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RELATIONSHIP BETWEEN THE BED MATERIAL SIZE AND THE AMOUNT OF METAMORPHIC AND VOLCANIC ROCKS IN HYDROGRAPHIC BASINS REGARDING TWO RIVERS FROM MARAMUREŞ MOUNTAINS (EASTERN CARPATHIANS – ROMANIA)

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Abstract. The Maramureş Mountains are situated in the North of Eastern Carpathians, at the border between Romania and Ukraine. Our researches were concerned with analyzing the bed material size and shape for Ruscova and Vaser rivers, from this mountain unit, and with the identification of the factors which influences these characteristics. Samples was taken from 5 sites for each river, using the Wolman (1954) *(pebble counts)* method, for surface particle sampling from gravel and cobble bed streams. Sorting and abrasion of particles has little influences in variations of median grain diameter D_{50} (mm) along rivers. A more important role has the amount of high resistant rocks (metamorphic and volcanic rocks) to the transport in fluvial regime, in part of hydrographic basins situated between the sample sites.

Keywords: gravel bed deposits, Wolman pebble-counts, GIS techniques, median grain diameter, gravel and cobble bed rivers, cailleux roundness index, graphic arithmetic sorting coefficient

1. INTRODUCTION

The biggest fluvial systems in the Maramureş Mountains, the main point of our attention, encompass the Ruscova and Vaser Rivers, both the 6 order on the Horton-Strahler hierarchic system (Fig. 1). These are tributaries to Vişeu River and the morphometric parameters (high slope of streams, numerous thresholds and cascades, high energetic potential), (Tab. 1) confirm the state of mountain rivers.

About the hydrologic characteristics, the mean annual discharge of Ruscova River, at the empties in Vişeu, is 11.49 m^3/s and the mean annual discharge of Vaser is 8.51 m^3/s.

The geological composition of the region is very complex (Fig. 2). There are four main tectono-structural units which are divided in few subunits (Săndulescu, 1984). Median Dacides (Central-East-Carpathian Napes) form the "vertebral column" of Maramureş Mountains and are composed of metamorphic rocks (micaschists, gneisses, schists); Outer Dacides have two main subunits: Ceahlău Nape, is composed of sedimentary rocks (sandstones, conglomerates, clays, marls, shale), (Bleahu, 1962) and Black Flysch Nape which is composed of clays, limestones, basalts, graphite schists, sandstone, black quartzites (Bleahu, 1962; Săndulescu, 1984); Neogene Magmatites is composed of andesites and dacites, which form a big structure in Toroiaga Massif Region and a few sills around them; Post-Tectogenetic Cover is composed of sedimentary rocks (clays, marls, sandstones, conglomerates, shale) with Createaceous, Eocene and Oligocene age (Bleahu, 1962; Dicea et al., 1978; Patrulius et al., 1952; Szasz L., 1974; Săndulescu et al., 1991; Iştvan et al., 2006).

Figure 1. The localization of Ruscova and Vaser hydrographic basins.

Table 1. Morphometric indicators of Ruscova and Vaser hydrographic basins.

Morphometric indicators	Ruscova	Vaser
Surface (km^2)	432.7	409.96
Perimeter (km)	96	116
Average altitude of hydrographic basins (m)	1138	1130
Average slope of streams (m/km)	134	129
Average slope of hydrographic basins (m/km)	445	461
Length of main stream (km)	41	51
Total number of stream segments (Horton-Strahler)	1406	1543
Total cumulative length of stream segments (km)	921	861
Bifurcation ratio (Horton-Strahler)	4.03	4.02
Hydrographic basin shape index (Zăvoianu, 1978)	0.752	0.486

2. MATHERIALS AND METHODS

2.1. River bed deposits analysis

The analysis of bed-material was made for main courses of Ruscova and Vaser Rivers. It was revealed the size and shape characteristics of surface bad-materials by using the Wolman (1954) *pebble counts* sampling method.

