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Preliminary data on the Jiu River meanders in the lower course (South-West Romania)

Oana IONUȘ[1,*]

[1] Geography Department, University of Craiova, Romania
* *Corresponding author*, oana_ionus@yahoo.com

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Abstract

The aim of this study is the complex monitoring of the Jiu river bed in terms of geometry and complexity of meanders in its lower sector (on a length of 77 km).
The detailed analysis of the lower Jiu sector meanders completes the geomorphologic knowledge of rivers in Romania, starting from the identification and determination of the type of meanders: the results that were achieved are represented by the indexes concerning their age and migration rate (wavelength, 1977 - 4721 m; meanders amplitude, 511 - 2862 m; the mean radius of curvature, 270 - 997 m and the sinuosity index, from 0.87 to 2.17).
Another aim of this study is the identification of the evolution features of the Jiu river, the relationships between some hydrological factors of control (liquid flow and suspended sediments - annual average values) and the generations of meanders (actual or open meanders, and incised meanders or paleomeanders) distributed in two sectors: Podari - Padea sector and the sector stretching from Padea up to the Danube confluence.
In addition, our concern is motivated by the fact that in the last years there were analyzed the landslides and subsidence on the right slope of the Jiu river (next to Bâzdâna and Drănic settlements), strongly eroded and in close connection with the meandering of the watercourse.

Keywords: *meanders, morphological parameters, paleomeanders, actual meanders, lower sector, the Jiu River*

Rezumat. Date preliminare asupra meandrelor râului Jiu din cursul inferior (Sud-Vest România)

Scopul prezentului studiu constă în monitorizarea complexă a albiei râului Jiu cu privire la geometria și complexitatea meandrelor sale din cursul inferior (pe o lungime de 77 km).
Analiza detaliată a meandrelor din cursul inferior al Jiului completează cercetările geomorfologice asupra râurilor din România, pornind de la identificarea și determinarea tipului de meandre până la rezultatele obținute care se prezintă ca indicii ai stadiului de existență și ai ratei de migrare (lungimea de undă, 1977 - 4721 m; amplitudinea meandrelor, 511 - 2862 m, raza medie de curbură, 270-997 m și indicele de sinuozitate, 0.87-2.17).
Un alt obiectiv al acestui studiu este identificarea caracteristicilor de evoluție a râului Jiu, relațiile dintre o serie de factori hidrologici de control (debit lichid și sedimente în suspensie - valori medii anuale) și generațiile de meandre (meandre actuale sau deschise și meandre incizate sau paleomeandre), distribuite pe două sectoare: sectorul Podari - Padea și sectorul Padea - confluență Dunăre.
În plus, cercetarea este motivată de faptul că în ultimii ani au fost analizate alunecările de teren și surpările de pe versantul drept al râului Jiu, puternic erodat și în strânsă legătură cu meandrarea cursului de apă (în apropiere de localitățile Bâzdâna și Drănic).

Cuvinte-cheie: *meandre, parametri morfologici, paleomeandre, meandru actual, curs inferior, râul Jiu*

Introduction

At European level, the type and rate assessment of the historical changes of river beds (Kondolf et al. 2002, Rinaldi 2003) present results that show the aggradation processes that have affected various parts of the fluvial system.

Ichim et al. (1979) studied in detail the meanders morphology issues, which are ranked as some of the most complex for a river in our country by their implications for the paleo -evolution.

The researches in our country on the erosion-alluvial successive phases in Pleistocene-Holocene, especially in the east part of the Eastern Carpathians (Donisă 1868, Ichim 1979) show the Wurmian age of the pebbles that mudded off the bottom of the eastern-Carpathian valleys, which thus justifies the assumption of a heavy deepening during the Riss-Wurm interglacial period.

