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Downstream Variation in the Pebble Morphometry of the Trotuş River, Eastern Carpathians (Romania)

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Abstract

Riverbed sediments morphometrical analysis can offer, along granulometric and petrographic analysis, relevant information on sediment source origin, transport environment and sedimentation process. Today, there are numerous descriptive indices for clasts shape and size, each one trying to evidence the influence of dynamic conditions and clasts petrography that are mobilized in certain transport environment, their shape at certain moments. Among these, this analysis focused on only 10 morphometric indices. The obtained data, either from direct measurements on 5,027 clasts or after index calculations, were processed and obtained a set of statistical parameter (average, median, standard deviation, etc.). Based on these data was assessed „*optimal shape*" for Trotuş riverbed gravels. Some parameters (like average value) were used to create frequency histograms for some morphometrical indices in sampling points and to make some mathematical modeling.

Keywords: *particle morphology, shape index, roundness, sphericity, optimal shape*

Rezumat. Variaţia unor parametri morfometrici ai pietrişurilor în lungul râului Trotuş, Carpaţii Orientali (Romania).

Analiza morfometrică a materialelor de albie poate să ofere, alături de analizele de granulometrie şi petrografie, informaţii asupra provenienţei aluviunilor, mediului de transport şi asupra modului de depunere a particulelor sedimentare. În prezent, există o mare varietate de indici descriptivi ai formei şi dimensiunii particulelor sedimentare, fiecare încercând să cuantifice cât mai fidel influenţa condiţiilor dinamice şi a constituţiei petrografice a materialelor supuse transportului în anumite medii, asupra aspectului acestora la un moment dat. Din multitudinea acestora noi ne-am concentrat atenţia doar asupra a 10 indici. Datele obţinute, fie din măsurători directe asupra a 5027 galeţi, fie în urma calculării indicilor, au fost prelucrate, obţinându-se o serie de parametri statistici (media, mediana, deviaţia standard etc.). Pe baza acestor indici s-a realizat şi o evaluare a "*formei optime*" a pietrişurilor din albia râului Trotuş. Unii parametri statistici (de exemplu, media) au fost utilizaţi pentru obţinerea histogramelor de frecvenţă a indicilor morfometrici în punctele de eşantionare şi a modelărilor cu ajutorul funcţiilor matematice.

Cuvinte-cheie: *pietrişuri, parametri morfometrici, indici de formă, rotunjime, sfericitate, forma optimă*

INTRODUCTION

Particle morphology, or form, refers to the sum of the surface characteristics of sedimentary grains. Processes of weathering, erosion, and transport may all leave distinctive imprints on particles, in the form of fractures, worn surfaces, and particular surface textures (Benn, 2010). In this way, morphometrical analysis can offer, along granulometric and petrographic analysis, relevant information on sediment source origin, transport environment and sedimentation process (Krumbein, 1941b; Pettijohn, 1949; Knighton, 1982; Bridgland, 1986; Howard, 1992; Illenberger and Reddering, 1993; Huddart, 1994; Ichim et al., 1998; Graham and Midgley, 2000; Moussavi-Harami et al., 2004; Demïr and Walsh, 2005; Attal and Lavé, 2006; Stanley and So, 2006; Lindsey et al., 2007; Ehlmann et al., 2008; Tamrakar and Shrestha, 2008; Mureşan, 2009; Hurst et al., 2010). Shape identification is also a key element in the study of transport. Sorting of sedimentary particles by size, shape, and density is of fundamental importance in the development of graded sediment beds in both space and time (Goede, 1975; Ueki, 1999; Milana et al., 1999; Domokos et al., 2010). The methods and schemes used to present/ of presenting primary particle shape data have been the subject of lively discussions, with a variety of schemes being advocated, a comprehensive summary is provided by Illenberger (1991), Graham and Midgley (2000) (Domokos et al., 2010). Each of these descriptive indices for particle size and shape try to quantify, as precise as possible, the influence of dynamic conditions and particle petrographic composition that were transported in certain environments and their appearance at a certain time. Many parameters for characterizing particle form were developed in the 1930s to 1960s because it was realized that particle form affects the area exposed to forces of flow, drag forces, lift forces, and therefore particle entrainment, transport, and deposition. Thus, two particles of the same weight or the same *b*-axis size but with different shapes can respond quite differently to water flow (Bunte and Abt, 2001). Three types of characteristics may be defined: *shape*, or the relative dimensions of the particle; *roundness*, or the overall smoothness of the particle outline and *texture*, or small-scale surface features (Benn, 2010). Among these, this analysis focused on only 10 indices as follows: *Cailleux roundness index* (R_c)*, Cailleux flatness index* (A_p)*, Cailleux asymmetry index* (A_s)*, oblat – prolat index (OP), disc – rod index (DRI), maximum projection sphericity (MPS), Corey Shape Index (CSI), elongation index c/a, elongation index b/a, elongation index c/b.* The obtained data, either from direct measurements on 5,027 clasts, or after index calculations were processed and were obtained a set of statistical parameter (average, median, standard deviation, etc.).

STUDY AREA

The Trotuş drainage basin is located in central-eastern part of Eastern Carpathians and Moldova Subcarpathians and has about 4,350 km^2 and a length of about 160 km (Fig. 1). Between headwaters and the Siret confluence, the altitude difference is about 1,290 meters (from 1,360 meters altitude at headwaters to 70 meters altitude at confluence). The Trotuş river is of VIIIth order in Strahler classification. The catchment area lies on four distinct structural and lithological units: the marginal syncline, the carpathian flysch, the pericarpathian molasse and the platform.

Petrographically, in the four litho-stratigraphical units dominate the following lithology: 40% clayey silty rocks; 35% sandstones of different types; 18% Quaternary deposits (gravels, sands, loams, clays); 5% crystaline schysts, limestones and dolomites; 2% menilites, disodiles, etc. (Dinu, 1985; Grasu et al., 1988, 1995, 1996, 1999, 2004).

Average annual rainwater spans from 722 mm/year in the Trotuş Valley and almost 1,000 mm/year in higher mountains. These values drop down about 100 mm/year in central part of Dărmăneşti Depression and towards the subcarpathian limit. Average annual discharge for the Trotuş river, recorded at Vrânceni hydrometric station, is of 33 m^3/s while the maximum was of 3,720 m^3/s, recorded on the 29th of July 1991. Between July 12 and 13, 2005 for the Trotus river, the increased water levels were caused by the extreme flow rates that surpassed the average multiannual discharge for the month of July. For example, a maximum discharge of 2,800 m^3/s was recorded at Vrânceni, comparing with 41.3 m^3/s. At several other Trotus River watershed, the discharge were large and reached the exceeding probabilities of 1–2% (Romanescu and Nistor, 2010).

