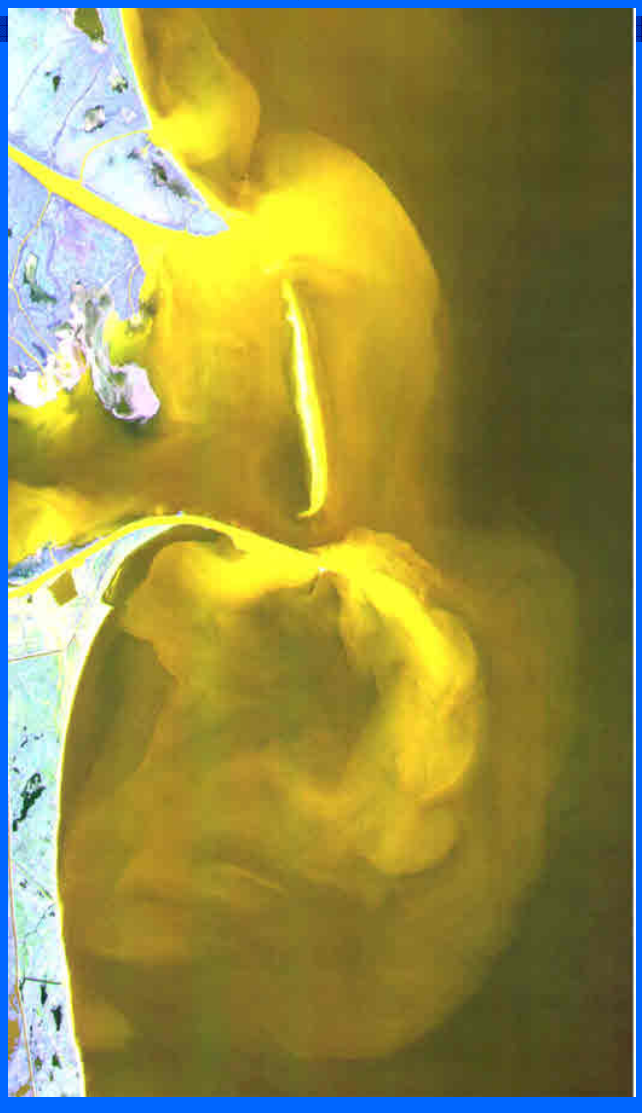
Kilia Delta

Satellite Image

2003



The lateral mouth bar at the Stambulul Vechi distributary mouth (Kilia Delta), northward Sulina



The bar has emerged (in the early 80') and reaches at present time about 10 km in length, its southern end being at less than 0.6 km from the Sulina distributary.

