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Differences in the reconstructions of the depositional environment of overbank sediments performed using the C/M diagram and cumulative curve analyses

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Abstract: In order to compare the results of the reconstructions of depositional environment of sediments performed using the C/M diagram (Passega, Byramjee 1969) and the cumulative curve analysis (Visher 1969), 49 samples of overbank sediment were collected in the valley of the Dunajec River. The samples were collected from the fill of an abandoned channel on the floodplain of the lower Dunajec (17 km from its mouth) and from the floodplain of the Dunajec in the backwater of the Czorsztyn Reservoir and analysed used the laser diffraction and sieve methods. A cumulative curve analysis of the samples located in the fields of dominant deposition from traction in the C/M diagram (Fields I, II, III, IX) showed that the dominant type of their transport prior to deposition was saltation and suspension (81%), while traction amounted to an average of 19%. In the fields of the C/M diagram corresponding to the deposition of graded suspension under the conditions of high (Field IV) and moderate turbulence (Field V), the dominant type of sediment transport before deposition was saltation, whose amounted to 78–86% (Field IV) and 50–76 % (Field V). In the fields of the C/M diagram indicating deposition from graded suspension transported in conditions of low turbulence (VI) and uniform suspension of varied grain size (VII), the dominant type of transport prior to deposition was suspension, amounting to 35–94%. Sediments located in the field of the C/M diagram corresponding to the finest uniform suspension and pelagic suspension (Field VIII) were in 91–95% transported in suspension prior to deposition.

Key words: depositional environment, C/M diagram, cumulative curve, settling velocity

Introduction

The grain size characteristics of sediments accumulated in river valleys can be a source of information on water flow conditions occurring during their deposition (Gradziński et al. 1986, Ludwikowska-Kędzia 2000, Racinowski et al. 2001, Mycielska-Dowgiałło 2007, Szmańda 2011). This information can be useful in the reconstructions of the environment in which forms built of the sediments analysed were developed. This relationship is used to study the fluvial relief response to environmental change and human impact.

The C/M (the first C-percentile to the M-median) diagram is a method frequently used in reconstructing the environment of deposition of sediments (Passega 1964 Passega, Byramjee 1969) together with the cumulative curve analysis of grain size (Visher 1969). These methods infer the type of sediment transport occurring before its deposition. An analysis carried out using the C/M diagram in the Passega and Byramjee's modification (1969), on the basis of the C/M ratio of the sediment sample grain size, determines its predispositions to be subject to one of the 9 types of transport before deposition. The limitations of this method indicated by Szmańda (2007, 2010, 2011) include rigidly defined ranges of sediment grain size (C and M), classifying a sample to a particular type of transport, and rather roughly defined shares of individual types of transport in the fields of the diagram. The method of cumulative curve analysis (Visher 1969) allows a deeper insight into the processes of sedimentation, because it enables us to determine the size and share of grains transported in a specified way, prior to deposition, in each sediment sample analysed. It is assumed in this method that the straight sections of the cumulative curve represent sediment populations which, prior to deposition, were subject to three types of sediment transport occurring in nature (traction, saltation and suspension) (Moss 1962, 1963 after Visher 1969). Therefore, there are no assigned closed intervals of grain size for a specific type of transport in this method. These ranges are determined based on the course of the cumulative curve of a particular sediment sample (Szmańda 2007, 2010, 2011). A comparison of the results obtained using the C/M diagram (Passega, Byramjee 1969) and the cumulative curve analysis (Visher 1969) performed by Szmańda (2007) for the same 150 samples of overbank sediments showed, among others, that:

- according to the cumulative curve analysis, samples grouped in the fields of the C/M diagram indicating sediments deposited in a predominant proportion from traction (Fields I, II, III) were deposited in a predominant proportion from saltation and suspension,
- according to the cumulative curve analysis, samples grouped in the fields of the C/M diagram indicating a predominant deposition from uniform suspension (VIII) were partially deposited from saltation.