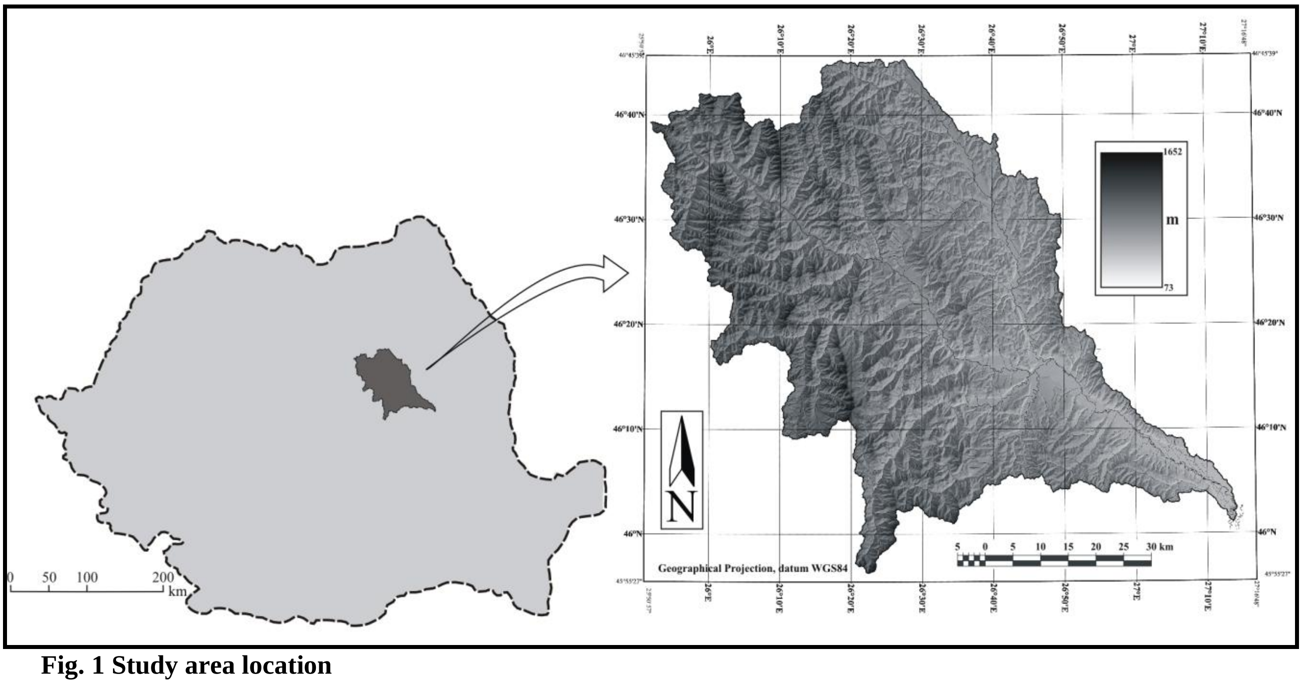

Fig. 1 Study area location

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Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume 10, Issue 1/ June 2011, pp. 78-90

MATERIALS AND METHODS

Riverbed sediments sampling

At first, it was started by sampling material from riverbed. In this study was used volumetric sampling for river channel sediments that uses sampling for surface layers or pavement layer and subsurface layer or subpavement layer (Mosley and Tindale, 1985; Church et al., 1987; Ichim et al., 1992). This sampling method consists in drawing of three sampling categories: *surface sample* (from the layer called hydraulic layer of which thickness is equal with the diameter of the largest clast; *subsurface sample* (or material located under hydraulic layer); *a global sample* (obtained by summing up the previous sampling categories). After setting up the sampling method and sampling points (21 channel sections at a distance of 7 km of each other – Fig. 2) topometric measurements were made, for each sampling point, to precisely assess the slope of the river channel and flood plain. Then, using the method proposed by Mosley and Tindale (1985), that states that the weight of the largest clast from sampled area is 5% from total weight of the sample, the clast with the largest diameter was identified. This was weighted to know the quantity of the sampled probe area. One square meter area was chosen as being representative for the entire section, out of which were collected surface and subsurface gravel. Some of granulometric fractions were sieved directly in the field using a set of sieves with holes having diameters according to the Wentworth scale. Sieving holes were of 64 mm (-6 phi), 32 mm (-5 phi), 16 mm (-4 phi), 8 mm (-3 phi). The clasts with diameters between 128-256 mm were measured and weighted using a special calliper. For the ones larger than 256 mm, more difficult to be weighted in the field, a diameter-weight scale conversion was used (Church et al., 1987; Ichim et al., 1992) built on the basis of the river clasts that were investigated by evaluating the weight of the biggest clasts on the basis of the *b* axis.

After all the sampled material was weighted, and grouped in classes (piles of gravel were made for them) sample clasts were taken from each class. It was randomly picked 100 clasts from classes of 16-32 mm and 32-64 mm for morphometrical and petrographical lab analysis. For the material smaller than 8 mm, sieving was continued in the lab using sieves of smaller diameter (6; 5; 2; 1; 0.5; 0.2; 0.1 mm). From the obtained results there were made assessments on differences from pavement and subpavement, on median diameter of riverbed deposits, on the percentage of each granulometric fractions, clasts morphometry, lithology, etc. Global samples (by summing pavement and subpavement samples) were separated in 14 granulometric classes, at 1 phi interval, on five dimensional steps, according with Wentworth scale (Church et al., 1987), as follows: *i) silt + clay* (< 4 *phi* or 0,063 mm); *ii) sand* (between 4 *phi* or 0,063 mm and - 1 *phi* or 2 mm); *iii) gravel* (between - 1 *phi* or 2 mm and - 6 *phi* or 64 mm); *iv) cobble* (between - 6 *phi* or 64 mm and - 8 *phi* or 256 mm); *v) boulder* (over - 8 *phi* or 256 mm). For morphometric and petrographic analysis were randomly selected 100 clasts (were analysed 5,207 clasts) from 16-32 mm (*coarse pebble*) class and 32-64 mm (*very coarse pebble*) class.