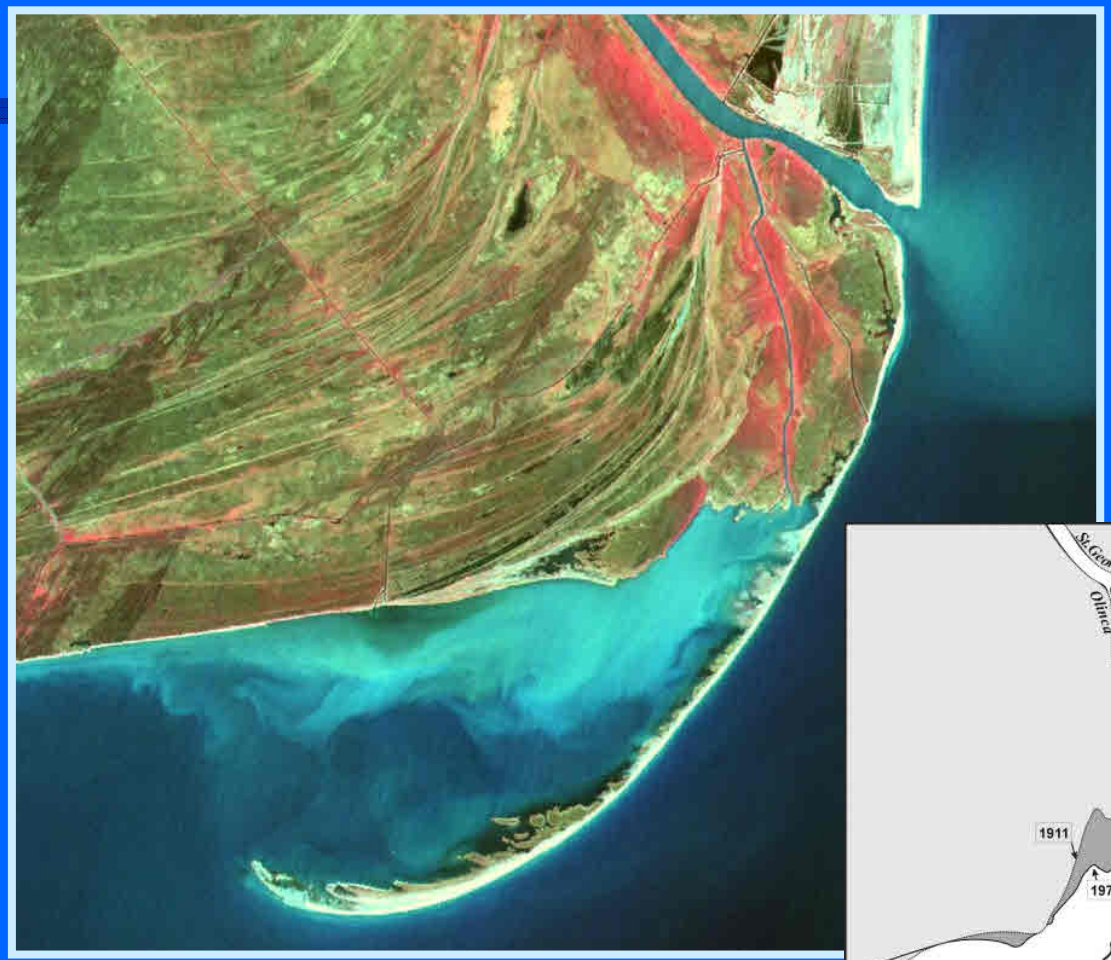
This bar almost closes the Musura bay, which is gradually transformed into a lagoon.

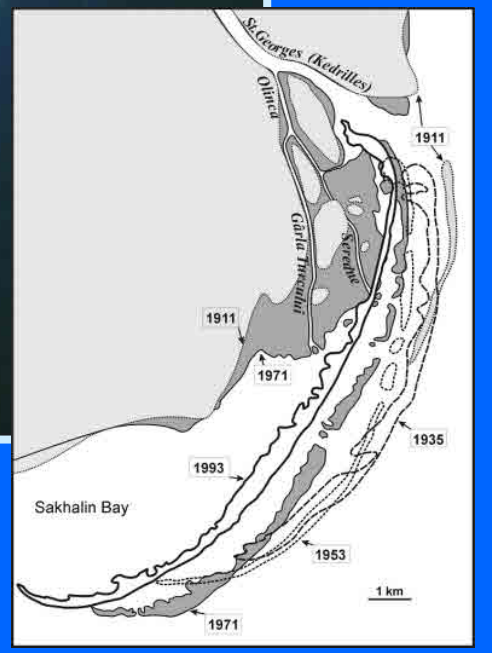
The St. George secondary delta and the lateral arcuate lateral bar Sakhalin

- The secondary delta and the Sakhalin bar started developing in 1897, after a catastrophic flood of the Danube River.

- At present the sediment drift flux is over 1.2 million m^3 per year.

- Consequently, the Sakhalin Island is lengthening by about 200 - 500 m/yr. The island is also moving landwards 10 – 70 m/yr by overwashing