Szmańda (2007, 2010, 2011) considers the results obtained using the cumulative curve analysis method as a more reliable way of analysis.

The purpose of this paper is to examine whether similar discrepancies in the results obtained using the C/M diagram (Passega, Byramjee 1969) and the cumulative curve analysis (Visher 1969) will occur for sediments deposited in the abandoned channel and in the backwater of a dam reservoir. To this end, an analysis was performed for the same 49 samples of sediments using the C/M diagram and cumulative curves.

Materials and methods

For the purpose of the analyses, samples of overbank sediments were taken from the abandoned channel in the lower section of the valley of the Dunajec river (30 samples) (17 km from the mouth of the river) and from the backwater zone above the Czorsztyn Reservoir, in the upper reaches of the Dunajec (19 samples) (Fig. 1). The reconstruction of the depositional environment of 30 samples of sediment deposited in the abandoned channel of the Dunajec, performed using the C/M diagram, has already been published earlier (Liro 2012). Sediments of less than 1 mm in diameter were analyzed using the laser method (Analysette 22 Comfort particle sizer produced by Fritsch) with data output grouped in1/2 phi interval. The samples with sediments of a diameter larger than 1 mm (8 samples) were analyzed using the combined sieve-laser method, with the help of a set of sieves, with a mesh interval of 1/2 phi. Merging sieve and laser diffraction data was done by converting the laser volume data (%) into weights (g), using the total weight of portion < 1 mm, and then merging together with the sieve weights for sediment >1mm to produce merged percentile distribution at 1/2 phi. The laser diffraction method is likely to overestimate the size of fractions larger than 0,1 mm and underestimate the size of fraction smaller than 0,1 mm, in comparison to the dry sieve method (Płoskonka 2010). This may potentially cause a slight deformation of the cumulative curves of grain-size of these 8 samples in the range of 0,1 to 1mm.

The grain size parameters were calculated according to Folk & Ward (1957) formulae using the Gradistat software. C/M diagrams and graphs of cumulative curves of the samples analysed were also made using this software.

An interpretation of the C/M diagram was conducted automatically in the Gradistat program. Interpretations of cumulative curves were performed according to Visher's

Fig. 1. Map of the sampling sites in the Dunajec River cathment. For wider description of the sampling site A see (Liro 2012) and for site B (Liro 2015)

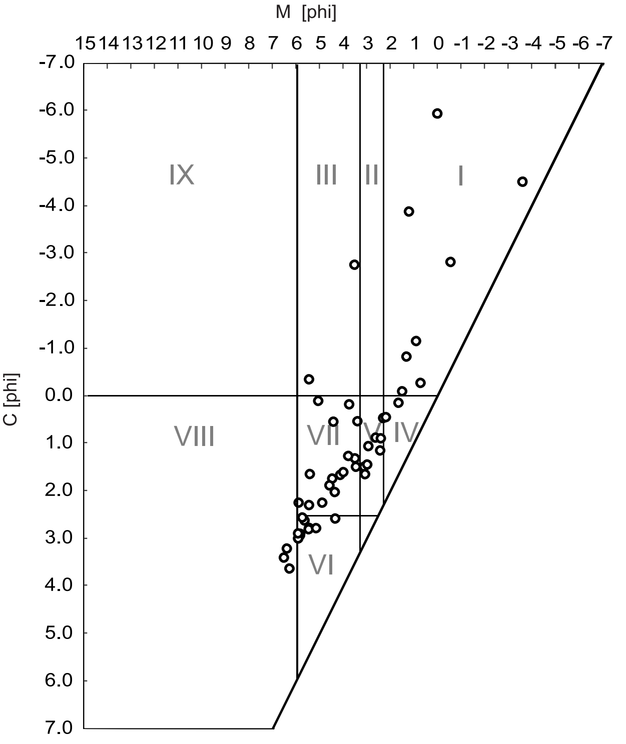

Fig. 2. Samples analysed showed on the C/M diagram (Passega, Byramje 1969)

