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Contrasted sediment processes and morphological adjustments in three successive cutoff meanders of the Danube delta

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ABSTRACT

Since the 1980s intensive anthropogenic disturbances have affected the channel of the St. George branch, the southern distributary of the Danube River. The meander cutoff programme since 1984–1988 induced different hydrosedimentary impacts on the local distribution of river flow velocities, discharge, and sediment fluxes between the former meanders and the man-made canals (Ichim and Radoane, 1986; Popa, 1997; Panin, 2003). This paper selects three large cutoff meander reaches of the St. George branch (the Mahmudia, Dunavăţ de Sus, and Dunavăţ de Jos meanders noted here as M1, M2, and M3, respectively) as an example to analyse the human impact in the Danube River delta. The diversion of the flow induces strong modifications by acceleration of the fluxes through the artificial canals combined with dramatically enhanced deposition in the former meander where it was observed in two cases (M1 and M3) with slight modifications in M2. An exceptional flood that occurred in April 2006 offered a good opportunity for scanning different cross sections of the meander systems. Bathymetry, flow velocity, suspended-load concentration, and liquid and solid discharge data were acquired throughout several cross sections of both natural channels and artificial canals of the three cutoffs, using acoustic Doppler current profiler (ADCP) technology, in order to investigate the distribution of the flow and sediment and its impact on the hydrosedimentary processes in each channelized reach and adjacent former meander. Therefore, the results obtained during the 2006 flood were referred to a long-term evolution (1970–2006), analysed by GIS techniques.

1. Introduction

Morphological processes of the fluvial channel are controlled by liquid and solid fluxes through hydraulic forces exerted by flow and sediment transport, erosion, and deposition, especially in the flood regime (Bridge, 2003). Geomorphologists particularly underlined the effectiveness of the bankfull discharge, renowned as the most morphogenic, i.e., the main long-term control factor of erosion or accumulation of sediments on river banks and bottom channel (Kondolf and Piégay, 2003). In this study, we use the definitions of bankfull proposed by Wolman and Miller (1960) and Leopold et al. (1964): bankfull discharge is the stream flow that fills the main channel and begins to spill water into the active floodplain. The bankfull stage approximates the stage at which the channel and the floodplain begin to be connected (Rosgen, 1994; Knighton, 1996).

The climatic changes and the anthropogenic pressure in the last 100 years have transformed the majority of river hydrosystems. Distributary network geometry is the most important factor controlling delta landforms (Syvitski et al., 2005) and related hydrological, geological, and sedimentological processes (Hood, 2010). Disturbances like river training operations, such as meander cutoff initiated for navigational or flood mitigation purposes, often lead to dramatic changes in streamwise profiles (Hooke, 1986; Kesel, 2003; Kiss et al., 2008). The evaluation of long-term effects of a meander cutoff project requires estimation of the long-term geomorphology of both the former meander and the man-made canal. The initial flow and sediment capacity will change with time as the hydraulic efficiency of the flow pathways within the former meander changes owing to the geomorphological evolution. Changes in the river bed associated with modified long-term sediment transport capacity may affect the stage–discharge relationship at the diversion site (Letter et al., 2008). The impacts of a single, small-scale meander correction may have a minimal effect on the system, but the cumulative effects of a number of small diversions can become significant for the entire system. The paper presented here provides a case study of anthropic changes in the morphogenesis and hydrosedimentary dynamics of a set of rectified meanders. The main objective is estimating the intensity of human activity impacts to river flow and sediment regime and to observe the different morphological responses.

This paper expands to two downstream meanders the scope of a previous work about the flow and sediment processes during episodic

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flooding in the Mahmudia meander (Jugaru Tiron et al., 2009), to underline the contrasting processes and evolution between the three cutoffs, and to look for relevant factors that explain the different responses.

2. Regional setting

2.1. Geographical context

With a mean annual water discharge of 1365 $m^3 \cdot s^{-1}$ and mean annual suspended sediment flux of 317 $kg \cdot s^{-1}$, the St. George branch is the most southern branch of the Danube delta (5600 km^2), downstream of the main contributor of fresh water and sediment into the Black Sea, the Danube River. The St. George branch starts out from a bifurcation at Ceatal St. George located 108 km upstream of the outlet to the Black Sea (Fig. 1) and carries about 24% of the water discharge and 21% of the suspended sediment discharge of the Danube (Bondar and Panin, 2000). The banks are bounded by a rich and continuous vegetal coverage (trees, poplars, and reeds). The St. George branch is highly sinuous and still morphologically dynamic as attested by migrating meanders (Popa, 1997; Jugaru et al., 2006; Tiron, 2010) and by the fast evolution of its mouth (Panin, 2003).

The study area consists of three former meanders located in the middle part of the St. George branch (Fig. 1): Mahmudia, Dunavăţ de Sus, and Dunavăţ de Jos meanders, named hereafter M1, M2, and M3, respectively. M1 is the largest and the most complex meander in the St. George branch. It is located between km 84 and km 64 and results from the river impingement against the Mahmudia hills that deflected the St. George channel into a large meander loop named the Mahmudia-Uzlina meander bend (Panin, 2003). Downstream, meanders M2 and M3 derive from one big fossil meander formed between 9000 and 7200 y BP and degraded over time (Panin, 1976).