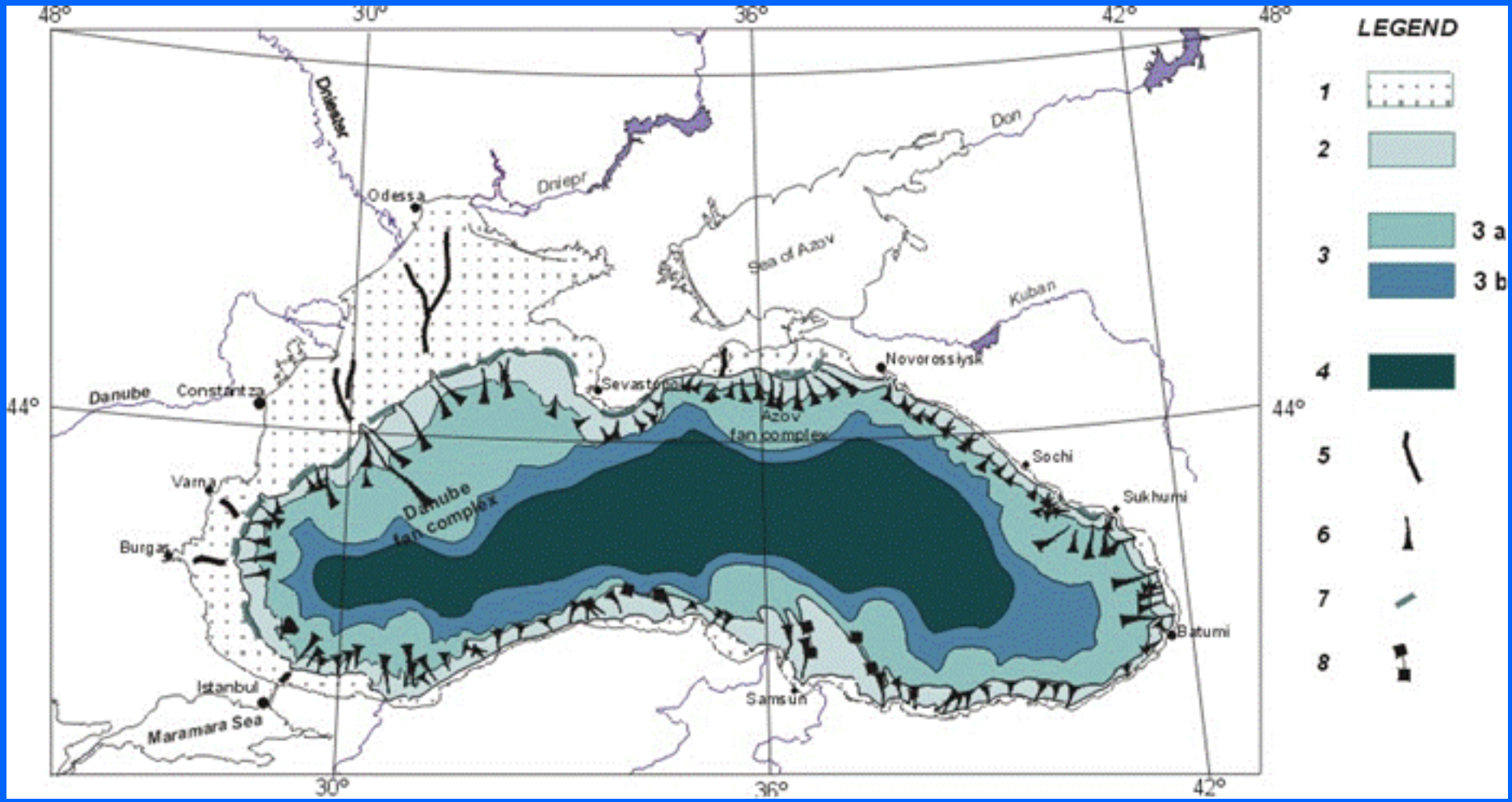
The Black Sea

Maximum water depth: - 2.212 m

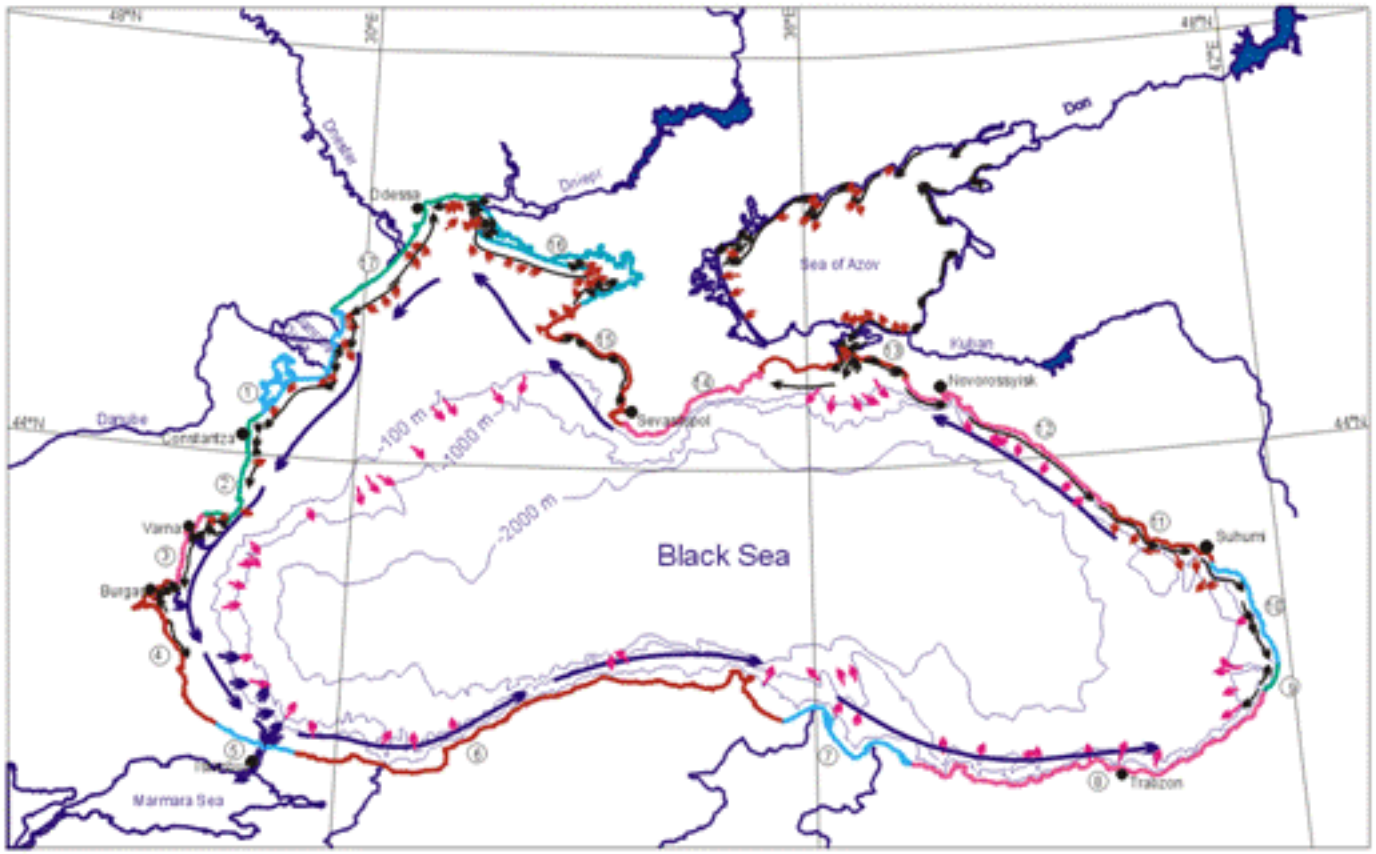
Total area: ~ 4.2 x 10^5 km^2 Total water volume: ~ 534,000 km^3

- **Below the depth of 150-200 m the Black Sea water is anoxic and contaminated with H_2S (the volume of the deep anoxic water is about 423,000 km^3).**
- **The *salinity* of the Black Sea water is about 17‰ at the surface and ~ 22 ‰ at the bottom**