For the study area, the literature abounds in analyses of the geological characteristics (Badea 1996, Enciu 2007), geomorphologic (Geografia României 1992, Roşu 1956, Coteţ 1957, Geografia Văii Dunării Româneşti 1969, Stroe 2003, Romanian Academy 2005, Boengiu 2008, Badea 2009, Boengiu 2004, Boengiu et al. 2011, Ionuș et al. 2011) and hydrologic (Savin 1990, 2000; Pleniceanu 1999) features of the limitrophe regions that the valley crosses through. The analyzed Jiu River sector has a length of 77 km and is located downstream of Craiova, where the valley has developed asymmetrically with a width of over 10 km and a maximum depth of 120 m at Craiova. The right slope is steep and has a very active dynamics (Fig. 1), the left slope has a stepped profile, the floodplain 4-5 km wide (Boengiu et al. 2011).

The evolution of the Jiu watercourse and floodplain is the result of the climatic variations influencing also the hydrological regime of the Jiu River, and also the result of the neotectonic movements influence (Boengiu – Enache, 2002).

Therefore, there are basically two main causes of this major stage in the historical evolution of the Jiu river course: the tectonic one, which facilitated the divagation of the course to the right of the floodplain, and the hydrologic one, which determined its change of direction and of river bed.

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The Jiu River general tendency is to build its floodplain on the left side and to destroy the right bank by lateral erosion. The altitude increases with 2-3 m due to the presence of agesters and sand dunes. An old course of the Jiu – the Jieţ can be noticed downstream of Rojiştea, on its left side (Boengiu 2005, Boengiu et al. 2010). The plain stretches on 80 km, located between the Podari – Cîrcea alignment and the confluence with the Danube, representing 8% (800 km2) of the total basin surface and has a slope of 1 - 0.3 ‰ (Savin 1990).

The very obvious horizontal instability in the last 50 years in this sector is explained by the alluvial transport type and the higher erosion of the banks. The intensity of erosion process varies from one section to another depending on the geologic structure of the river channel, slope variation (mean declivity is 7‰ - Podari and 6‰ - Zăval) (PMBH JIU 2010).

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Figure 1: The Jiu riverbed and Drănic landslide on the right slope