The sediments of the submerged banks are fine and differently distributed according to the channel type: coarse silt to fine sand (between 20 and 135 μm) along the man-made canals, concave banks, and at the bifurcation/junctions between the natural/artificial channels and clay to fine silt (between 10 and 20 μm) along the former meanders (Tiron and Provansal, 2010).

2.2. Control factors

Within the lower Danube, two barrages (Iron Gates I and II, built up in 1970 and 1984, respectively) and the hydrotechnical regulation works along the Danube tributaries have dramatically decreased the sediment discharge at the Danube mouths (within 25–30%) (Panin and Jipa, 2002; Panin, 2003).

Along the St. George distributary, the cutoff of the natural channels by navigational canals between 1984 and 1988 caused dramatic

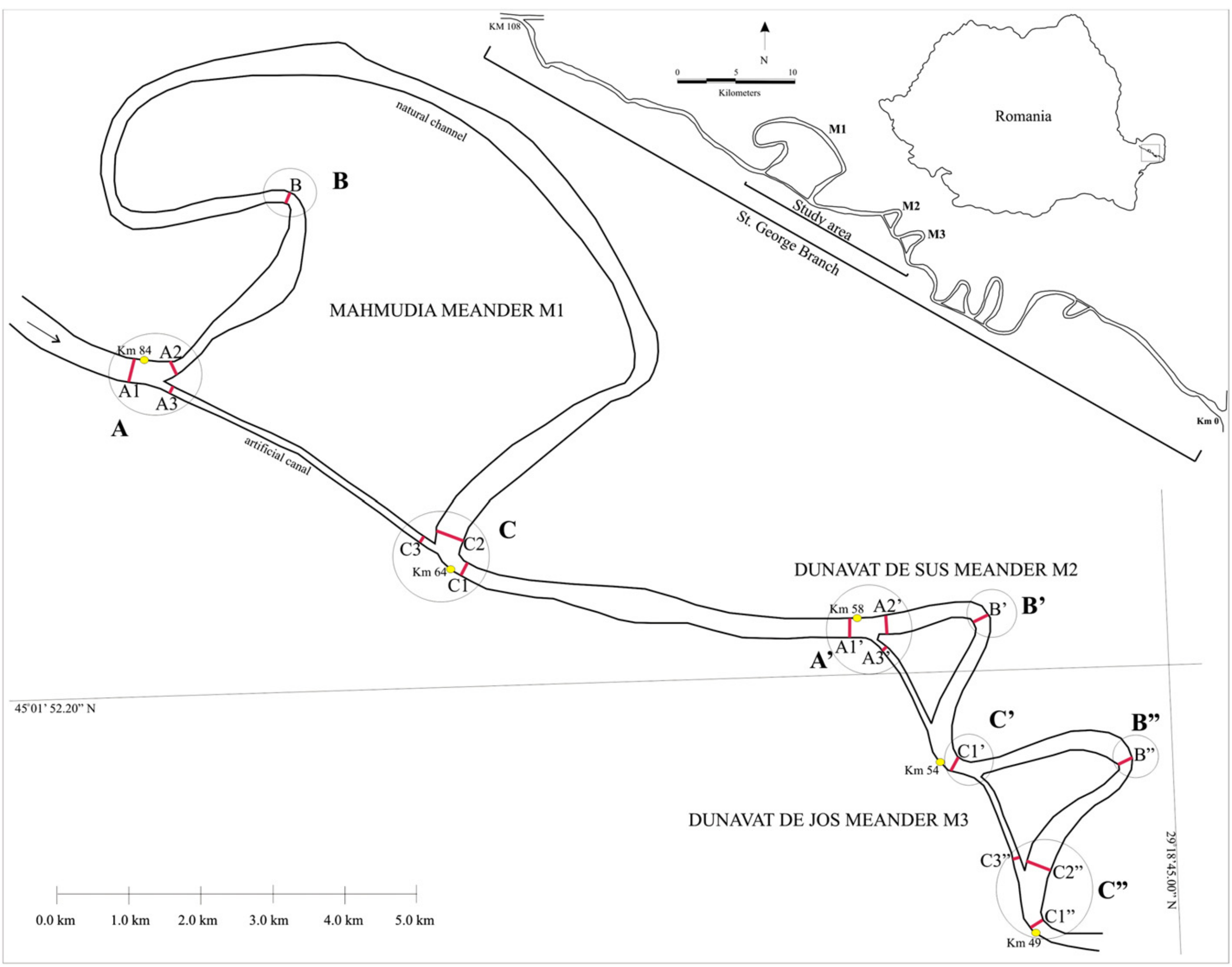

Fig. 1. Location of study reach within the St. George Branch, Danube delta and the ADCP profile position.