Main physiographic units of the Black Sea



ZONATION OF THE BLACK SEA COASTAL ZONE
Sediment movement systems



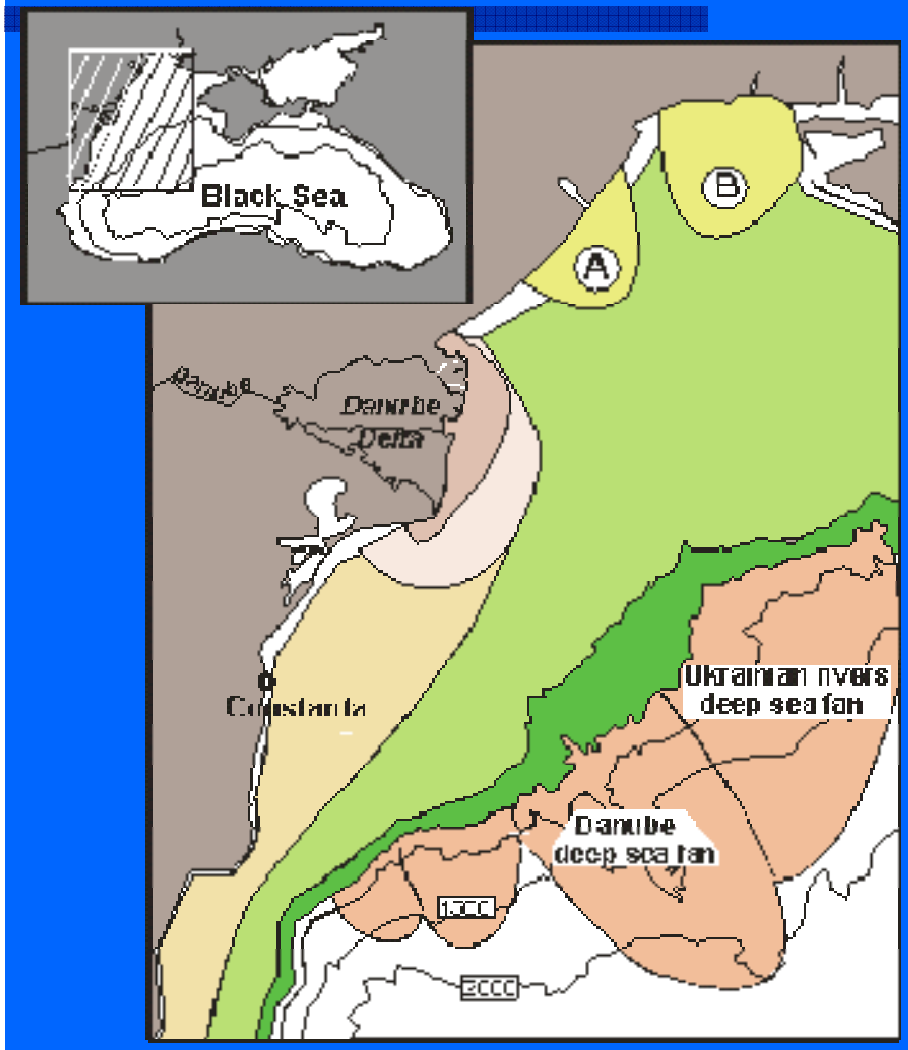
- sediment drift system in the coastal zone
- suspended matter flows in the off shore zone
- sources of sediments for the littoral drift system
- main terrigenous sediment supply system of the deep sea zone

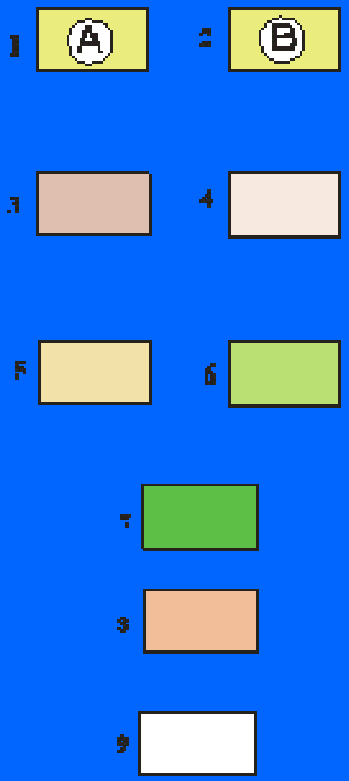
Name of littoral zone

① Danube Delta or Northern Zone
② South Dobrogean Zone
③ Frandza - Stara Planina
④ Burgas - Istrandza
⑤ Pre-Bosphorous Zone
⑥ Western Pontidae Zone (Isfendyar Daglari)
⑦ Samsun Zone
⑧ Eastern Pontidae Zone
⑨ Batoumi Zone
⑩ Rioni Depression Zone
⑪ East Caucasian Zone (Mzimta River-Kodori River)
⑫ West Caucasian Zone (Kudepsta River-Anapa)
⑬ Taman - Kerch Zone (Anapa-Feodosia)
⑭ South Crimean Zone (Feodosia-Balaklava)
⑮ West Crimean Zone (Balaklava-Bakal)
⑯ Karkinit - Dniepr Zone
⑰ N-W Black Sea Zone

After: N. Panin, E. Ion, G. Ion

Major sedimentary units in the NW Black Sea





Legend

1 and 2 – Zones of influence of the Dniestr (A) and Dnieper (B) Rivers;