Source: photo by Boengiu, 2012

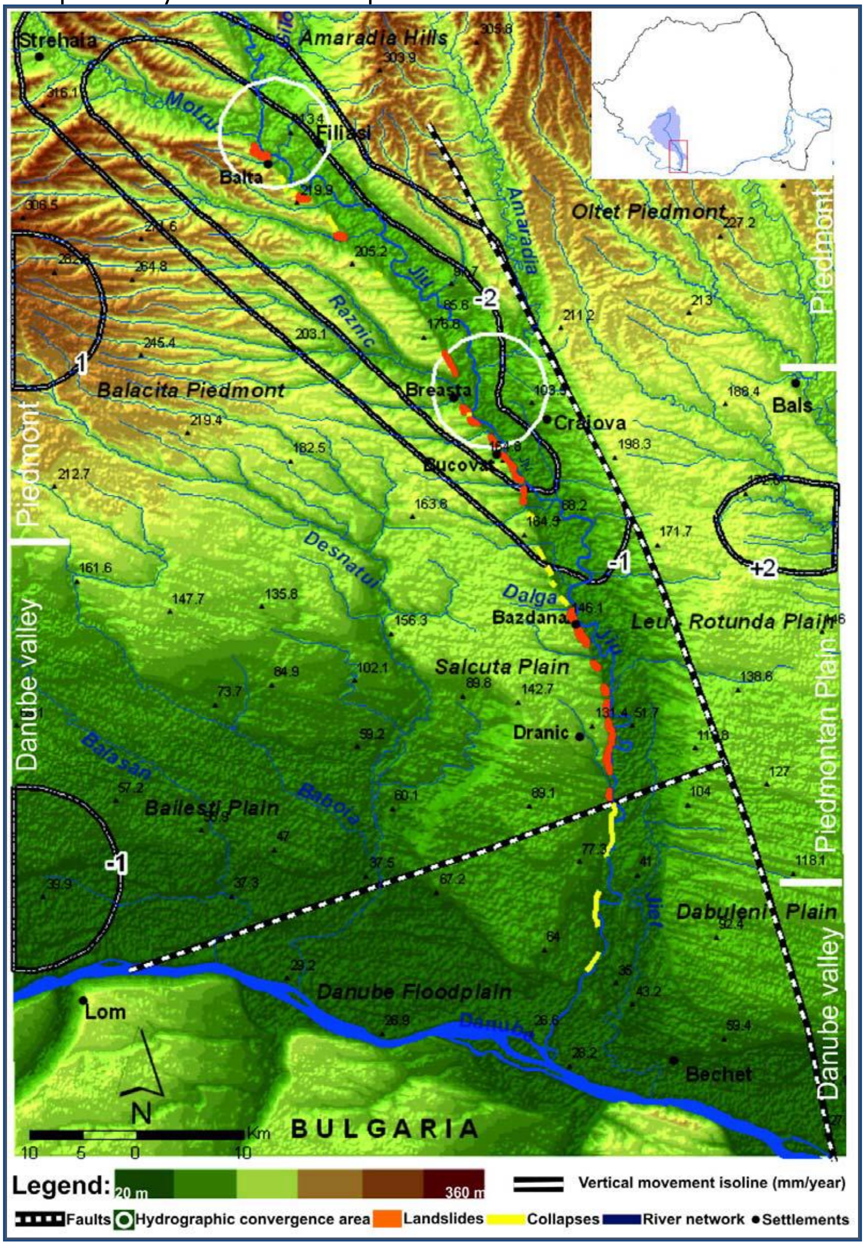

Figure 2: The general map of the study area *Source: Boengiu et al 2011*

The Jiu river bed is steeped in relatively fine deposits and reflects the type of solid flow transported by the river, respectively, suspended sediments.

The sinuosity index (sinuosity index: Podari - 1.96, Zăval - 1.25) is used to determine the types of river beds along the river, but also for capturing some evolution tendencies on a larger scale (Ichim et al. 1989, Rădoane – Rădoane 2008). The values below 1.5 (Leopold – Wolman 1957) rank the river sector within the category of sinuous river bed type, and the values higher or equal to 1.5 are associated with the meander river bed sectors. The formation and deepening of the minor river bed on the current path must be of recent geological time, or even of historical age, as many traces of watercourses, river branches and abandoned meanders indicates an intense activity of the river in the last period of time (Savin 1990, Rădoane et al. 2008)

Data and methods

To characterize the Jiu river bed from the geomorphologic point of view, a morphometric database was created correlated with the meandering process in the lower sector. In order to create a database, there was necessary to define the morphometric parameters of meander loops and their actual measurements using cartographic support (orthophotos, scale 1:5000, 2009) and the ArcGIS 9.3 software.

The measured parameters for a meander: wavelength, meander amplitude, mean radius of curvature and sinuosity coefficient are already acknowledged in the fluvial geomorphology (Rădoane – Rădoane 2003).

The Jiu minor riverbed was monitored hydrologically in the two control sections of the lower sector: Podari hydrometric station and Zăval hydrometric station between 1967 and 2010.

The modification of the river bed was correlated with the water and sediment transport along the river as they were measured at the mentioned hydrometric stations.

Results and discussions

The Jiu River channel is very dynamic due to the correlation between the morphometric and hydraulic elements in the cross section with the water flow and level, as it can be seen from the parameters registered at the two hydrometric stations located within the analysed sector: Podari (S – 9253 km2, average height – 446 m), Zăval (S – 10046 km2, average height – 417 m), (Atlasul Cadastrului apelor din România 1992).

The liquid flow and suspended solid flow which crossed the river bed section in the monitored period are the most important and sensitive factors, which determined the behaviour of the river bed (Fig. 3). Thus, we notice that during the studied period, the liquid flow had a variation with a slightly negative trend during 1971-1990, and then there were alternating years with high values of the flow with years in which the flow had values lower than the average yearly value of the period (88.3 m3/s - Podari and 92.2 m3/s Zăval).

The highest value of the liquid flow was registered in 1969 (153 cm/s - Podari, 154 cm/s - Zăval) and 2005 (150 cm/s - Podari, 153 cm/s - Zăval) for both hydrometric stations and the lowest value in 1993 (45.8 cm/s - Podari, 41.9 cm/s - Zăval). But the amount of sediments that crossed the Zăval section was much higher.