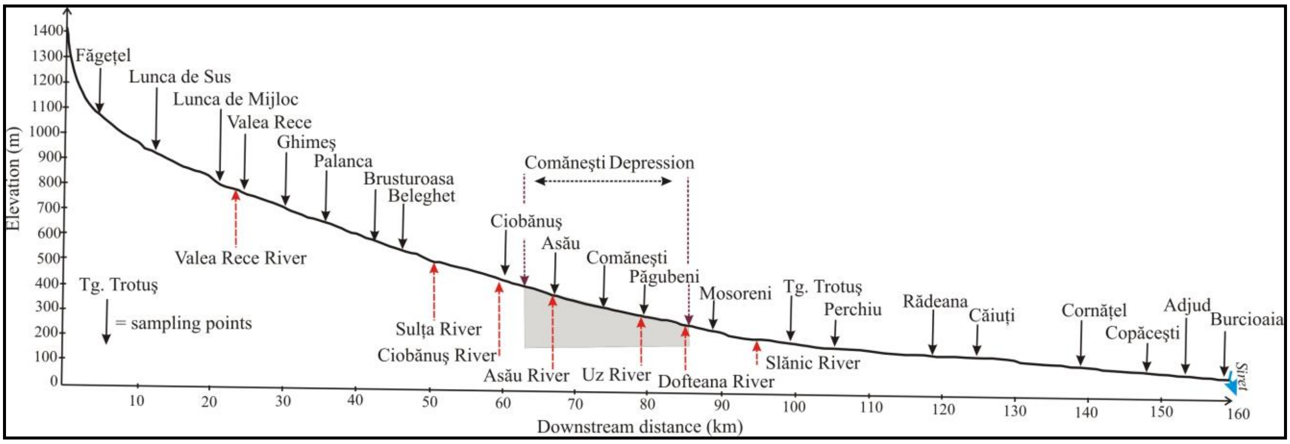

Fig. 2. Sediment sample points distribution

The analysis of gravel morphometry

The particles shape and roundness indices are calculated using formulas that contain a set of parameters. Basic parameters are represented by the values of the three axes (*a*, *b, c*), which, in our case were obtained by direct particle measurements using sliding callipers and the value of the ray of the sharpest corner (r_1) from particle maximum

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projection plane (*ab* plane). Plane shape of the particle was obtained by using an instrument whose working principle consists in creating a light beam plan-parallel using a concave mirror and in its focal point was put a source of light. Particle to be measured is placed on a flat glass piece in front of the light beam and its shadow is drawn on paper. Knowing *a*, *b*, *c* axe values and curvature rays a whole set of indices can be computed, among these, the ones proposed by Zingg (1935), Cailleux (1945, 1947, 1952), Sneed and Folk (1958), Dobkins and Folk (1970), Krumbein (1941), Corey (1949), with which it can be assessed the precise shape of the particle (Fig. 3 and Table 1).

Other calculation methods were proposed by Hockey (1970), Ballantyne (1982), Benn and Ballantyne (1993), Blott and Pye (2008). These have the advantage of the ease of computation for individual ratios.

Table 1 Used morphometric indices

Index	Formula	Author
Cailleux roundness index	$R_0 = 2r_1 / a$	Cailleux (1947)
Cailleux flatness index	100 (a +b) / 2c = FI	Cailleux (1945)
Cailleux asymmetry index	A_s = AC / A	Cailleux (1952)
Sneed & Folk (1958) elongation index	c / a b / a c / b	Sneed & Folk (1958) Zingg (1935) Zingg (1935)
Disc-Rod Index (DRI)	(a - b) / (a - c) = DRI	Sneed & Folk (1958)
Oblate-Prolate Index (OPI)	OPI = 10 (((a - b) / (a - c) - 0,5) / C / a)	Dobkins & Folk (1970)
Maximum projection sphericity (MPS)	$\sqrt[3]{(c^2/ab)}$ = MPS	Sneed & Folk (1958)
Corey Shape Index (CSI)	CSI = c / $\sqrt[2]{(ab)}$	Corey (1949)

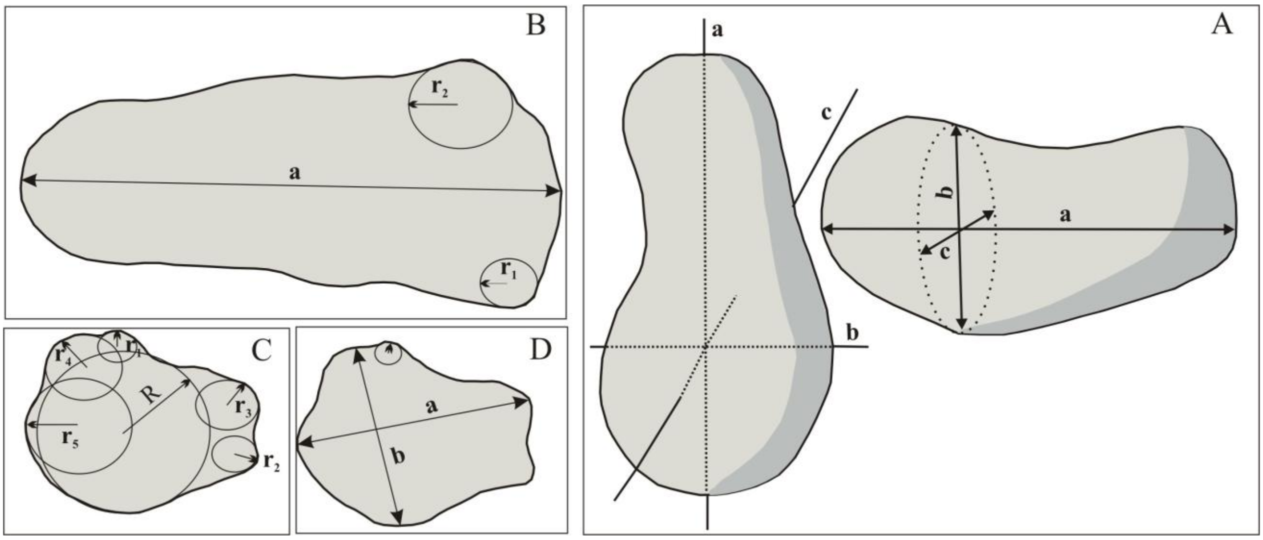

Fig. 3 A. The measurement of a, b, c particle axes after Cailleux (1947) method; B. Particle roundness measurement after Cailleux (1947) method; C. Particle roundness measurement after Wadell method; D. Particle roundness measurement after Wentworth method

RESULTS AND DISCUSSION

Variation tendency of morphologic indices along the Trotuş river were assessed by using mathematical functions as follows (Maria Rădoane et al., 1996, Ichim et al., 1998): *linear* - $y = a + bx$; *exponential* - $y = a\ e^{bx}$; *power* - $y = ax^b$; *logarithmic* - $y = a + b\ lgx$; *hyperbolic* - $y = a + b\ 1/x$; *polynomial* - $y = a + bx + cx^2 + dx^3$, in which: *y* – is the analysed morphometric parameter ; *x* – transport distance from headwaters, in km ; *a, b, c, d* – regression coefficients. Obtained results allowed us to confirm some general reports made by Miclăuş et al., (1995) and Ichim et al., (1996) according which: *(i)* particle shape is strongly controlled by *transport distance*; *(ii) the value and the sign of regression coefficients (b, c, d,* e) reflects the way in each morphometric index is influenced by the increase of transport distance.