3 – Danube Delta Front

4 – Danube Prodelta

5 – Danube-borne sediments drift area

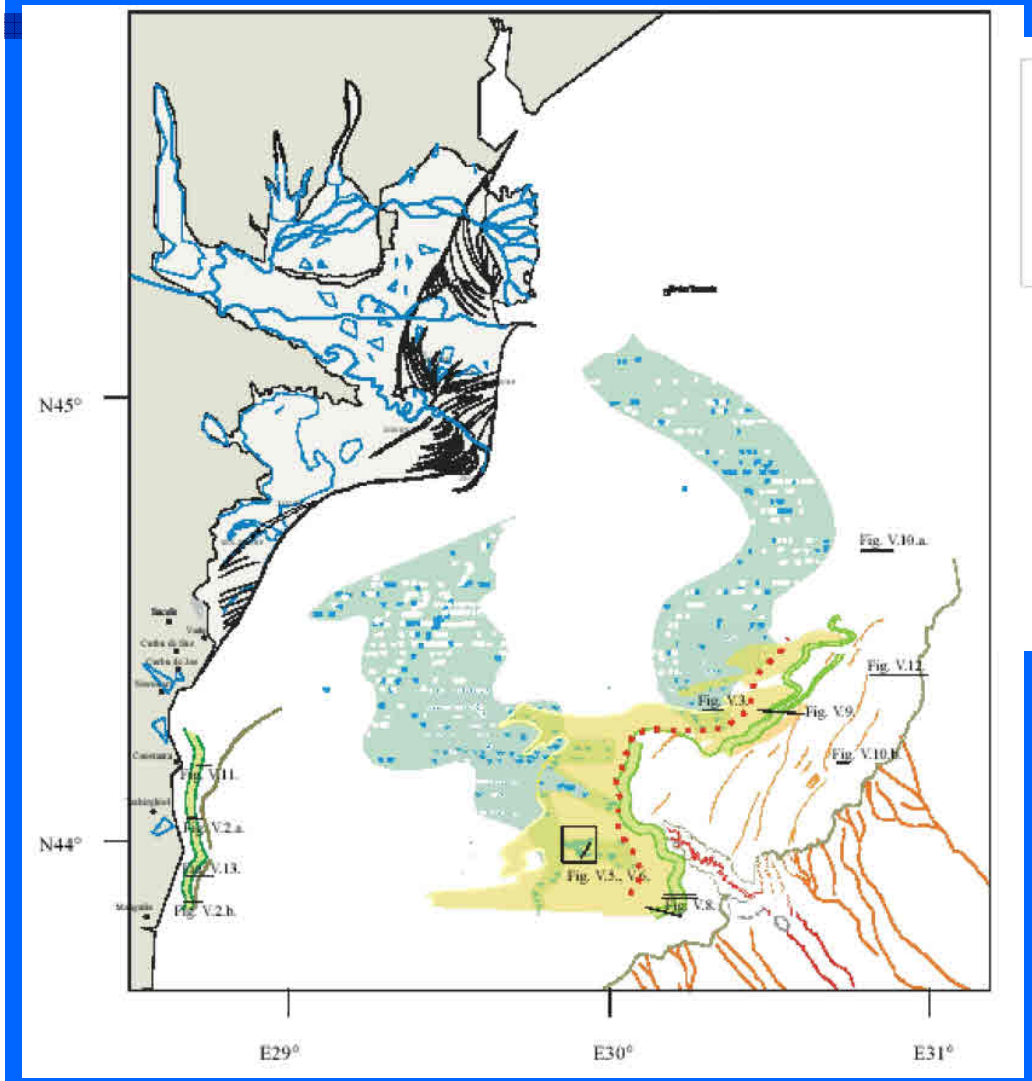
6 – Sediment starving continental shelf

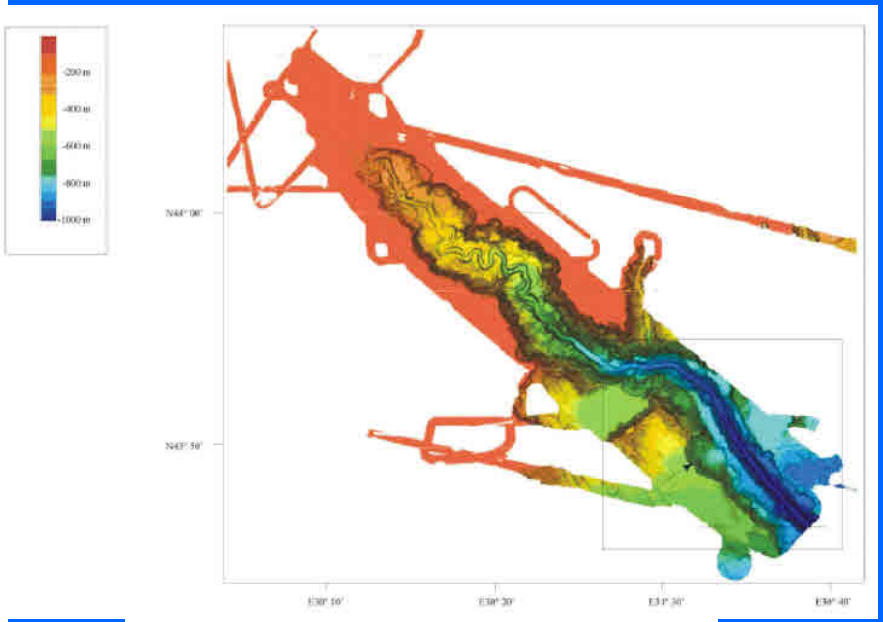
7 – Continental Slope