recommendations (Visher 1969, Mycielska-Dowgiałło 2007, Szmańda 2007, 2010, 2011). Inflection points were marked on each curve as CT and FT (Szmańda 2011, Fig. 13). The CT point (*coarse truncation point*) separates sections of the curve representing the populations of traction (C) and saltation (A) transport, and the FT point *(fine truncation point*) separates the populations of transport in saltation (A) and suspension (C). A subpopulation of intermitted suspension was not additionally isolated in the population of saltation (cf. Szmańda 2007, Fig. 2). The slope of the cumulative curve illustrates the sorting of sediment. The interpretations of curves were started from isolating the segment with the largest slope, which corresponds to the population of saltation. The size of grains in which a change in the way of transport occurred was defined by projecting inflection points on the horizontal axis. By projecting the same points on the vertical axis, the percentage of different types of transport prior to deposition, in each sample of sediment, was specified. The grain size at inflection points was also used to calculate the range of water current velocity at which a given type of transport occurred. The Koster formula was used to calculate these velocities (Koster 1978).

Results

A comparison of the conditions of deposition interpret from the C/M diagram and cumulative curves

The cumulative curve analysis of the samples located in the fields assigned to the dominant deposition from traction in the C/M diagram (Fields I, II, III, IX) showed that the predominant type of transport prior to deposition was saltation (7–89%) (Table 1, Fig. 2, 3). The share of saltation in the fields of the C/M diagram corresponding to the deposition of graded suspension in conditions of high (Field IV) and moderate turbulence (Field V) amounted to 78–86% (Field IV), and 24–77% (Field V). Deposition from suspension of 35–94% dominated in the fields assigned to the deposition of graded suspension transported in conditions of low turbulence and uniform suspension of varied grain size (Fields VI and VII) (Table 1, Fig. 2, 3). Sediments located in the field of the C/M diagram corresponding to the finest uniform suspension and pelagic suspension (Field VIII) were deposited in majority from the suspension of 91–95% and saltation of 5–7,7% (Fig. 3, Tab 1).

The water current velocity during deposition from traction, saltation and suspension

The velocity ranges (Koster 1978), at which deposition from different types of transport occurred, largely overlap in the samples studied (Fig. 4). This indicates that, prior to deposition, transport in saltation, suspension, and partially in traction occurred at similar flow velocities for 49 samples used (Fig. 4).

Discussion

Discrepancies in the results of the C/M diagram and cumulative curve analyses

Comparing the results of the C/M diagram and cumulative curve analysis is to a certain extent hindered by their different specificity, the degree of detail and terminology used in both methods, e.g. saltation is determined by

Table 1. Summary of the results of the cumulative curve analysis (based on Visher 1969) for specific segments of the C/M diagram (Passega, Byramjee 1969)

Fields on C/M diagram	Conditions of depositional environemt based on (Passega & Byramjee 1969)	Proportion of sediement transport types based on cumulative curves analysis (Vischer 1969), mean (min-max)			Comments
		Traction	Saltation	Suspension	
I, II, III, IX	Dominant deposition by traction with small share of suspension	19 (0–86)	51 (7–89)	30 (0,7–92)	Predominance of transport in saltation and suspension
IV	Graded suspension transported in highly turbulent conditions	0	82 (78–86)	18 (14–22)	Lack of transport in traction, Predominance of transport in saltation
V	Graded suspension transported in moderately turbulent conditions	0	53 (24–77)	46 (23–76)	Lack of transport in traction, similar proportion (about 50%) of transport in saltation and suspension
VI, VII	Graded suspension transported in low turbulent conditions (VI), uniform suspension with more complex deposition (VII)	0 (0–1)	19 (6–64)	81 (35–94)	Lack of transpot in traction, predominance of transport in suspension
VIII	Finest uniform suspension and pelagic suspension	0	7 (5–9)	93 (91–95)	Lack of transport in traction, very Little proportion of transport in saltation, predominance of transport in suspension