Cailleux roundness index

Coarse pebble roundness (16 – 32 mm) is growing, between the two extreme sampling point (Făgeţel, located at 7.1 km from headwaters and Burcioaia, at 159 km), from 0.170 to 0.365.

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Considering these values we can say that we are almost in an ideal situation, in which roundness index doubles from headwaters to the outflow. Between the two extreme points there are some sectors in which roundness index grows up to 0.300, and after each important confluence a decrease is reported, mostly influenced by materials inputs which were transported on much shorter distances.

In this way, particle roundness becomes greater, in general, down to the Ciobănuş confluence, then is reduced to 0.231. Between the Asău and Oneşti, the coarse gravel roundness index is above 0.300, after the confluence of Trotuş with Oituz, Caşin and Tazlău rivers, it drops to 0.273, then downstream of Rădeana is reported a small increase of this index. Smaller value of this index for the gravels sampled in sections located closer to headwaters reflects, on one hand shorter transport distances, and the Sinaia sandstones dominance in the riverbed deposits petrographic spectra which start their travel with a strong flatness index, on the other hand.

For very coarse gravels, the roundness index grows from 0.136 in Făgeţel section, to 0.360 upstream the confluence of the Trotuş river with the Siret river (Fig. 4). Compared with the values reported for the previous class, the very coarse gravel displays a much more uniform variation of this index along the river longitudinal profile. Some variations, generally specific along large rivers, like fast change on short distance for roundness index in high energy environments and its decrease along the transport distance, were reported in many studies (Mills, 1979; Richards, 1982; Ichim et al., 1998; Rengers and Wohl, 2007; Miao et al., 2010).

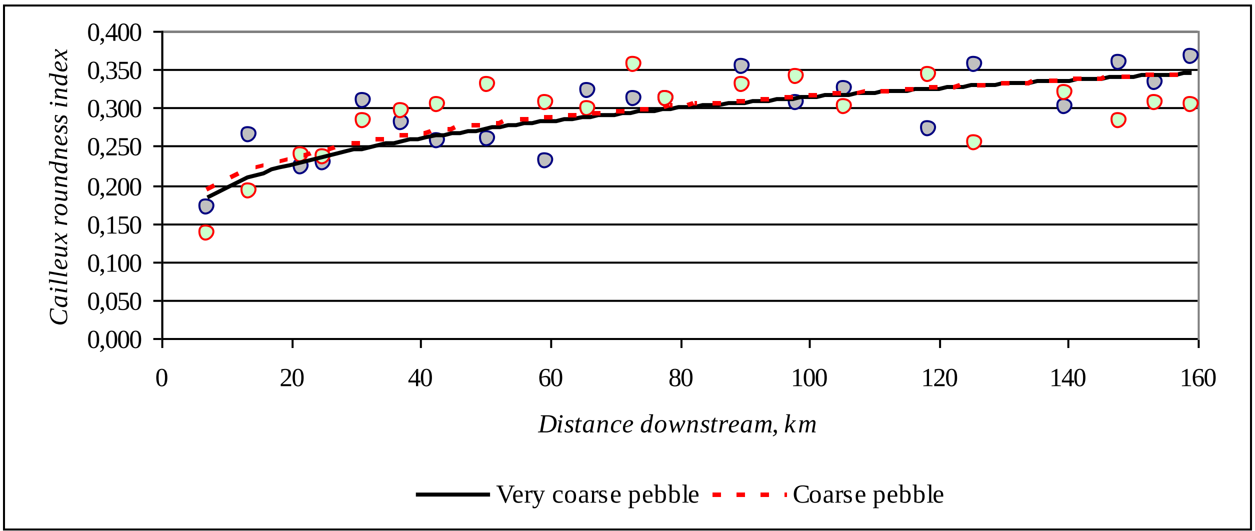

Fig. 4 Cailleux roundness index variations for gravels along the Trotuş river

Cailleux flatness index

Coarse pebble flatness (16-32 mm) within the Trotuş riverbed deposits is best described by second polynomial function. Dal Cin (1967), reported for the Piave river, in Italy, that the flatness is a very good indicator for hydro-dynamic conditions by the fact that in the river upper course very flat pebbles have many chances to break perpendicularly on *ab* plane, due to stream turbulence, while in mid course, with less transport competence, coarse particles rest longer in riverbed and are polished by the sand transported at low level waters. While flatness variations in upper and mid courses received reasonable explanations, the increase of this index in lower course, for most studied rivers, still lack sound explanations. Dal Cin (1967) considered that lower course saltation phenomenon can explain pebble flattening along the entire length of the river. The trends reported by Dal Cin (1967) were confirmed, for some Romanian rivers by Ichim et al., (1990) and (1998).

Coarse pebble flatness from the Trotuş riverbed tends to have a certain increase downstream, but as it can be noticed in Fig. 5 still has a constant slight decrease in the same direction. Theoretically, this situation is normal – roundness is increasing downstream and the flatness is decreasing in the same direction.

As for roundness index, this general tendency does not reflect in field situations. From one river sector to another, there are large variations for flatness index. For example, within only 8 km, flatness index increase from 227.946 (in Lunca de Sus section, which has almost the minimal value) to 316.818 (in Lunca de Mijloc section, which is the maximum value). We consider that pebble petrography has a more important role in pebble flatness and roundness than hydro-dynamic

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conditions, at least in this case. Flattened sandstones (Sinaia sandstone, convoluted sandstones, Podu Secu-Plopu sandstones, etc.) dominant in pebble petrographic spectra, for many river sectors, have an important effect on shape and size of coarse particles. For example, it was reported that pebble flatness index is over 240 for sampling sections in which the Sinaia sandstone clasts is over 50% from global sample (Ghimeş, Palanca, Brusturoasa). Another reason that might lead to our results partial uncorrelation, with the ones reported in other studies, is that statistical processing was made on global samples and not on certain lithologies. However, we can draw the following conclusion: the smaller the pebble size, the greater is the roundness index and the smaller is the flatness index.

