THE LOW DANUBE PALAEOHYDROGRAPHY

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Abstract: The authors have summarized extensive information on the chronologically and spatially development of the palaeohydrographic and hydrologic evolution of the Low Danube River and its catchment basin since the Miocene. Special attention has been paid on the proto river formation, the changes in the standing water basins and the tectonical impact on them.

The presented concept on this issue may be regarded as an intermediate stop in the incessant evolution of knowledge, that will be expanded and improved in the future by making use of innovative tools and research methods.

This paper is an abbreviated version of the contents of the volume No V/2, Palaeography of the Danube and its catchment with a special emphasis on the Low Danube stretch. The objective of the paper is to favor the dissemination of the information collected on the subject among a broad circle of interested readers.

Key words: palaeohydrography, river network, river morphology, sediments, tectonics, Danube catchment basin

The Low Danube River basin and the formation of the present orohydrography, natural and cultural landscape has undergone multiple changes since the Miocene till the present days (more than 25 million years).

Major sources of the palaeohydrographical study of the Danube river basin till the present days

The study has revealed that Marsigli's work (Marsigli, 1726) is defined as the first attempt to study the palaeohydrographic evolution of the Danube River and its catchment. In the next three centuries one may note the high achievements of Cvijić's (1908), morphological studies on the river terraces, those of Kéz (1956), or the works of different Hungarian, Romanian, Bulgarian and other scientists, dealing with the progressive elevation of the Carpathian basin and the accompanying changes in the river beds (Sümeghy 1955, Somogyi 1960, Borsy and Félegyhàzi 1988), as well as the achievements of Töry (1952), Niculescu (1977) and Mike (1991). Systematic studies in Bulgaria on the formation and dynamics of the Lower Danube have been conducted mainly by Michailov and Popov, (1978), Kojumdgieva and Popov, (1966, 1989). The authors (Michailov and Popov) identify and describe seven river terraces, landslides and land slips along the river banks. In connection with a study on the stability of the section and the possible neotectonic activities that might endanger the normal and safe work of a nuclear power plant Iv. Vaptsarov and his team have conducted independent geomorphological investigations on the area of the town of Belene (Vaptsarov et al., 1993) after "removal" of the loess cover of the area. The articles of Kojumdgieva, Popov (1989), the large-scale geomorphological studies of Galabov (1966) etc. summarize and develop the Bulgarian studies on the geomorphology of the river bank zone by elaborating the ideas about the stratigraphy of the geological formation and neotectonic processes. Contemporary study on typology of the bed forms of the rivers in Bulgaria as they emerge with the river fluvial processes is presented by Gergov (1975). The study ends with a comprehensive classification of the river network in Bulgaria. In another study Gergov and Nenov (1986) offer a typology of the river islands in the Danube River course according to their origin. The regularity of their forms and the dynamics of their changes have been determined. It becomes evident that the morphological processes on the Lower Danube and its tributaries have been much affected by the human activities and thus the irreversible lowering of the basis of erosion is under development. Such investigations have been also conducted by Michailov and Popov (1978), Karagyozova and Hristov (1995) and others.

Until recently the work of Fink (1996) was considered to be the one of outstanding significance on this subject. Its greatest merit is the detailed description of the evolution of the Danube catchment basin, including identification of the inherent relationships and controversial issues. He presents three palaeohydrographic maps, each of them visualizing the reconstructed state of the river system of the Danube watershed basin for a typical geochronological period.

Brief description

Table 1 shows in a logarithmic scale, the geochronological development of the Earth (Palaeogeography…, 1999) with a brief reference notes about the most important events on the hydrographic evolution of the three major portions of the basin: upper, middle and lower Danube area, situated downstream the Devin Gate and the Iron Gate.

History of the palaeohydrographic evolution

Lower Miocene

The Danube catchment basin belongs to a zone called "Neo-Europe", which was connected to the continent only during the Tertiary orogenesis. During the Tertiary the Danube basin has been part of the so-called. Paratethys, part of the Tethys, the primary source from which the Mediterranean has emerged (Palaeogeography…, 1999). It used to be a closed basin of low salinity as the Black Sea it is (Popov and Kojumdgieva, 1987; Kojumdgieva and Popov, 1989).