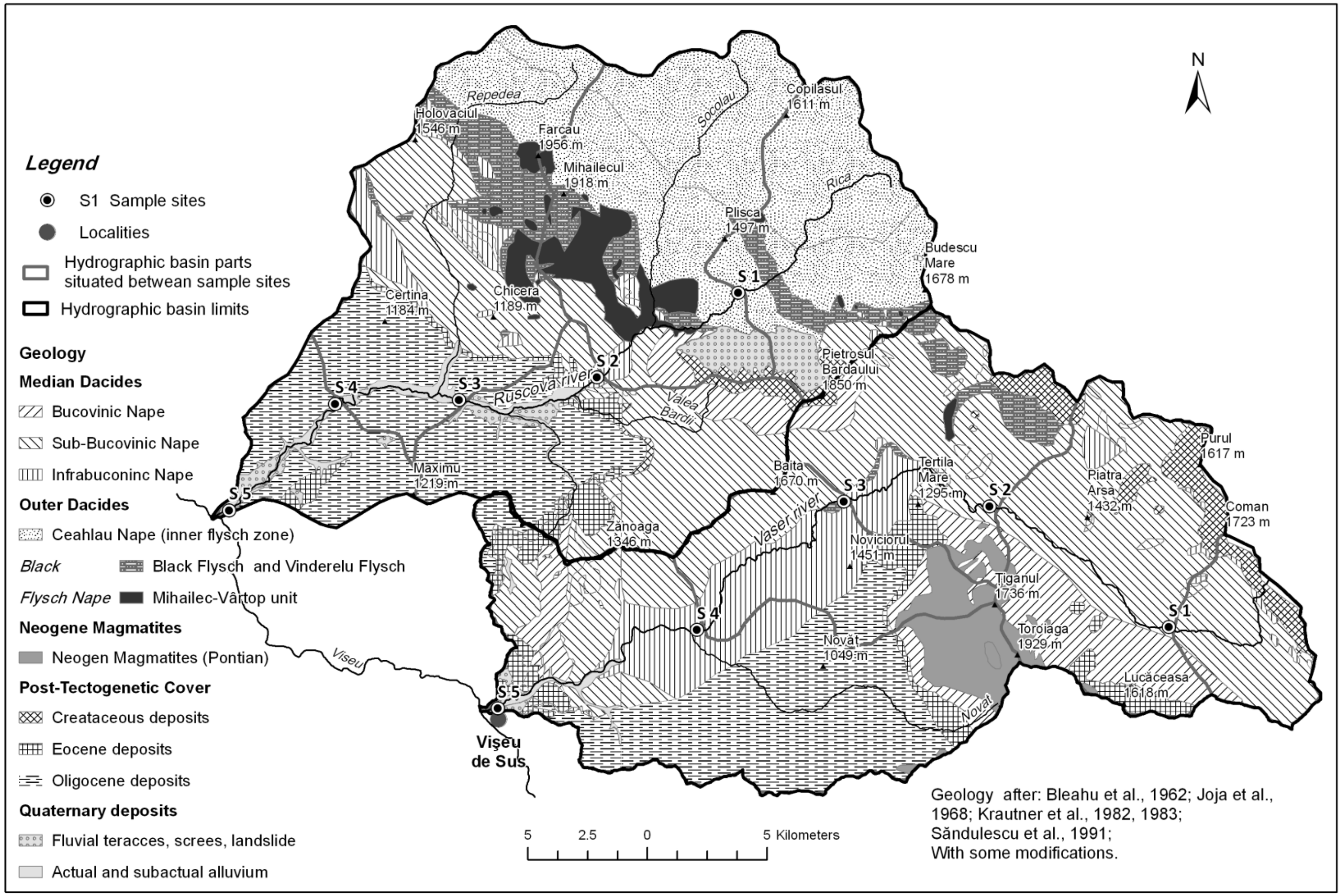

Figure 2. The geologic structure of region and location of sample sites.