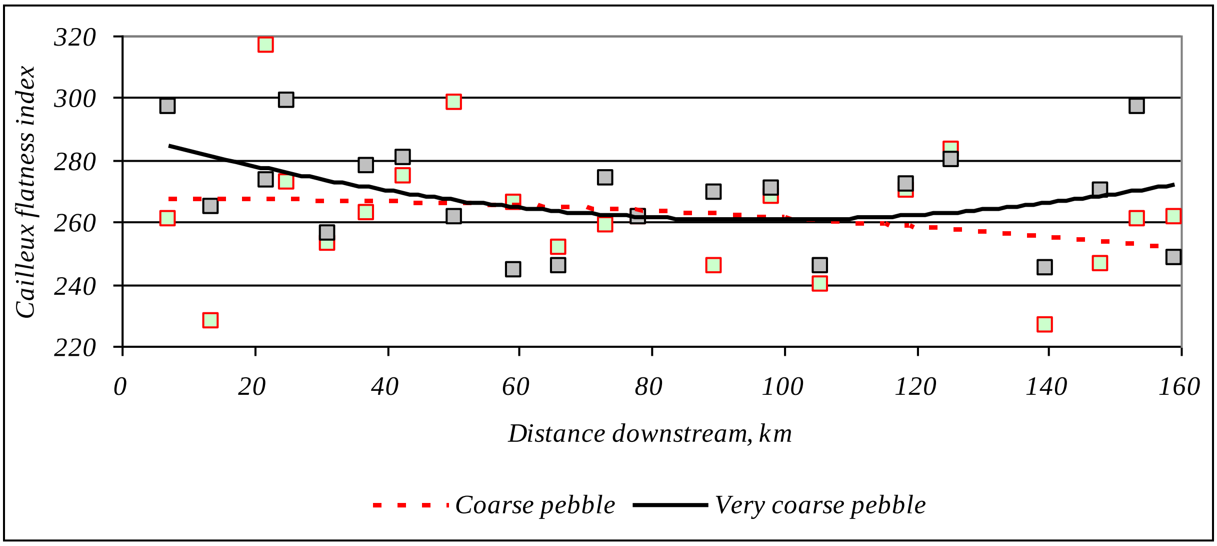

Fig. 5. Pebble flatness index variation along the Trotuş river

Very coarse pebble (32 - 64 mm) flatness index generally comply the tendency reported in the above-mentioned rivers. There is a decrease of it from upper course to mid course and a small increase towards the end of river, with values close with the one recorded in the first 20 km of the stream (for example, at Făgeţel, flatness has a value of 297.033, and at Adjud, at 150 km distance downstream, is of 296.697).

Cailleux asymmetry index

Asymmetry index, like roundness and flatness indices have some differences between the two pebble classes. Coarse pebble asymmetry has a longitudinal profile variation with close mean values (the minimum value is 0.616 in Rădeana section, and the maximum is 0.670 at Lunca de Mijloc section) which correlate well enough with the data recorded for roundness and flatness values. The maximum value for asymmetry index correlates well with the greatest value of flatness and with the second average minima for roundness (all reported at Lunca de Mijloc section). Except some anomalies recorded downstream important confluences or where the slope materials reach directly in the channel, general tendency of coarse pebble asymmetry index is a slight decrease towards the Siret confluence (Fig. 6).

Ichim et al. (1998) stated that asymmetry index, records, for most studied rivers, a tendency of exponential decrease. For coarse pebble, the tendency confirms the one reported by the above-mentioned authors, but not for very coarse pebbles, where some anomalies were recorded. In this case the difference between average minimum value and average maximum value is much higher. On 125 km distance, very coarse pebble asymmetry records a visible decrease (from 0.690 at Făgeţel section, to 0.621 at Căiuţi section, there being the average extreme values) then, downstream towards the Siret confluence, a small increase is recorded. Also, in this case, it is reported a direct correlation with the pebble asymmetry. Reports from different studies focused on pebble shapes indicated that fast and constant decrease of asymmetry, after a long fluvial transport, this index is capable to replace roundness index. This situation can be used when are made assessments for clasts decay over large transport distances (Ichim et al., 1998). In our case this replacement cannot take place, as previously stated, asymmetry decrease is constant in a certain sector, then an increase, in this way creating a better correlation with flatness and roundness indices.

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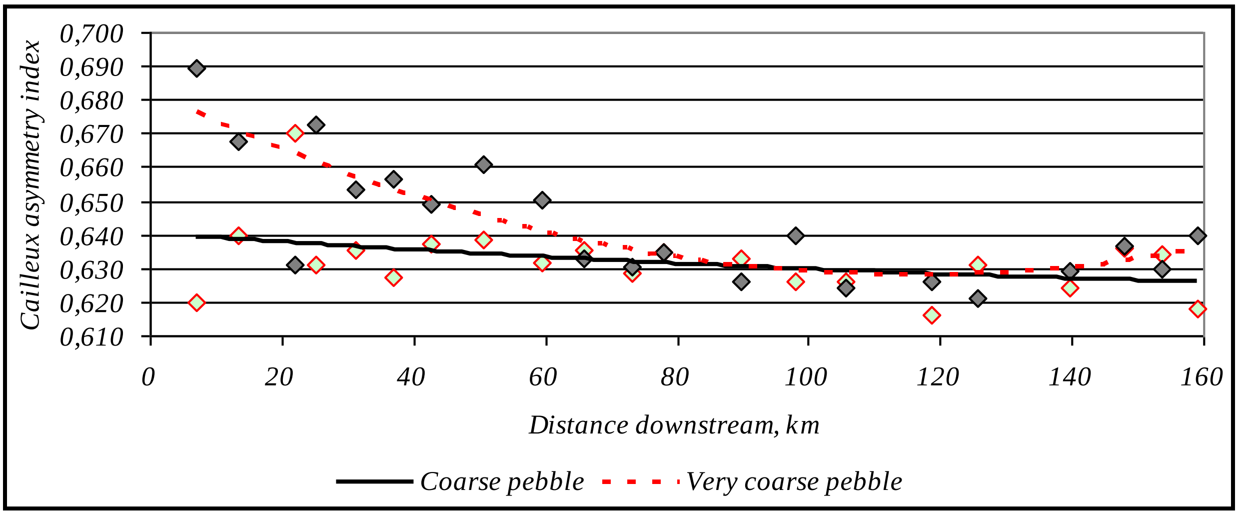

Fig. 6 Pebble asymmetry index variation along the Trotuş river

Maximum projection sphericity

Sphericity records ups and downs, among the main confluences, as this index is strongly influenced by lithology and our analysis was done on pebbles with very different petrographic spectra from one sampling section to another. Out of lithology, was reported a very good correlation between sphericity and quality class forms (rods and discs, blades and spheres) and, therefore, this index can influence sorting processes by the control made on particle mobility and ease of transport (Lane and Carlson, 1954). This authors demonstrate that low sphericity particles (disc shape ones, for example) are well anchored in the riverbed and, therefore, difficult to mobilise, but if so, are easy to be transported. According to the authors, this fact is caused by the small values recorded by vertical speed components. In the case of coarse pebble, maximum projected sphericity great values are reported in the first two sampling sections in the upper river course (Făgeţel and Lunca de Sus – 0.578 and 0.623, respectively). Lunca de Sus high value can be caused, at a certain extent, by the presence of Mesozoic limestones and Bistra sandstones whose increased sphericity is reflected in average general sphericity from the sampled point. Only at 8 km downstream, there is a very different situation. The decrease of Bistra sandstones and Mesozoic limestones share within petrographic spectra from coarse pebbles has as a result a decrease of clasts sphericity down to 0.510, which is the smallest value recorded. From this point further, with few exceptions, the sphericity index comply the rule available for most of the rivers, i.e. a slight increase towards the river mouth (Fig. 7).