The nuclei of the future mountain chains emerged as islands in the relatively shallow sea. The young mountain chains that took shape during that period are the Alps, the Carpathian mountains, the Dinar Mountains and the Balkan. These elements, part of the Alpine mountain system, are divided by depressions in which the rock debris from rising mountains were accumulated. The intensive erosion, preconditioned by the sub-tropical climate during the late miocene, compensate their elevation. No tributaries that may be assigned to the Danube River network are known since that time.

According to a study, conducted by Bulgarian morphologists, during that period Northern Bulgaria used to be a dry land - a plain inclined to the north towards the Southern Carpathians, where the pre-Carpathian lowland was formed (Kojumdgieva and Popov, 1989). The rivers used to reach it by cutting deep river valleys. Such valleys have been depicted in the area of the city of Pleven at a depth of up to 400 m. Bokov (1968) identified an old, buried, Pre-Neogene releif of Palaeogenic valleys in Northwest Bulgaria, which date back to the lower or upper Oligocene age. These palaeo-valleys, overlapping in their outlines with the Lom, Voynishka, Topolovets, Ogosta, Osam and Vit Rivers, may be traced on the Romanian territory as well and therefore require specific attention and new further studies. At the same time the longitudinal Miocene depression in the Varna-Balchik area was formed, in which for a short time thick clay deposits were formed (Popov and Kojumdgieva, 1987).

The hydrographic network, originating from the Balkan, continues to develop. It took shape and extended the hydrographic link of the Pre-Carpathian basin with Southern Bulgaria via the deep indented antecedent valley of the Iskar River.

The above described changes in the palaeohydrography of the Paratethys, of its outlines and size, follow in sequence the inner structural and more short-termed cyclic changes in the course of the entire neotectonic phase (neogene and quaternary).

Table 1. The palaeohydrographic development of the Danube Catchment

Years B.Pr.	Geologic epoch	Palaeohydrographic events in the Danube Region		
		Upper	Central	Lower

3000		HOLOCENE	Upper Holocene		Due to continued karsting of the Schwäbisch Alb, increasing seepage from the spring region of the Danube to the Rhine	The Tisza is compelled to a northern detour by the uplift of the Nyirség Region	Beginning of progressive accretion of the present Delta Region
					The present river system comes into being		
8000			Lower Holocene		Formation of lakes in the valleys created by glacial erosion	Formation of lakes and marshes in local depressions	Due to transgression of the Black Sea, inundation of the present day Delta Region up to Braila
10000	QUATERNARY	PLEISTOCENE	Upper Pleistocene	Wurm-Glacial	Due to vigorous uplift of the Alps and glacial erosion, significant deepening of the valleys and sediment production. Genesis of terraced valleys	Due to tectonics the Danube abandons its alluvial cone and creates its present day riverbed along the depressions of Trans Danubia	Due to uplift of the Dobrugea, the lower Danube turns northward
				Riss-Wuml ntergl.		Terraced valleys in the mountains bordering the basins	Starting from Iron Gate, the Danube creates a terraced valley through the Romanian Lowland up to Calaraci
				Riss Glacial	Detachment of the Alpine Rhine from Danube Catchment	The riverbed of the Tisza gradually shifts eastward	
500000			Middle Pl		Repeated icing of the higher mountainous regions provides debris for the accretion on the basins. At medium hights and on the margins of basins, terraced valleys are formed. Significant shifts of riverbed courses within the basin		
1 Mln			Old Pl.		The catchment of the Proto-Main joins the Rhine Catchment	The Danube turns toward the Visegrad Pass and fills up the Great Hungarian Lowland, jointly with the rivers Proto-Tisza, Proto-Maros etc.	After filling up the rest-lakes of Petrosani and Geta, the whole Romanian Low-land becomes a dry land. The main branch of the Danube reaches the Black Sea at Constanta
			Early Pleistocene or Eopleistocene		Strong uplift of the Alps	In the Small Hungarian Lowland the Danube flows southward, along the margin of the Pannonian Basin, down to the Iron Gate	
2 Mln	UPPER TERTIARY	PLIOCENE	Pliocene		The upper Neckar Valley is annexed by the Rhine	Subsidence of the Pannonian Basin stops and it is gradually filled up. Rest lakes in the Pannonian Basin	The Moesian Sea joins the Black Sea
5 Mln			Pannonian		The headwater regions of the Alpine Rhine and the Aare are annexed to the Danube Catchment. The SW rivers of the Czech Massif join the Elbe Catchment.	Accretion of the Vienna Basin. The Proto-Danube reaches the border of the Small Hungarian Lowland. The gradually subsiding Pannonial Basin is being filled up with thick maritime layers originating from erosion of the margins	On the Sarmatian Table, gradual advance of the mainland at the expence of the Black Sea
					Capture of the Proto-Alpine Rhine by the Proto-Aare		
10 Mln		MIOCENE	Upper		Accretion of the Svabian-Bavarian Basin.Genesis of the Upper Proto-Danube	Vigorous volcanism on the margin of the Pannonian Basin. Salt accumulation in the Transylvanian Basin, temporary cut off the main sea	The southern coastal region of the Moesian Sea is being filled up by the rivers of the Balkan Mountains. The foothills area of the Southern Carpathians subside
			Middle				
20 Mln			Lower		Integrated Danube Catchment not yet existing. Significant erosion on the basin margins and in the lowlands		

