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Hydropower impact on the ice jam formation on the upper Bistrita River, Romania

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ABSTRACT

In this work, we investigate the causes of ice jams along the Bistrita River, which has the longest mountainous course (216 km) of any river in Romania. Over a length of 25–30 km on the upstream portion of the Izvoru Muntelui Reservoir, ice block accumulations known as ice jams form almost yearly during the cold season. Analysis of the hydroclimatic and morphological conditions of the riverbed has revealed that a certain combination of their temporal variations is favourable to ice jam formation. The hydraulic geometry of the Bistrita river bed is favourable to the flow of frazil slush, frazil pans, and ice floes while the air temperature is below −7 °C and the water level of the Izvoru Muntelui Reservoir is below 500 m. Above this level, ice jams block the river bed, and this blockage advances upstream at velocities of several hundred meters per day. The most dramatic instances of this phenomenon were recorded during the winter of 2002–2003, when the thickness of the ice was on the order of 6 m and the resulting floods caused damages and claimed human lives. The appearance in 2003 of the Topoliceni Reservoir, 4 km upstream of the Izvoru Muntelui Reservoir, has complicated the evolution of these winter phenomena, with the lake itself acting as an accumulation pool for ice from upstream. This development has led to damages and inconveniences in canals and at the entrances to power plants, spillways, outlet works, and other hydraulic structures.

1. Introduction

Ice agglomerations or dams that form on rivers during the winter are a common phenomenon in temperate regions. The ice season can last more than 100 days for most of the rivers of Scandinavia, Russia, and Canada, and can reach latitudes of 42° to 30°N in North America and Asia (Bates and Billelo, 1966). Also known as ice jams (in Romanian as *zapor*; in Russian, *zator*; in French, *embâcle*; in German, *Eisbarre* according to Savin, 1996), these ice agglomerations can block the flow of the river and cause large floods, making them the most hazardous winter phenomenon on rivers (Ashton, 1986). For this reason, scientists have long attempted to establish the causes of ice jams and to find ways to avoid their negative effects. Numerous examples of damages and loss of human life have occurred during winters on rivers in Canada, the United States, Russia, the Scandinavian countries, Iceland, Japan (Shen and Liu, 2003), China, and other regions, all of which have been thoroughly commented on in a long series of studies by several Canadian scientists (Beltaos, 2007, 2008; Prowse and Conly, 1998; Beltaos and Prowse, 2001; Prowse and Beltaos, 2002; Prwose and Bonsal, 2004). In addition, inventory catalogues have been published for Siberian rivers (Korytny and Kichigina, 2006), and large works, inventories, and specialized web sites exist for other regions of the world. In particular, the website of the Cold Regions Research and Engineering Laboratory of the U.S. Army Corps of Engineers presents some of the most complex information available regarding the systematics of the ice jam phenomenon, including field and laboratory experiments, effects of their components of the environment, and a whole range of attenuation measures (see http://www.crrel.usace.army.mil/icejams/) (White and Eames, 1999; Weyrick et al., 2007). In addition, many ice jam case studies in Canada have been inventoried in Beltaos et al. (1990), Wigle et al. (1990).

In Romania, research interest in such winter phenomena on rivers dates back to the 1960s, at the beginning of the development of a national observation network of hydrological phenomena on rivers (Semenescu, 1960; Constantinescu, 1964; Ciaglic, 1965; Ciaglic and Vornicu, 1966; Ciaglic et al., 1975). Winter floods on mountain rivers

Table 1
General data on the Bistrita River in the gauging station points.

River	River cross-section	Drainage basin area A (km²)	River length L (km)	Mean yearly discharge Q ($m^3 s^{-1}$)	Suspended sediment load Qs ($kg\ s^{-1}$)
Golden Bistrita	(1) Carlibaba	471	32.5	7.86	
	(2) Dorna-Giumalau	721	62.5	12.2	1.45
Bistrita	(3) Dorna Arini	1687	73.4	22.3	3.70
	(4) Brosteni	1192	116.5	30.3	4.40
	(5) Frumosu	2901	143.5	37.9	6.68

(1) Cross-section numbers are shown in Fig. 1.