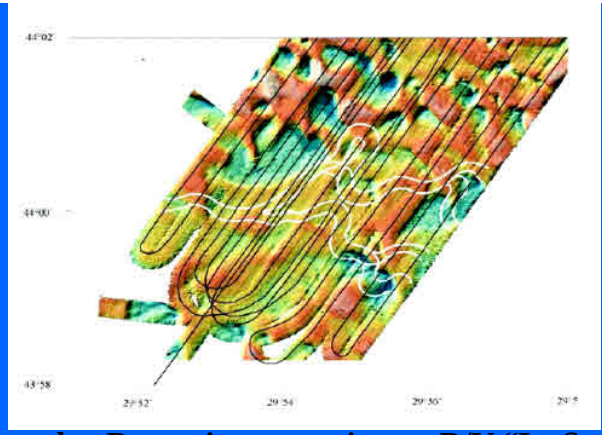
8 – Deep-sea fan complexes

9 – Deep-sea zone

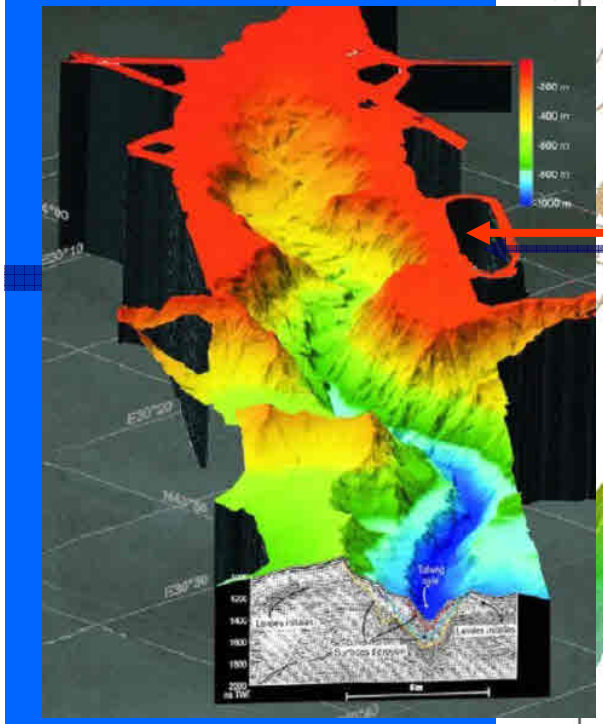
Sedimentary Systems in the Black Sea preserving features of Past Global Changes