Middle and upper Miocene

The present rivers have emerged for the first time during the middle Miocene (Rögl and Steininger,1983). They appeared as small river systems, forerunners of the modern hydrographic network, above all in the coastline land areas. What is surprising is that the watershed of the former Paratethys is, with minor exceptions, identical with that of the contemporary Danube catchment basin (Hámor, 1995).

Pliocene

During the Pliocene period the erosion processes increased because of the more rapid rise of mountains. The rocky debris filled up gradually the sea bottom and formed sub-basins. This process is particularly characteristic for the Pannonian basin, i.e. for the Middle-Danube area. Later Paratethys has gradually turned into a network of lakes, marshes and streams of progressively diminishing depth. This river-lake system disappeared only when the residual lake Getha (Getha depression), in the centre of the Moesian basin, got fully sludged with sediments during the first half of the Pleistocene.

At the same time the Lom depression was formed at the northwestern periphery of the Moesian platform in the sector of the Lower Danube and began to get filled in with thick sludge layers in the form of semi-salinated basins. The depression is surrounded by the mounting Balkan Range at the South. As a result of it the sandy terrigenous component increases in the facies of the deposits (Popov, Kojumdgieva, 1966, 1987). Later, the basin extended eastward up to the area of Rousse-Silistra. This has been connected with certain changes in the young hydrographic network of the region. Thus the Suhobrakyovska River has shifted from the area of the Lower Danube to that of the Middle Danube, changing from a tributary to the Lower Danube to a tributary of the Middle Danube by the Nishava River.

Pleistocene

The periodical cooling of the climate during the Pleistocene has resulted into partial (the Alps) or complete icing of the still rising mountains (Penck and Brückner, 1901-1909). The physical weathering, that predominated during the cold periods of Pleistocene, generated huge masses of solid matter. A part of them have been presently identified as depositions (Kvitković et al., 1956, Molnàr, 1973). It was found that when the mountain streams entered the lowland area the debris used to build large alluvial trains and ramps (Töry, 1952, Rónai, 1985). Alternatively, in the non-icy mountains the river streams were fixed by permanent bank indentation. In the ice-covered areas, the valleys were heavily reshaped by the glacier erosion, while in the mountain areas and hills they have developed under the influence of the climatic changes.

Since the end of the Pliocene the central Danube region is characterized by clear changes in the direction of the river stream. Following the formation of the Vienna basin, the Danube River originally used to flow along the eastern boundary of the Alps in southern direction, and later it turned eastwards along the southern boundary of the Pannonian basin, reaching the Iron Gate (Rónai, 1985, Mike, 1991). The tectonic processes during the middle Pleistocene directed the lower stretches of the Danube River from the Vienna basin in eastern direction towards the Visegràd Pass, where one of the biggest alluvial trains was deposited, called the Island or Szigetköz. The lower stretch at the Visegràd Gate has gradually filled in the depression of the Great Hungarian Plain, while the direction of the stream slowly moved to the south (Juhász, 1992).

The shift of the main stream in the region and the ongoing tectonic processes (rise and drop) had a strong impact on the direction of the tributaries, running down from the hills down to the lowland. By the end of the Pleistocene marshlands and some of the biggest lakes - Fertö and Lake Balaton in this area were formed.