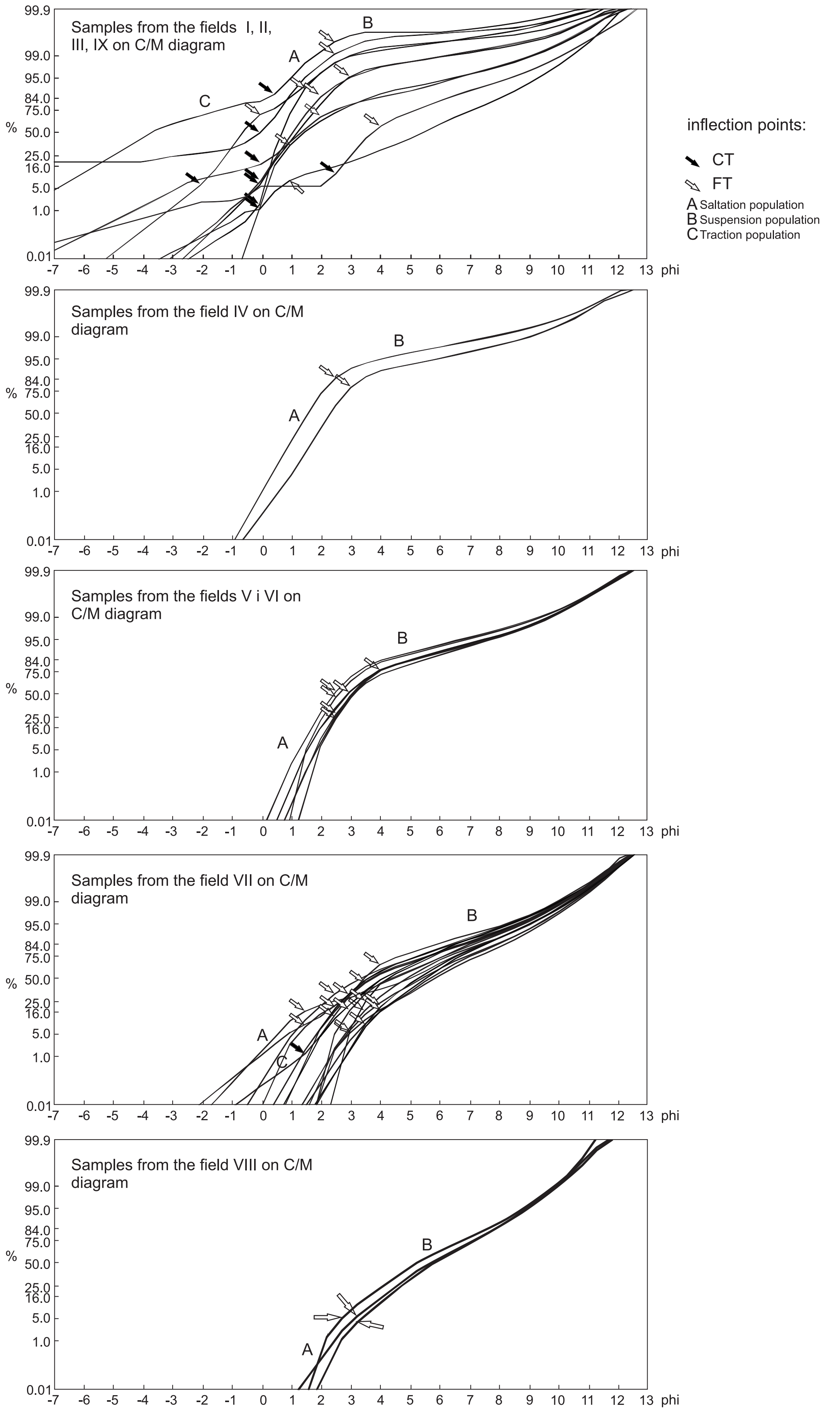

Fig. 3. Cumulative curves of samples located in specific fields of C/M Diagram

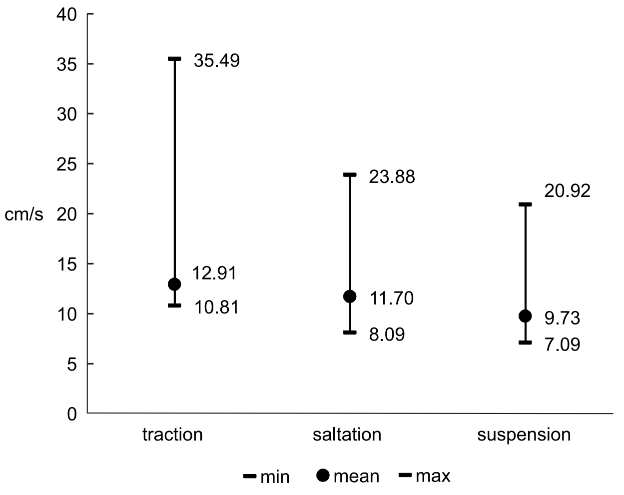

Fig. 4. Minimum, average and maximum settling velocities for sediments deposited from traction, saltation and suspension, interpreted from cumulative curves

Passege and Byramjee (1969) as part of graded suspension transported in conditions of high turbulence (Field IV in the C/M diagram). In addition, the shares of specific types of transport are not quantified for each field in the C/M diagram, for example Passega and Byrmjee (1969, 248) described for sediments grouped in fields I, II, III and IX: *...these sediments contain rolled grains either deposited near their source or transported across environments where sedimentation of suspensions was scarce.* Due to the difficulty in comparing these two methods at the same level of detail, the comparison applied was to serve the purpose of verifying the results of the C/M diagram in general, by analysing the cumulative curves, which is considered a more precise method (Szmańda 2007). The presented discrepancies of the results obtained using the C/M diagram method and cumulative curve analysis are generally consistent with those previously observed by Szmańda (2007).

Discrepancies in the fields of deposition from traction in the C/M diagram

In Fields I, II, III, IX of the C/M diagram, assigned to the dominant transport in traction, its share according to the cumulative curve analysis averaged at 19%, and in only one of the 11 samples locating in these fields it amounted to 86%. In the remaining 10 samples locating in Fields I, II, III, IX, deposition from saltation (51%) and suspension (31%) dominated (Table 1). In the comparison made by Szmańda (2007) for samples located in the same fields of the C/M diagram, the share of traction ranged from 0 to 42%.