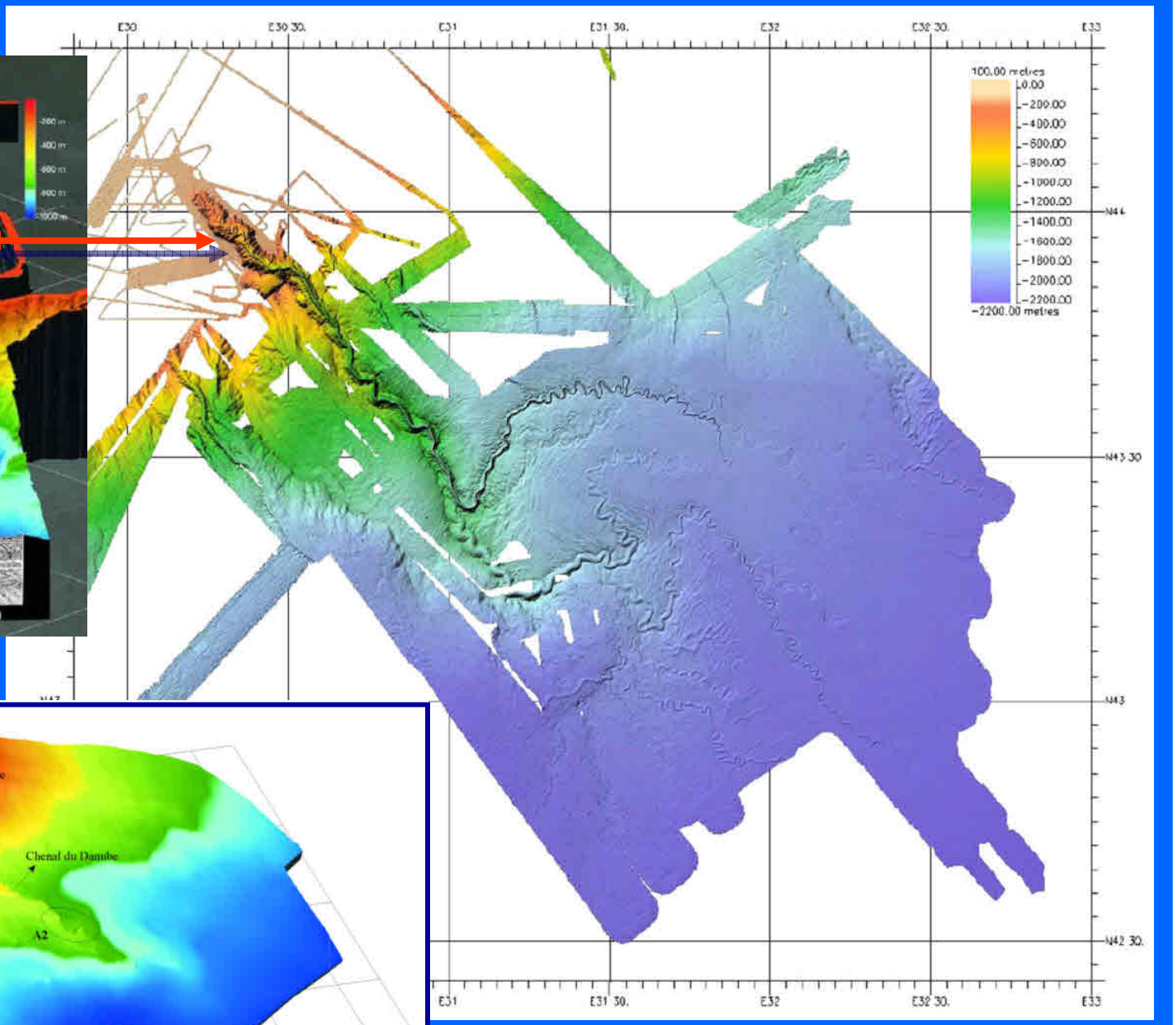


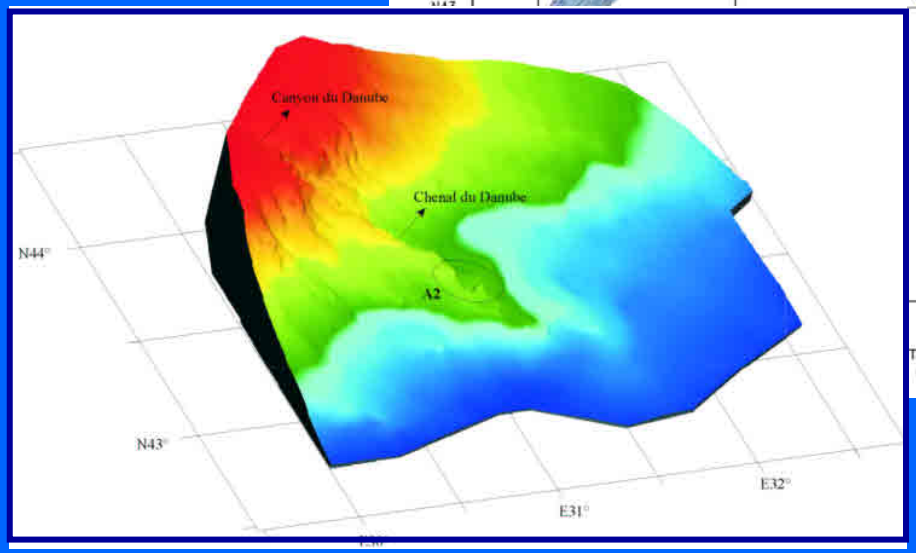




French – Romanian campaign on R/V “Le Suroit”







Deep-sea fan of the Danube

Gas seeps in the northwestern Black Sea