In the Lower Danube region the changes in the direction of the river stretches were less significant. Because of the low runoff for climatic reasons the tributaries, flowing down the mountains have rapidly deposited the rough sediment matter, so that only small volumes of it (mainly floating matter) could reach the Danube (Popov and all, 1964). Its river valley, comprising several terraces, extended up to the southern boundary of the Romanian Lowlands. In the early Pleistocene a marshland existed there and was later gradually filled in by the river. When Getha, the last residual lake was filled with slime, the river cut its way towards the Black Sea. By assumption this is the first Danube River estuary, located south of

Dobrudga. However because of the tectonic rise of the area during the second half of the Pleistocene the river mouth moved to the northern boundary of Dobrudga. The changes in the Black Sea water level due to climate change (in the range of 70-80 m) caused a shift of the estuary far ahead in east-west. Evidence to that are the traces of ancient river beds of the Danube, found on the sea bottom. The Olt River has undergone one of the most remarkable changes of direction - originally it used to be tributary of the Maros River, however later it was trapped by a smaller direct tributary of the Danube River, cut deep in the Southern Carpathians. In this way the Transylvanian basin, which originally used to be one whole in hydrographic terms, was divided into two watershed basins that of the Tisza River and another one of the Danube River. The development of the Iskar River in Bulgaria is almost identical. The deposit of sediments before the present-day Balkan mountain lead to a rise in the water level, which later cut a gorge through and the river dashed towards the Danube and became its tributary.