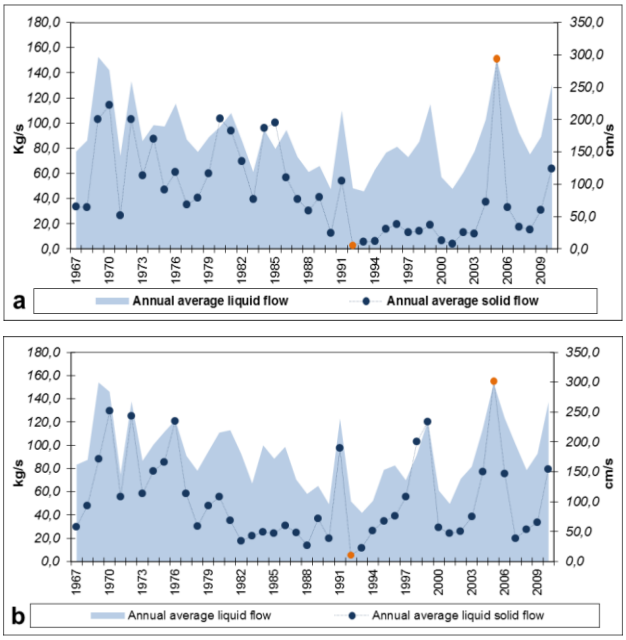

Figure 3: Variation of the annual average liquid and solid flows of the Jiu river: a. Podari hydrometric station; b. Zăval hydrometric station

Source: processing of the data supplied by the "Romanian Waters" National Administration—the Jiu Branch

The suspended sediments value decreased below the annual average value (103.5 kg/s) during 1976-1990, then it varied between the two threshold values, the minimum of 10.9 kg/s and maximum of 302 kg/s. The year 2005 registered the highest annual average values of suspended sediments at the both hydrometric stations (294 kg/s - Podari, 302 kg/s - Zăval). We conclude therefore that the size of alluvial flow that crossed the Zăval section had direct influence in the river bed behaviour: the oscillation of sediments transport after 1992 had direct influence in the appearance of the instability tendency of the minor river bed.

The observations derived from the analysis of the Fig. 3 are closely related to those resulted from the variability of water and sediments flow in the Podari and Zăval sections. After 1990, the riverbed tends to slightly increase its sinuosity due to the reduction of the sediments transport (even if the liquid flow volume in the river bed remains constant or even increases slightly).

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The period between 2004 and 2006 was outstanding for Romania because of the recorded values of the liquid flow and suspended sediments in the two control sections of the Jiu River. There were no damages and destructions along the Jiu River, as it was for other rivers, such as the Timiș, Trotuș, Siret or the Danube (Romanian Ministry of Environment 2006).

In terms of the development of the meandering process, the Jiu River can be subdivided into the following sectors:

- the sector between the Amaradia`s confluence and Malu Mare, where there are no meanders at all of the watercourse;
- Podari – Padea sector, where there are meanders with very large bends and some broad changes in stream direction, moving the watercourse under the right slope (Fig. 4, 5 and 6);
- Padea – the Danube confluence sector, in which there are paleomeanders sectors and sectors where the Jiu watercourse slightly winds horizontally under the right slope, to the mouth of the river.

The meanders from the sectors of Malu Mare and Padea localities are the most typical and well-developed with large bends on a broad surface of the floodplain width (1/3-2/3). Starting from Podari to Zăval, in the direction of water flow, the analyzed meanders received a serial number to facilitate the subsequent measurements (Table 1).

Table 1: The Jiu River's present and paleo-meanders morphometry (lower sector)

A	B	C	D	E
1	3277	2862	516	1,87
2	3850	1260	899	1,50
3	4223	875	786	1,46
4	2380	1050	315	1,95
5	1977	900	270	2,17
6	2637	1808	479	2.03
7	2826	1855	478	2,13
8	2789	633	596	1,17
9	4632	1080	513	1,23
10	3552	511	997	0,87
11	4721	2042	471	1,68
12	3567	639	397	1,25
13	3072	1058	383	1,33

A - Meander no.; B - Wavelenght (λ, m)
C - Meanders amplitude (a, m)
D - The mean radius of curvature (Rc, m)
E - Sinuosity index (k)

The actual meanders of the Jiu river overlap a large sinuous path indicating an earlier phase of river meandering, because their dimension contrasts sharply with the current river flows, too small to explain their formation (Dury, 1964). Thus we can talk about two generations of meanders, actual meanders and paleomeanders. In figure 7 there are examples of these types of meanders.