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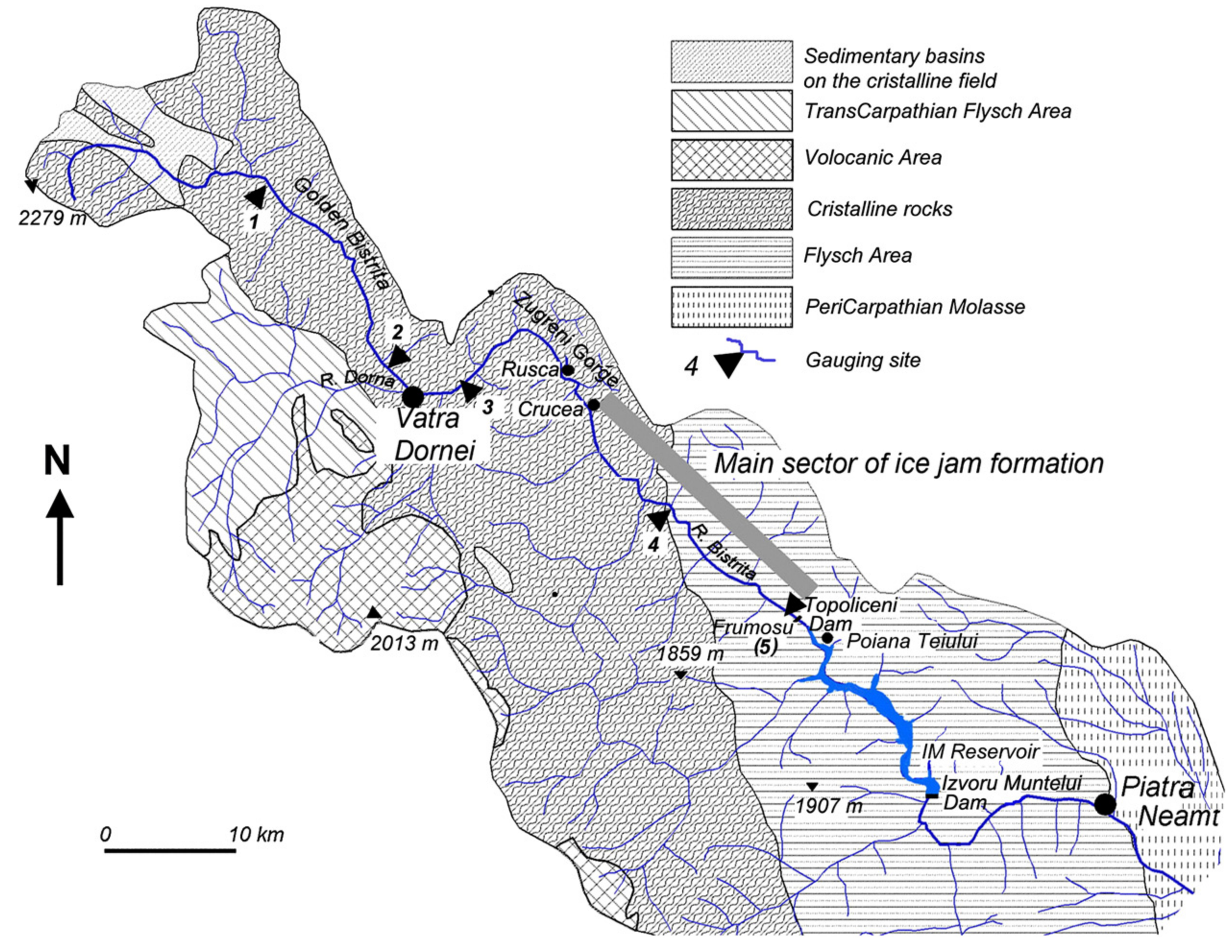

Fig. 1. Bistrita drainage basin upstream of Izvoru Muntelui Reservoir. Location of the area is discussed in the text.

in Romania (Moldavian Bistrita, Transylvanian Bistrita, the Mures, the Danube, etc.) have captured the interest of climatologists, hydrologists, and geomorphologists, as well as specialists in river engineering, resulting in PhD theses and numerous articles and book chapters (Miţă, 1977; Musteţea, 1996; Păvăleanu, 2003; Rădoane, 2004; Romanescu, 2003; Surdeanu et al., 2005; Ştefanache, 2007).

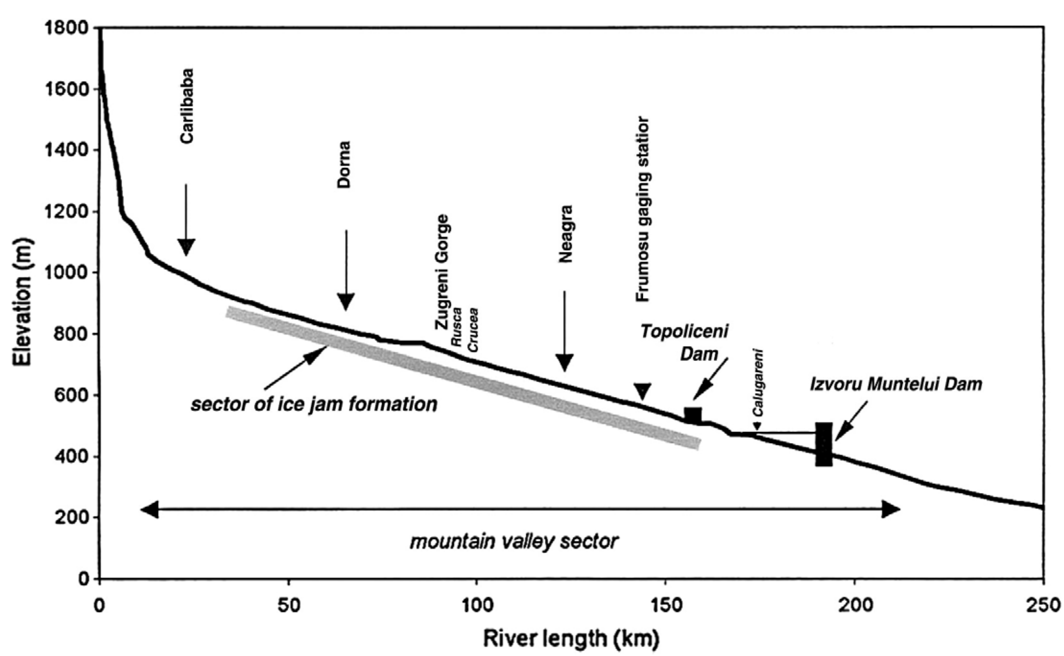

Fig. 2. Longitudinal profile of the Bistrita River, with the research location. The bold line represents river bed elevation.