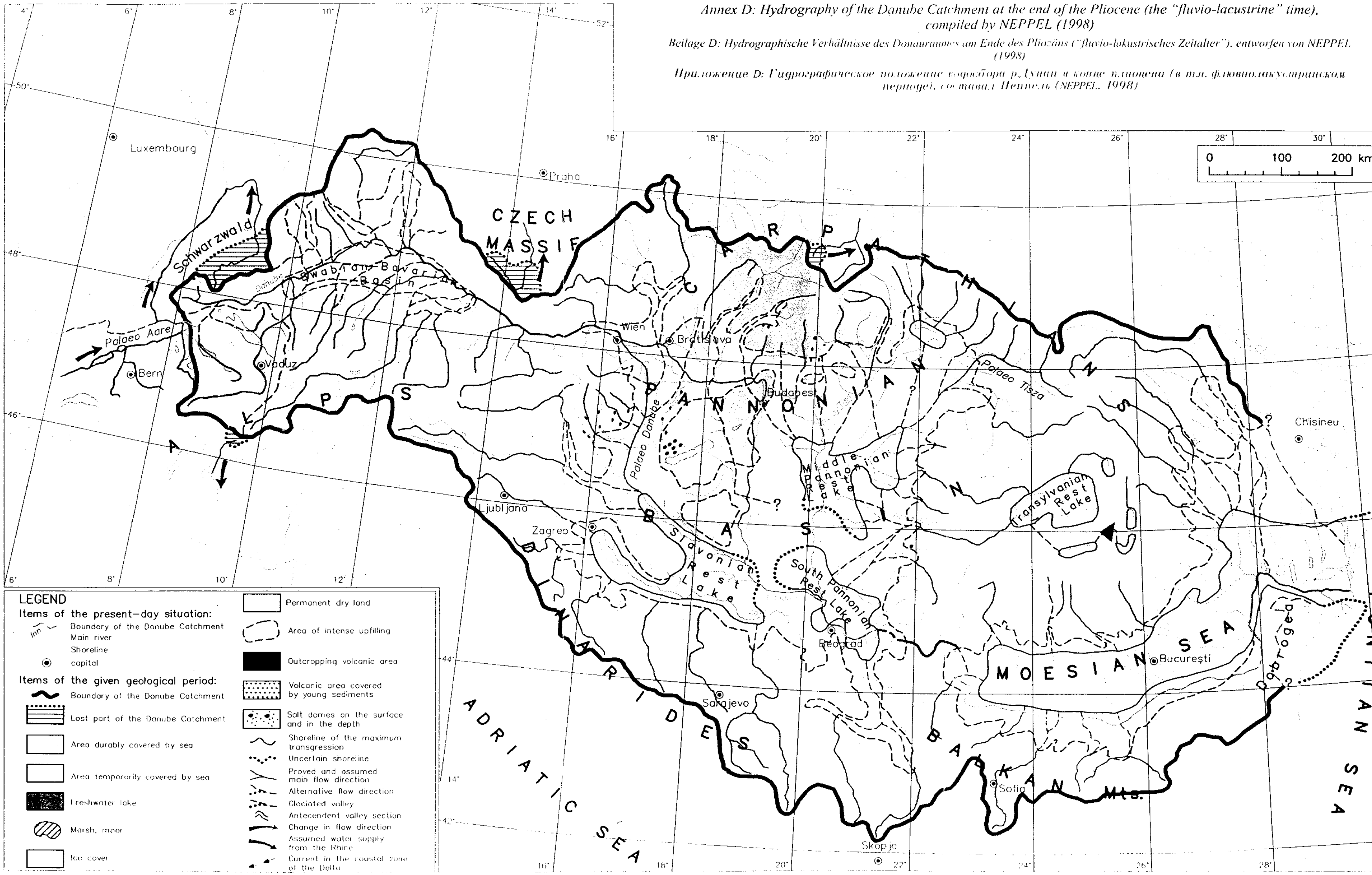
Holocene

Until the beginning of Holocene the development of the present river system has been almost completed. Three changes are worth specific attention.

First, the karstification of the Schwäbish Alb has continued and as a consequence of it a considerable part of the runoff of the Danube River has reached underground the Rhein River basin (Vogelsang, Villinger, 1987).

Second, a tectonic rise took place in the north-eastern end of the region at Nyírség in the north-eastern part of the Great Hungarian Plain. The Tisza River followed the depression along the northern boundary of the lowland, so that its entire system of tributaries was restructured (Fig. 1) (Somogyi, 1960).

Finally, during the late Holocene a transgression of the Black Sea from the estuary of the Danube River to the skirts of the Carpathian mountains took place, where large sediment deposits were formed in the river bed. This transgression was limited in time, so that the Danube River has filled in and developed its present-day delta in the course of the next 2000 years (Diaconu et al., 1963). The transgression may be looked at from a tectonic point of view as a rise of the Black Sea basin and flooding the adjacent areas without changes in the hydrological conditions (Spiridonov, 1998). Evidence to this are the sunk estuaries of the Danube River tributaries and the formation of numerous lakes in the flooded terraces of the river. Cumulative flooded terraces were formed. An alternative explanation is also possible, namely climate warming and increased influx of river water due to melting of the glaciers. The increased water availability has caused flooding of large territories. The ample sedimentary matter on the bottom has blocked the estuaries of the shorter right-hand tributaries of the main river and as a result of it natural lakes were formed at the estuaries Garvansko, Srebarna, Garlitsa, Oltina, Mirlyanu etc.



Annex D: Hydrography of the Danube Catchment at the end of the Pliocene (the "fluvio-lacustrine" time), compiled by NEPPEL (1998)
Beilage D: Hydrographische Verhältnisse des Donauraumes am Ende des Pliozäns ("fluvio-lakustrisches Zeitalter"), entworfen von NEPPEL (1998)
0
100
200 km
Luxembourg
Praha
CZECH
MASSIF
Schwarzwald
Swabian-Bavarian Basin
Palaeo Aare
Bern
Vaduz
ALPS
Wien
Bratislava
Budapest
CARPATHIANS
PANNONIAN BASIN
Palaeo Danube
Palaeo Tisza
Middle Pannonian Rest Lake
Transylvanian Rest Lake
Slavonian Rest Lake
South Pannonian Rest Lake
Ljubljana
Zagreb
Beograd
Sarajevo
Skopje
Sofia
București
Chisineu
Dobrogea
MOESIAN SEA
PONTIAN SEA
ADRIATIC SEA
DINARIDES
BALKAN Mts.
LEGEND
Items of the present-day situation:
Boundary of the Danube Catchment
Main river
Shoreline
capital
Items of the given geological period:
Boundary of the Danube Catchment
Lost part of the Danube Catchment
Area durably covered by sea
Area temporarily covered by sea
Freshwater lake
Marsh, moor
Ice cover
Permanent dry land
Area of intense upfilling
Outcropping volcanic area
Volcanic area covered by young sediments
Salt domes on the surface and in the depth
Shoreline of the maximum transgression
Uncertain shoreline
Proved and assumed main flow direction
Alternative flow direction
Glaciated valley
Antecendent valley section
Change in flow direction
Assumed water supply from the Rhine
Current in the coastal zone of the Delta

Figure 1

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