Figure 4: The Jiu riverbed branches in the Bâzdâna sector Source: photo by Boengiu, 2012

Figure 5: Meander "goose neck" of the Jiu river in the Drănic sector *Source: photo by Boengiu, 2012*

Figure 6: The Jiu riverbed branches in the Drănic sector Source: photo by Boengiu, 2012

The incised meanders (paleomeanders) develop on almost 80% of the river length and the open or alluvial meanders (actual meanders) are formed on approximately 3.5 km in Padea locality (meander 8), on 4 km in Horezu Poenari locality (meander 10) and on 4.5 km in Comoşteni locality (meander 12).

The wavelength and the meanders amplitude of the incised meanders are much higher (λ = 4721 m, a = 2862 m) than those of the open meanders (λ = 1977 m; a = 511 m), the values are reflected in the development of "goose neck" type uniform meanders, which favoured the self-capture (Fig. 5).

These meanders overlap much larger meanders loops (with wavelengths above 2000 m and amplitude of 1000 m), which testify for several generations of paleomeanders, a phenomenon previously presented at the national level for the Bârlad river (Rădoane and Rădoane, 2003).

The meanders mean radius of curvature is lower than 1.3 m at the actual meanders, in comparison to the values of paleomeanders ranging between 1.30 - 2.17 m. The explanation is that the incised meanders inherit the shape of the river beds modelled by other liquid flows than those that control currently the minor riverbed.