This method was used by many researches who were concerned with gravel and cobble bed streams analysis, both in international studies (Leopold et al., 1964; Montgomery & Buffington, 1997; Rice & Church, 1998; Wohl et al., 1997, 2005; Gomez et al., 2001; Haschenburgera & Rice, 2004; Keaton et al., 2005; Wright et al., 2000; Harelson et al., 1994, Brummer & Montgomery, 2003) and in Romania (Rădoane et al., 1985, 2007; Ichim et al., 1984).

For particles with b axes between 16mm and 32mm (-4ϕ and -5ϕ) shape analysis was made. The measurements were carried out during the Wolman sampling, the number of shape sample was conditioned by proportion of 16-32mm classes in a given sample site.

In case of both rivers the sampling was made in 5 sample sites situated at 8-10km each to other, along rivers. It was used the same distances in researches about rivers situated in Southern and Eastern Romania (Rădoane et al, 1991, 2003, 2004, 2006, 2007).

The particle analysis was made in geomorphological units (point bars and islands) where it existed. In reaches where the geomorphological units were missing, transversal sampling was made.

Particles was sampled at even-spaced marks along transects by using a 50m long measuring tape. The sampling distance was set to a value 2 times larger than the b axis of D_{max} particle size within a reach. The b axis of 2 mm – 150mm particles was measured with a caliper and the larger particles b axis, with a measuring tape. Was collected the first touched particles either by the pointer vertical finger or with a sharp object. The particles smaller than 2mm (-1ϕ) were included in a single class (< 2mm).

The sample sizes were between 150 and 200 particles for size analysis and between 12 and 45 for shape analysis (Tab. 2). Such sample sizes were used in many researches (Ichim & Rădoane, 1984; Leopold et al., 1964; Haschenburgera şi Rice, 2004; Gomez et al., 2001; Montgomery & Buffington, 1997; Harelson et al., 1994, Brummer & Montgomery, 2003).

Table. 2. The sample sizes for particle size analysis and shape analysis.

		Sect. 1	Sect. 2	Sect. 3	Sect. 4	Sect. 5
Ruscova River	Sample for size analysis	181	191	174	195	201
	Sample for shape analysis	40	36	33	45	37
Vaser River	Sample for size analysis	170	182	142	184	186
	Sample for shape analysis	12	20	30	35	40

After the sampling procedure, the particle-size distributions were computed. It was obtained the median grain diameter D_{50} (mm) and the particle distribution parameters (mean, mode, median, Folk & Ward sorting, skewness, kurtosis). For shape analysis, the Cailleux roundness index was computed.

2.2. The assessment of percentage of different lithological units in drainage basins

In order to analyses the relationship between litholology of drainage basins and bed material size, we have built a GIS data base which includes also geologic data. We used the information available from geologic maps of region (Bleahu et al., 1968; Săndulescu et al., 1991, Krautner et al., 1982) and from other sources too. The amount of different lithological units in part of drainage basins situated between sample sites was obtained by GIS techniques. The delineation of these parts is shown in figure 2.

3. RESULTS AND DISCUSSION

According to Sternberg law, the bed material size decrease in downstream direction "*downstream fining"*. Sternberg (1875), quoted by Gasparini et al., (1999), attributed downstream fining on the Rhine River to abrasion and developed an expression which describes the downstream decrease in grain size as an exponential function. However, in many later studies was emphasized an inverse tendency of grain size variation "*downstream coarsening"*.

Until present were identified few causes of bed material size variation along rivers: the abrasion of grains by hydraulic transport (Sternberg, 1875); the selective sorting of bed deposits (Montgomery et al., 1999; Gasparini et al., 1999, Gomez et al., 2001); the importance of tributary inputs (Rădoane Maria et al., 2002, 2006); the geomorphologic history of drainage basins (Rice & Church, 1998); the spatial distribution of sources for resistant lithologies (Pizzuto, 1995); the systematic increase in unit stream power, and controls from the temporary accumulation of lag deposits forced by mass wasting events (Brummer & Montgomery, 2003).