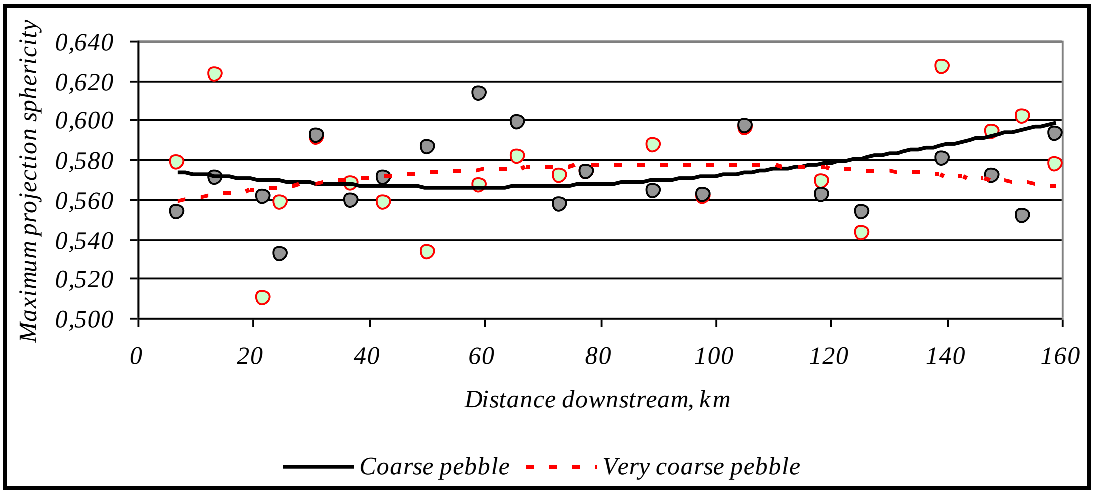

Fig. 7 Pebble maximum projected sphericity variation along the Trotuş river

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Exceptions appear where strong flattened rocks have over 50% from the petrographic spectra (Beleghet, Căiuţi etc.). This increase is very different compared with the results reported for other rivers (Moldova, Putna etc. - Ichim *et al*., 1994, 1998). The authors concluded that the pebble have the tendency to get a less spherical shape downstream, in order to be more resistant to the water flow. Also, in this case, we consider that the differences are given by the analysis type, for a certain lithology or for the entire pebble spectra. Moreover, we have to consider that most of the previous studies were done on very coarse pebble (32 - 64 mm) and then, were generalised for all pebble classes. As far as we can say, the behaviour is different from one petrographic class to another. Regarding sphericity index for very coarse pebble, a slight increase was reported in the first the 60 km, then the values are almost constant throughout the rest of the river.

Disc-Rod Index

The values of this index can be theoretically interpreted, as follows: if are closer to 0 value, pebbles shapes are more closer to a disc shape, and if the index value is closer to 1, clasts shape are closer to a rod/cylinder. For the Trotuş river, the average value for coarse pebble spans between 0.502 at Păgubeni (located at 78 km from headwaters) and 0.400 at Ghimeş (at 32 km from headwaters). Because 99% from the measured values are under 0.500, we can say that coarse pebble shape from the Trotuş riverbed deposits have a median position between the two extremes, much closer to disc shape, but with a slight tendency towards elongated shapes in the Trotuş lower course (Fig. 8).

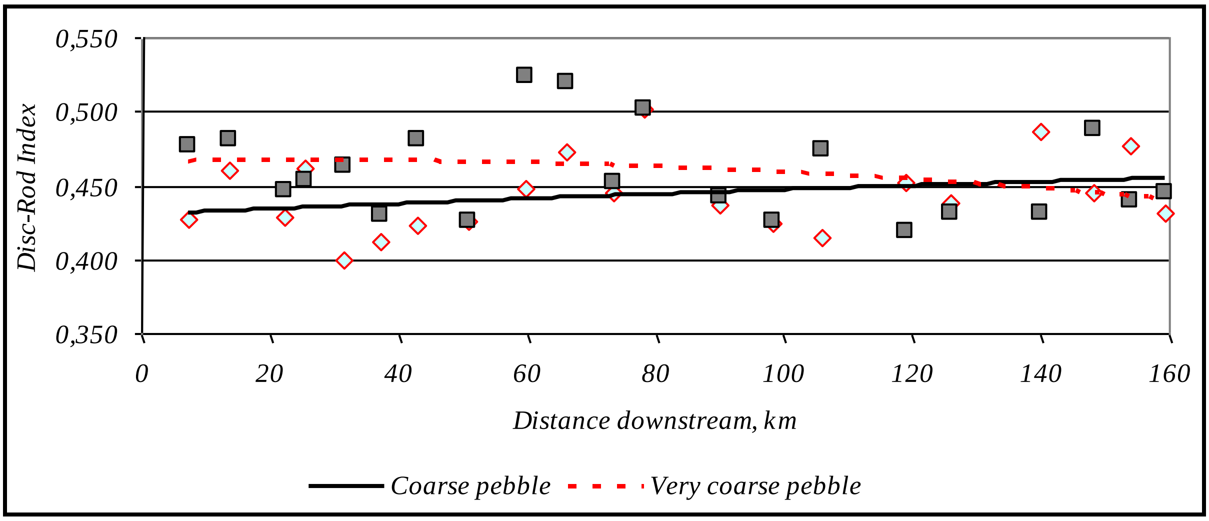

Fig. 8 Disc – rod index variation along the Trotuş river

Disc – rod index variation along the Trotuş river, specific for very coarse pebbles, seem to be much closer to the results demonstrated in scientific literature, in the way that higher values are specific for upper course, followed by a slight reduction tendency towards the mouth of the river. This behaviour seems to be reversed for coarse pebble.

Oblate-Prolate Index

Oblate - prolate index is somewhat alike with the previous one, in the way that smaller values are specific for more flat/ oblate shapes, and as these values are growing the pebble shape is much more elongated. The analysis for very coarse pebble within riverbed sediments it can be noticed a small downstream transition tendency from more advanced oblate shapes to a transitory oblate-prolate shape. Values of -2 and -3 are frequently recorded in upper and mid course, while downstream the Rădeana sampling section these values are close to 0, which indicates a certain change in the clasts shape (Fig. 9). Oblate-prolate index records a downstream general reduction tendency for very coarse pebbles which becomes flatter, but important tributaries can induce some anomalies for this index (sometimes visible enough).