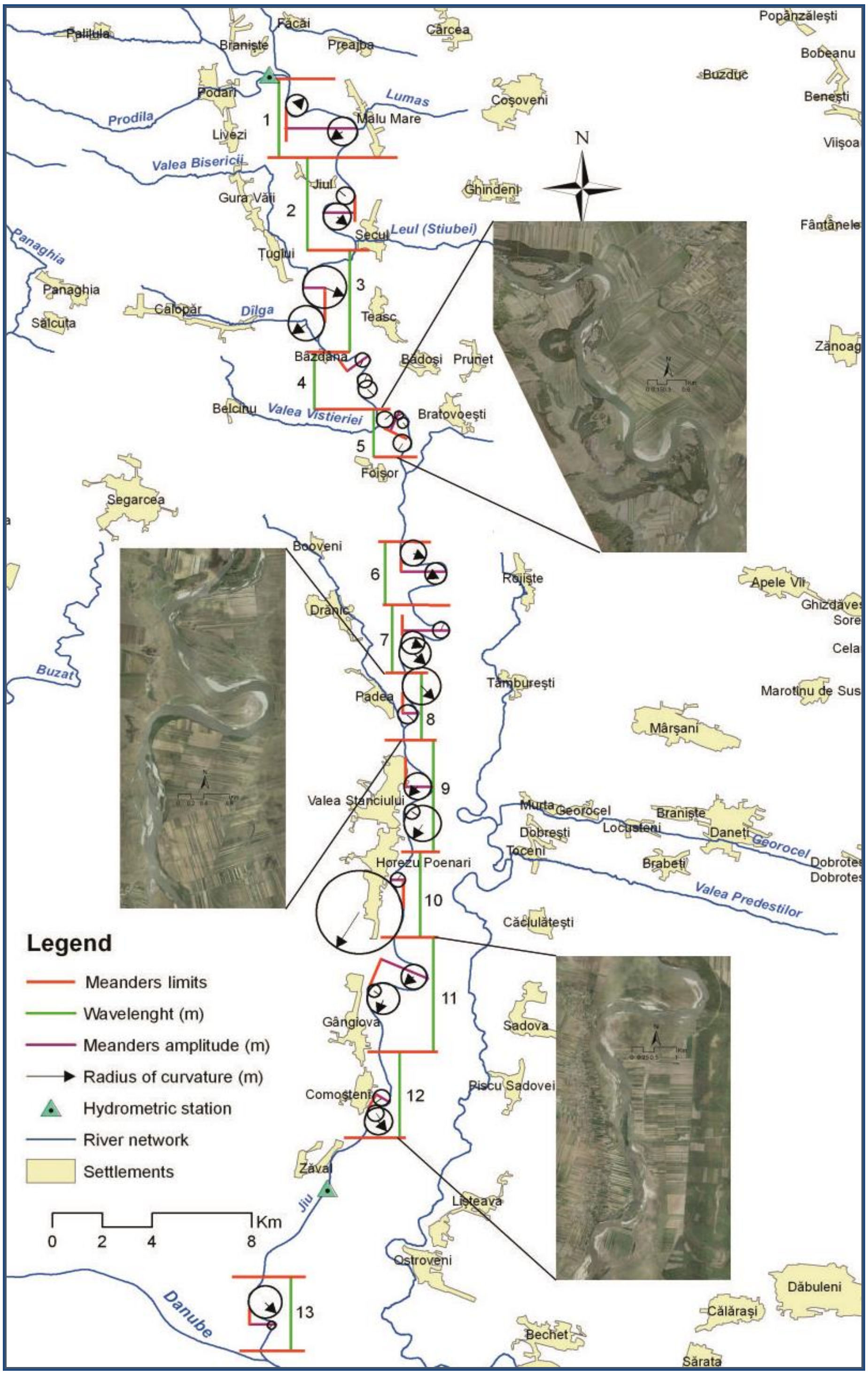

Figure 7: Types of meanders of the Jiu River in the lower sector (case studies)

(Processing of cartographic data supplied in the orthophotos, scale 1:5000, 2009)

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The phenomenon also stands out from the presentation of meanders variability in longitudinal profile of the Jiu river (Fig. 8), where the variability of wavelength and meanders amplitude are much higher for the incised meanders (paleomeanders) than for the open ones (the actual ones).

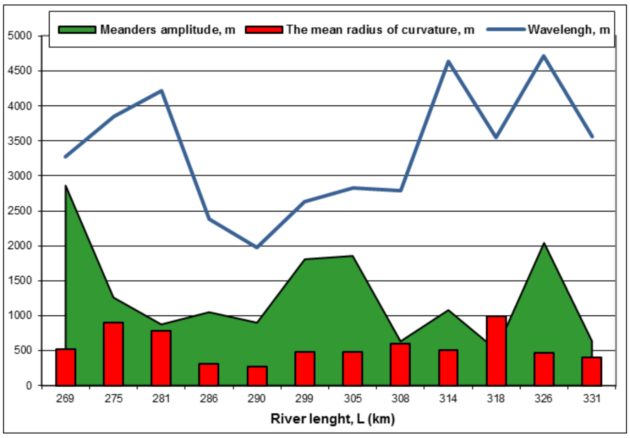

Figure 8: Variation in longitudinal profile of Jiu river`s meanders morphometry

(Processing data after the orthophotos, scale 1:5000, 2009)

The consequences on the river bed dynamics are high because the river is forced to rebuild its solid load by erosion in the cross section.

Based on the relations and the formula proposed by Dury (1976) and Gabris (1986) there can be determined the relationship between meander wavelength and mean discharge: $L/2 = 80,3\ (Q\ cp.)^{0'36}$. A new formula was derived from the original data of Gabris (Timar et al. 2008) as the following - $Q\ cp. = 0.0009\ (L/2)^{1'8}$, cited by Popov and al. 2008 and applied for the Tisa Valley.

Conclusions

The morphological, morphometric and hydrographical characteristics were evaluated to analyze the current geomorphologic processes.

The data obtained from measurements (made on the orthophotos, 1:5000, 2009 and updated through field observations in spring 2012) lead us to the following conclusions:

- the disequilibrium of the river bed is highlighted by the increase of the sinuosity index values, calculated for a meander;
- the sinuosity of the minor river bed developed, creating some complex meanders (almost incised or paleomeanders);
- the paleomeanders amplitude is generally decreasing, indicating an approaching tendency of the meander loops.

In this context, creating the fluvial geomorphologic database of the Jiu river meanders, a direct tributary of the Danube in the south-west of Romania, was a real challenge.

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