Analyzing the variation of median grain diameter D_{50} (mm) (Fig. 3) along Ruscova and Vaser Rivers, we can see that Sternberg's (1875) law of bed material variation *(downstream fining)* is suitable in the case of Vaser River, while in case of Ruscova River, an inverse tendency occurs (*downstream coarsening*). In both cases there is an exponential variation, and the coefficient of determination (R^2) is small, a fact which indicates a weak correlation between median grain diameter D_{50} (mm) along rivers.

The sorting of bed material (Folk & Ward, 1957) increases in downstream direction (the value of sorting coefficient decreases) for Vaser River, according to the "normal" tendency pointed out by the above mentioned authors, (Fig. 4). In Ruscova drainage basin, although the sorting variation shows an inverse tendency in downstream direction, the correlation between median grain diameter D_{50} (mm) and the Folk & Ward (1957) sorting coefficient is better, (Fig. 5). In this case, the median grain diameter decreases together with the bed material sorting increases, if we look at the coefficient of determination (R^2).

The abrasion of river bed material (*Cailleux roundness coefficient*) computed by using the particle shape measurements data (Rădoane et al., 1996), has a normal variation tendency, by downstream increasing in case of both rivers, (Fig. 6).

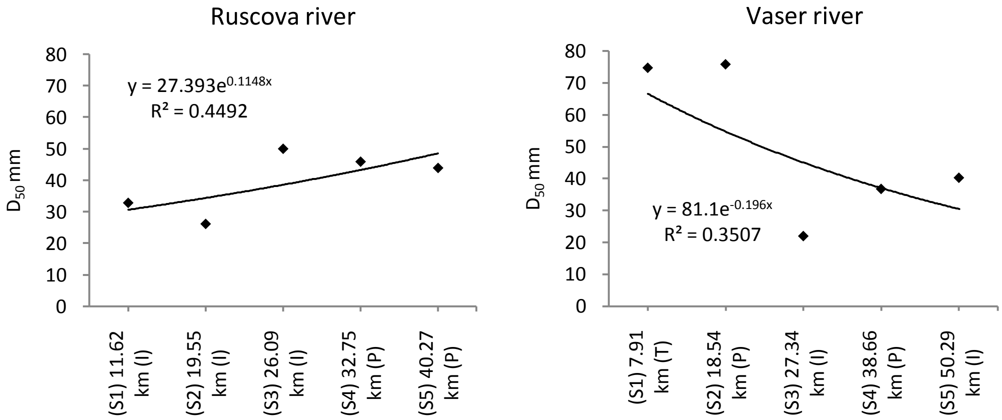

Figure 3. The river bed deposits median grain diameter D_{50} (mm) downstream variation for Ruscova and Vaser rivers; S1-S5 – sample sites; I- sampling on islands; P – Sampling on point bars; T – transversal sampling.

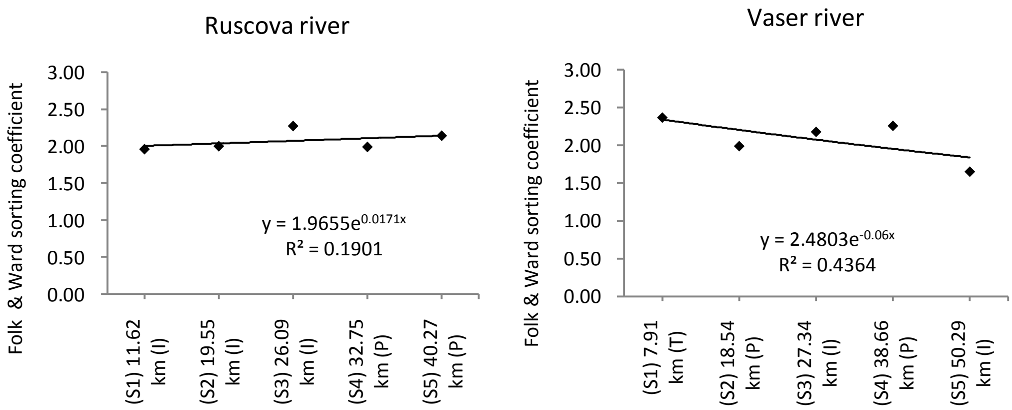

Figure 4. Folk and Ward (1957) sorting coefficient downstream variation for Ruscova and Vaser rivers; S1-S5 – sample sites; I- sampling on islands; P –Sampling on point bars; T – transversal sampling.