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Volume 10, Issue 1/ June 2011, pp. 78-90

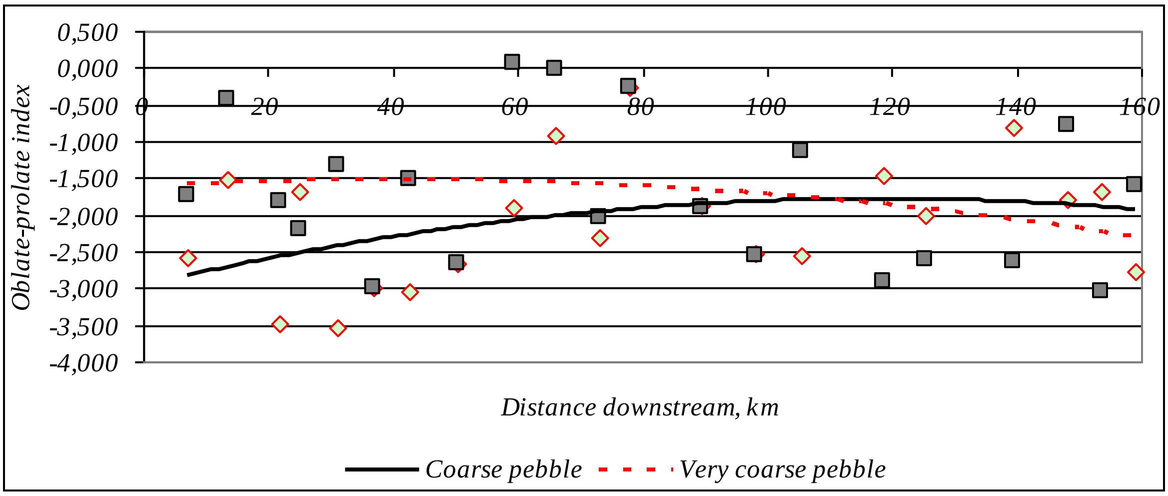

Fig. 9 Pebble oblate-prolate index variation along the Trotuş river

Corey shape Index and Sneed & Folk elongation index (*c / a*)

Both of them have almost the same variation tendency along the longitudinal profile. It was reported that in the upper and mid course (which is mostly the mountain area) average values for these indices locates the coarse pebble in plane-prismatic transition shapes class, while downstream (Subcarpathian and plateau area) are closer to the prismatic class shape (Fig. 10 and Fig. 11).

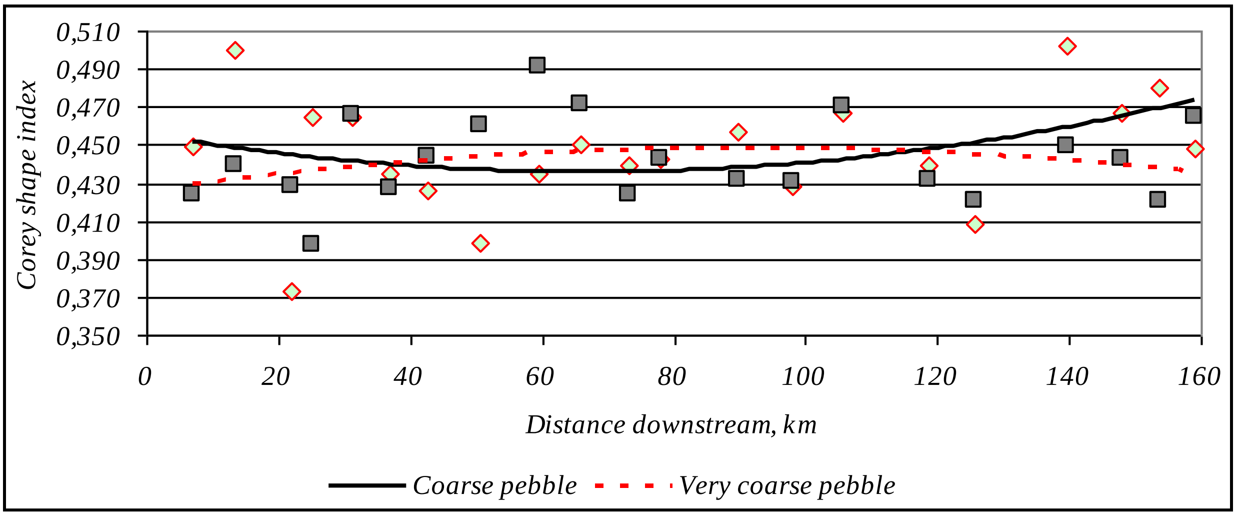

Fig. 10 Corey shape index variation along the Trotuş river

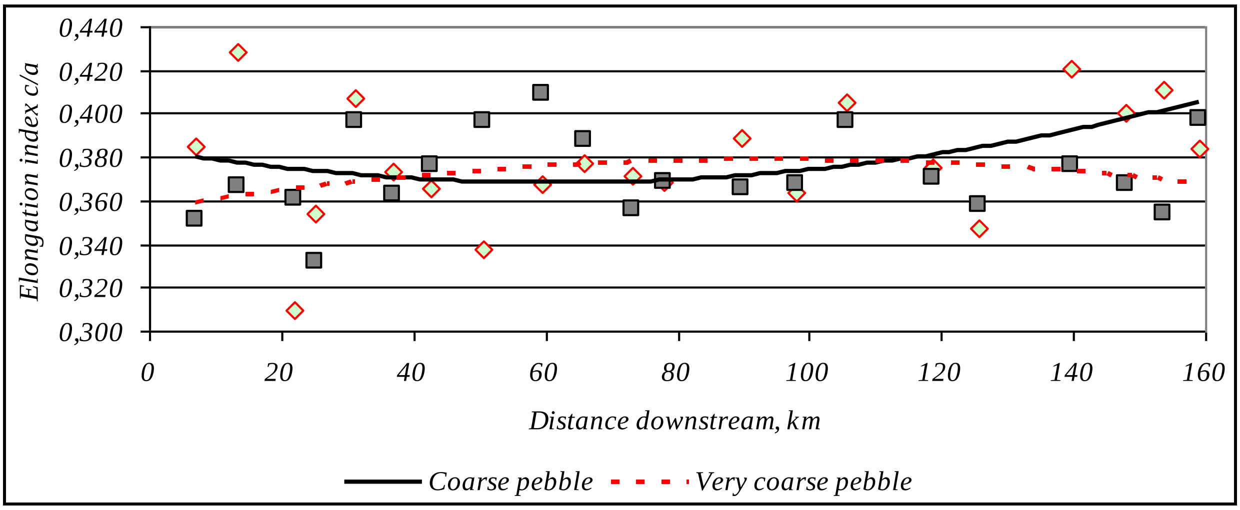

Fig. 11 Elongation index c/ a variation along the Trotuş river

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For very coarse pebble is reported the same downstream reduction tendency, which means that the clasts shape is more and more flat.