Discrepancies in the field of deposition from the finest suspension in the C/M diagram

In Field VIII of the C/M diagram, assigned to deposition from the finest uniform suspension and pelagic suspension, a small share of deposition from saltation occurred, ranging from 5% to 9%, in each of the 5 samples located in this field. In the comparison conducted by Szmańda (2007), the share of saltation was much larger in this field and amounted to an average of 37%. However, the results of the analysis for this field can hardly be considered representative due to the small number of samples located in this area.

The different purpose and level of detail of the CM diagram and cumulative curve analysis

The usability of the C/M diagram and cumulative curve analysis

The C/M diagram indicates a predisposition of particular sediment to its being a result of deposition under specified conditions. This is highlighted by the authors of this method themselves (Passega, Byramjee 1969: 251): *The fact that a given grain-size distribution corresponds to a preferential deposition mechanism can be used to subdivide clastic sediments into types indicative of a probable genesis.* Passega and Byramjee (1969: 248) even indicate that in the case of sediments from the fields of dominance of traction I, II, III, IX: *Reference to cumulative curves may be needed to determine the diameter of the coarsest suspension sediments as an index of turbulence.* The analysis performed and the data from literature (Szmańda 2007) show that, in the case of more detailed analyses, the lack of verification of the results of the C/M diagram, especially for the fields of deposition from traction, using other methods or the analysis of sedimentary structures can lead to misinterpretation of the depositional environment.

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