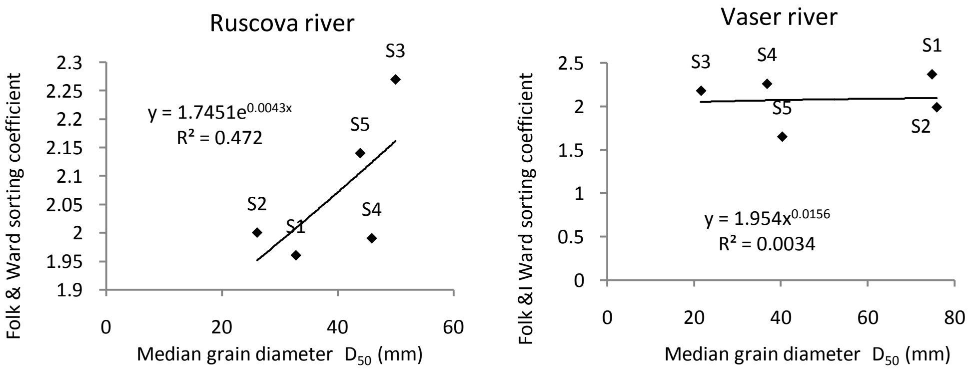

Figure 5. Correlation between Folk and Ward (1957) sorting coefficient and the median grain diameter of river bed deposits; S1-S5 – sample sites.

The tendency of variation is more obvious for Ruscova River; in this case the coefficient of determination (R^2) has a bigger value (R^2=0.938), compared to Vaser River (R^2=0.017). In case of Ruscova River we also can find a better correlation between the bed deposits abrasion and the median grain diameter D_{50}, (Fig. 7). The coefficient of determination has a value of 0.514 for Ruscova River, compared to 0.096, for Vaser River.

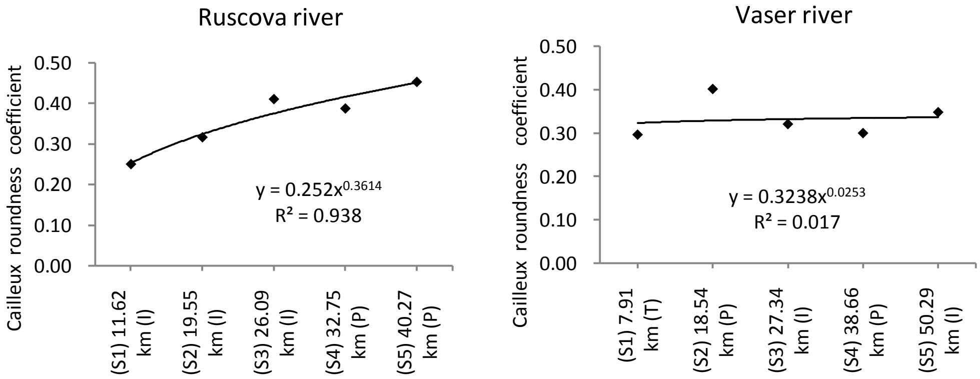

Figure 6. Downstream variation of river bed deposits abrasion (Cailleux roundness coefficient) for Ruscova and Vaser rivers; S1-S5 – sample sites; I- sampling on islands; P – Sampling on point bars; T – transversal sampling.

In order to demonstrate the existence or non-existence of a relationship between the drainage basins lithology and the bed deposits size, the percentage of main petrographic units in the drainage basin parts, situated between sample sites, was computed. Among these petrographic units a bigger importance for bed deposits size has those of higher geologic resistance, because if the resistant rocks reach in river bed, these will moreover resist to the river hydraulic forces. Haidu (1993) sustains that the resistance of rocks to the mechanical stresses is proportional to the resistance to erosion. Therefore, he adopts for rock classification by resistance, a standard of Ministry of Mines, Petroleum and Geology, Bucharest (M.M.P.G./1985) in which the rocks are classified according to the resistance to perforation and other mechanical stresses.