Ternary diagram created for five representative sampling sections (Făgeţel, Valea Rece, Comăneşti, Rădeana and Burcioaia), lead to obtaining the percentage values for some pebble morphometric indices (Dumitriu, 2007). Using Zingg (1935) classification (Fig.12 B), for example, it came out that for riverbed sediments dominates oblate class, for coarse pebble values are dominant in the upper course and for the inferior course dominate very coarse pebble values. For bladed clasts category the sectors are reversed, for both pebble classes. Oblate-prolate index classifications evidence that oblate shapes pebbles are dominant.

Pebble 'optimal shape' within the Trotuş riverbed sediments

Within Sneed and Folk diagram were delineated the areas for the following shape types: *compact, compact platy, compact bladed, compact elongated, platy, bladed, elongated, very platy, very bladed and very elongated* (Fig. 12 A).

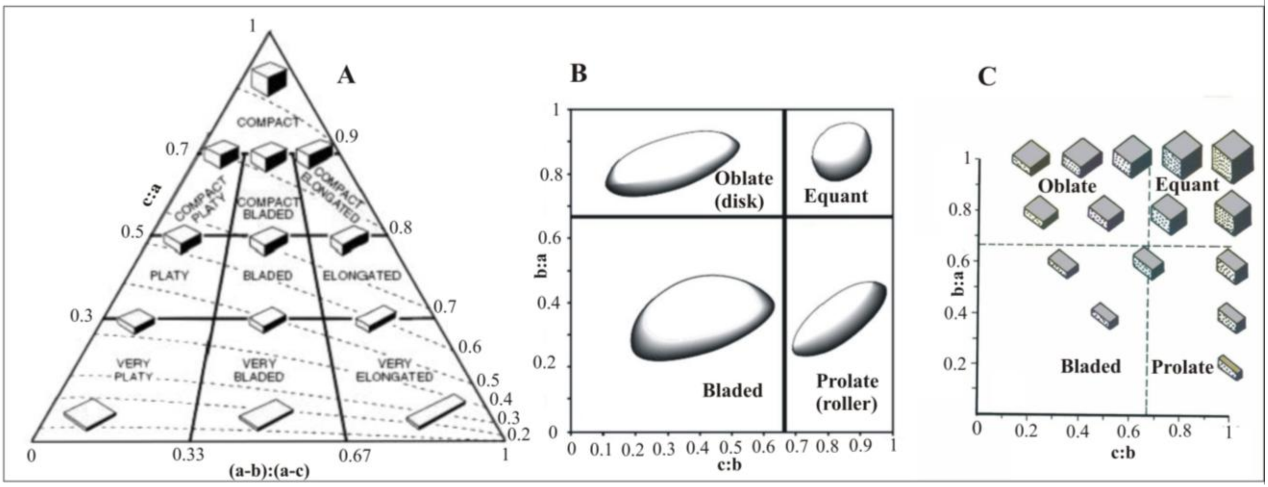

Fig. 12 A. The 10 descriptive classes defined by Sneed & Folk (1958); B. Zingg diagram. Shape classes definition; C. Zingg diagram particle distribution and shape

Based on these 10 descriptive classes it was made an assessment of the 'optimal shape' for gravel riverbed sediments within a river. The results evidenced that the cluster of values display a strong bimodality among these classes for the entire length of the river that confirms the results reported for other rivers (Ibbeken and Schleyer, 1986, for rivers in Calabria; Ichim et al.,1998 - for the Putna river). The dominating class, according with the percentage values, along the entire river length is the bladed class, within 12 out of 21 sampling sections. Cumulated percentage of the bladed class for the pebbles sampled in all 21 sections has values from 20 to 27%. Only in 4 sections (Făgeţel, Valea Rece, Brusturoasa, Mosoreni) the bladed class is not dominant for very coarse pebbles, while coarse pebbles is in minority for other 5 sections (Lunca de Mijloc, Beleghet, Păgubeni, Rădeana, Căiuţi). Very bladed class holds about 15-20% for both granulometric class pebbles, while platy and very platy classes hold 10-15% each.

CONCLUSIONS

Gravel morphometrical analysis evidenced the following conclusions:

- for *Cailleux roundness index* was reported that the two analysed granulometric classes have largely the same behaviour. In general, it was noticed a twofold increase of the index value between first and last sampling section. This index value decrease for Ciobănuş-Asău and Oneşti-Rădeana sectors can be explained by the intake of weak river processed materials (reported downstream several confluences) or of completely raw materials, when the slopes feed directly the river channel;
- in the case of *Cailleux flatness index* it was reported that for coarse pebble is a uniform slight decrease of the index value, a reverse tendency that was reported for most of the studied rivers. Very coarse pebble flattening comply, widely, the general accepted tendency i.e. a decrease of the value from lower to midcourse, followed by a new increase of the value;
- *Cailleux asymmetry index* should record an exponential decrease tendency, but this is true only for coarse pebble, while for very coarse pebble it seems to display a certain increase downstream the Căiuţi section and downward the Siret confluence;

DOI: 10.5775/fg.2067-4635.2011.00008.i

• *maximum projection sphericity* for the Trotuş riverbed gravels is closely related with lithology, which, in turn, decides the shape of the clasts. In this way, coarse gravel sphericity has the same tendency reported for most of the rivers, i.e. a certain increase downstream. For very coarse pebble it was reported a slight increase of the index value for the first 60 km of the river, then the values are almost constant throughout the rest of the drainage channel;

• for *disc-rod index* was reported that about 99% of the values are under 0.500, which can lead us to conclude that coarse pebble shapes from Trotuş riverbed have an average position between the two extremities, much closer to disc form and a slight tendency to more elongated shapes in the lower river course;

• *oblate-prolate index* has a general decrease tendency downstream, which tell us that pebbles are more and more flattened, but with certain disturbances induced by the most important tributaries;

• for *Corey shape index* and *Sneed & Folk elongation index (c/a)* was reported that in upper and midcourse average values for these indices locates the coarse pebble in plane-prismatic transition shapes class, while in lower course are closer to prismatic class shape. For very coarse pebble is reported the same downstream reduction tendency, which means that the clasts shape is more and more flat.

• estimation of the *optimal shape* of gravels was made using the Sneed and Folk's (1958) 10 descriptive classes. Their distribution points out two shape classes, namely: *bladed*, specific for 20 - 27% from the all sampled pebbles; *very bladed*, with values between 15% - 20% from the Trotuş river sampled pebbles.

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