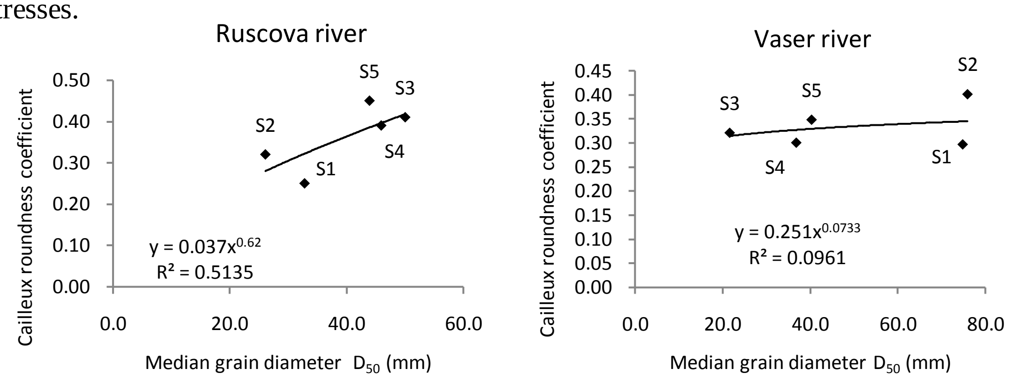

Figure 7. Correlation between the bed deposits abrasion (Cailleux roundness coefficient) and the main grain diameter D_{50} (mm); S1-S5 – sample sites.

For the Maramureş-Bucovina Carpathian Region, this author adopts the following classification: (Gr – geologic resistance) Neogene sedimentary deposits, Gr = 4,00; volcanic-sedimentary deposits, Gr = 5,24; flysch, Gr = 5,71; crystalline schist, Gr = 8,14; volcanic rocks, Gr = 10,29. A similar classification is offered by Pandi (1997).

In the mountain regions where the slope dynamics are high, the amount of rocks of high resistance to mechanical stresses in the river bed depends on the percentage of these rocks in drainage basins.

On the ground of the above exposed classification systems we may conclude that the most resistant rocks are the metamorphic and volcanic rocks. Because the amount of these rocks in the Ruscova and Vaser drainage basins is high, we took into consideration the relationship between the percentage of this rocks in the drainage basin parts situated between sample sites and the size of river bed deposits (median grain diameter D_{50}), (Fig. 8).

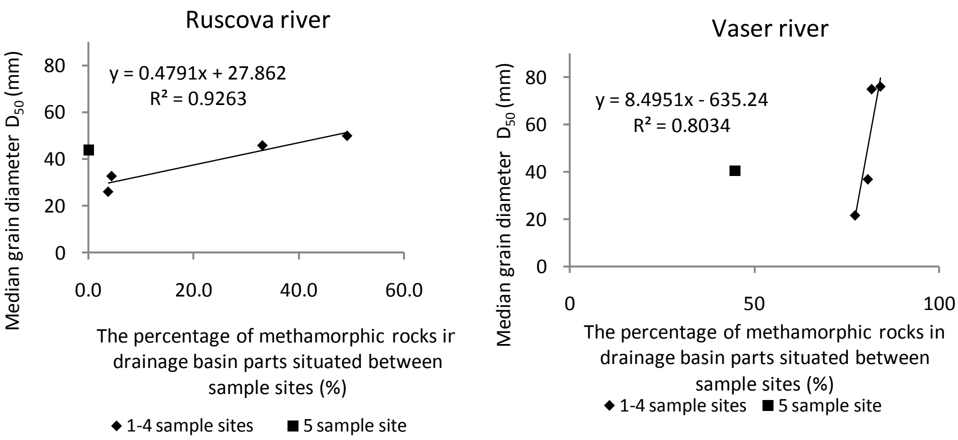

Figure 8. Correlation between the percentage of metamorphic and volcanic rocks in part of drainage basins situated between sample sites and the median grain diameter D_{50} (mm) of bed deposits from sample sites.

If we exclude the sample sites situated at the outfall of the both rivers we can find a high correlation between the percentage of metamorphic and volcanic rocks in the part of drainage basins situated between sample sites and the river bed material sizes from sample sites, (Fig. 8).

In the sample sites "*5*", for both rivers, the decrease of percentage of resistant rocks from drainage basins is not proportional with the median grain diameter D_{50}(mm) decrease. This phenomenon could be explained by more intense fluvial transport of this particles with bigger sizes, in the same time with the discharge increase and thus with the increase of hydraulic energy. However, the more intense transport of these grains, at 10 km distance did not cause a significant decrease of its sizes. Excluding these sample sites from correlation appreciation, results the coefficients of determination R^2=0.926 for Ruscova River and R^2=0.803 for Vaser River.

If we take into consideration the presence of a relative high correlation between the sorting, abrasion and the median grain diameter D_{50} in Ruscova drainage basin, there is necessary a new analysis of median grain diameter downstream variation. Although, at a first sight, the median grain diameter increase downstream, in a more detailed analysis we can identify two regression lines with decreasing tendency, (Fig. 9). The first segment is composed of S1 and S2 sample sites, situated in the upper part of drainage basin where the Ceahlău Nape sedimentary unit prevails and which are composed of sandstones, conglomerates, clays, marls and shale (Fig. 2). The S3, S4 and S5 sample sites form the second segment. This segment began after a geomorphic threshold which is shown by the increase of median grain diameter due to entrance of mechanical resistant rocks (crystalline schists and micaschists) in river bed. These rocks are supplied by Valea Bardii and Cvaşnița tributaries to 5 Horton-Strahler orders. We may observe that the disturbance of normal variation *(downstream fining)* of river bed deposits sizes is caused by the lithology of drainage basins, which determines the lateral input of bed materials with other characteristics than the main channel bed materials.

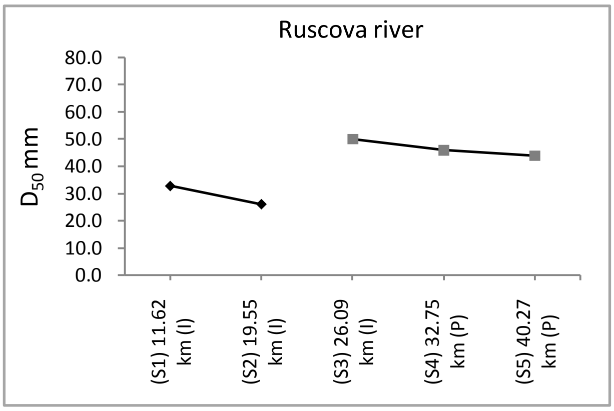

Figure 9. Downstream variation of river bed deposits median grain diameter D_{50} (mm) for Ruscova River; S1-S5 – sample sites; I- sampling on islands; P –Sampling on point bars; T – transversal sampling.

4. CONCLUSIONS

Among all the variables taken into consideration the most important role in the river bed material characteristics control plays the petrography of drainage basins. This fact was due to the presence of relative small fluvial systems and to the presence of slopes with high dynamics in this mountain region. The high inclined slopes facilitate the rapid transit of sediments to river beds. For an obvious hydrodynamic control of river bed deposits size and shape characteristics, the fluvial systems must have bigger sizes in such physical-geographic settings.

If we compare the two fluvial systems, mentioned above and studied, we may conclude that in case of the Ruscova River, the correlation between the sorting, abrasion and the main grain diameter D_{50}(mm) is a higher and better one. This fact results from a higher hydrodynamic processing of bed deposits in Ruscova drainage basin due to higher length of river courses and a bigger discharge, (Tab. 1).

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