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SEDIMENT BUDGET FROM THE ARGEŞ DRAINAGE BASIN (VIDRARU DAM – OEŞTI RESERVOIR). A GEOMORPHOLOGICAL APPROACH

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Le bilan des alluvions du bassin de la rivière Argeş (le secteur du barrage Vidraru – le lac Oeşti). Un abord géomorphologique. Le secteur étudié représente le bassin hydrographique Argeş entre Vidraru et le lac Oeşti (A = 146 km^2), où nous avons en vue: 1) L'évaluation des sources des alluvions; 2) la granulométrie des dépôts comme une signification dans le bilan général des alluvions; la susceptibilité de la région aux processus d'érosion et de transport des alluvions; 4) l'évaluation du bilan général des alluvions. Le volume moyen annuel entré dans le lac Oeşti, dans la période 1969 – 1990 a été de 193 000 t/an, ce qui représente 23% de l'érosion effective des versants. Les sources des alluvions fournissent 836 633 t/an, dont 77% sont retenus dans les petits bassins et dans le lit de la rivière Argeş.

Key-words: sediment sources, geomorphological processes, grain size analysis, sediment budget, Argeş (drainage basin).

THE CONTEXT

Hydropower management of the Argeş River occasioned a remarkable focalisation of the researches on the sediment system. The phenomenon affecting the optimal work of different anthropical structures and, especially, of the reservoirs has continued. As far as this problem is concerned, Hydropower Research Institute invited our research team to reevaluate the main causes of reservoir siltation, especially, of the Oeşti Reservoir. Our approach is based on the sediment system concept which offers a unitary view on the phenomenon: sediment sources → transfer → sinks → sediment delivery (Ichim *et al.*, 1986).

The reach under study is the Argeş Basin drainage between the Vidraru Dam and the Oeşti Reservoir. The problems discussed are the following:

– sediment source evaluation (as source area; as types of deposit transfer toward and into river channels);

– deposit grain size as significant in the sediment general budget;

– region susceptibility due to erosional processes and sediment transfer;

– evaluation of the general sediment budget.

The studied area is, relatively, well known from the viewpoint of sediment problem (Bălteanu *et al.*, 1976; Roşca & Breier, 1979; Raţiu *et al.*, 1991; Şerban & Teodor, 1992). But there are some realities which must be taken into consideration for the sediment analysis in this region, namely:

– scarcity of field measurements on the sediment source process rate and on the sediment transfer rate [1];

– lack of estimations relied on international standard of deposit grain size, susceptible of being drawn into sediment transfer;

– ignoring the petrographical and mineralogical competition effect on the sediment load and its partition as bed load and suspended load;

– lack of a quantitative evaluation on the torrents arranged behaviour and its effects on sediment budget.

GEOMORPHOLOGICAL FEATURES AS SEDIMENT SOURCE POTENTIAL

Drainage basin difference of the Argeş River between Vidraru Dam and the Oeşti Reservoir (A = 147 km^2) is located on crystalline rocks (14%) and sedimentary rocks (86%), with an erosional susceptibility large spectrum. Since the crystalline field, as sediment source, has a low weight (Sy = 130 – 150 t/km^2/yr), attention has been paid to the geomorphological field of sedimentary rocks, where the sediment yield (Sy) may be over 7000 t/km^2/yr. The main sedimentary rocks characterising this area are: conglomerates, breccia and Senonian limestones; a complex of breccia and bituminous limestones on which a thick slope deposit (over 10 m in Arefu drainage basin) has developed; conglomerates and gray pelites with thin sandstone interlayers; molasse deposits (conglomerates, sandstones, sandy marls, sands).

Geomorphological potential in the sediment system has been evaluated by hydrographical network hierarchy (Strahler's system), by the analysis of relief energy maps and of relief breaking up maps, and by distribution of present geomorphological processes.

A maximum relief between 1130 m in Turburea basin and 493 m to Oeşti Dam, a relief breaking up of 9 km/km^2, a creep movement (rockcreep) of rock debris (as far as Vaja Creek confluence to Argeş River) and of the landslides characterising, especially, Arefu and Turburea basins have been determined. These data and information were used as input variables in empirical relationships that have been proposed (Ichim *et al.*, 1986) for sediment yield determination.

GRAIN SIZE ANALYSIS AS A SUPPORT OF BED LOAD AND SEDIMENT DELIVERY EVALUATION

Direct measurements on bed load are very important parameters for hydropower work designing and for other arrangements. The lack of these measurements renders their evaluation very difficult. Many authors consider the surveillance of sediment stock from reservoirs to be the best way of evaluating this process. This possibility has been applied as far as the Argeş River is concerned. Evidently, we have considered the Oeşti Reservoir as reference. This reservoir with a total initial volume of 1.8 mil. m^3 was finished in 1967. Since the Vidraru Dam controls the whole upstream basin of the Argeş River, the Oeşti Reservoir has proved to be a real decantation apparatus of the sediments delivered into the Vidraru – Oeşti basin difference. Between the two extremes, the Argeş River has 14 km in length and a 13.8‰ fall. It successively crosses an area with crystalline rocks (where the valley is very narrow) and an area with friable sedimentary rocks

[1] Echizli, Anca, Alexandru, T. *et al.* (1991), *Cercetări privind colmatarea lacurilor de acumulare de pe râurile Olt, Argeş, Buzău,* ISPH, Bucureşti (manuscript).

(where the valley is larger with fluvial terraces). The characteristic note of channel deposits is given by the coarse material; grain size and petrographical analyses were made for six river cross sections. In order to have comparative data of the sediment source areas and the sediment stored or transferred by the Oeşti Reservoir, grain size analyses of both reservoir sediments and slope deposits were made.

Channel deposit grain size analysed in six river cross sections by Ichim, Rădoane & Rădoane (1992) methodology shows the following tendencies:

– the cobbles class (20 – 200 mm) is prevailing, D_{50} ranging from 69 mm to 90 mm;

– the boulder fragments increase along the river, i.e. particles of 200 mm diameter represent 13% from the channel deposit whole. Finer particles (i.e. sands) have an important percentage (10 – 15%) per total, as well, which reflects an effect of sediment contribution of the Arefu drainage basin. This contribution is greater than the main river (i.e. Argeş River) transport power, especially for coarse particles.

Petrographical analysis of pebbles from the Argeş river channel was undertaken for pebbles and cobbles, with the help of thin sections. About 900

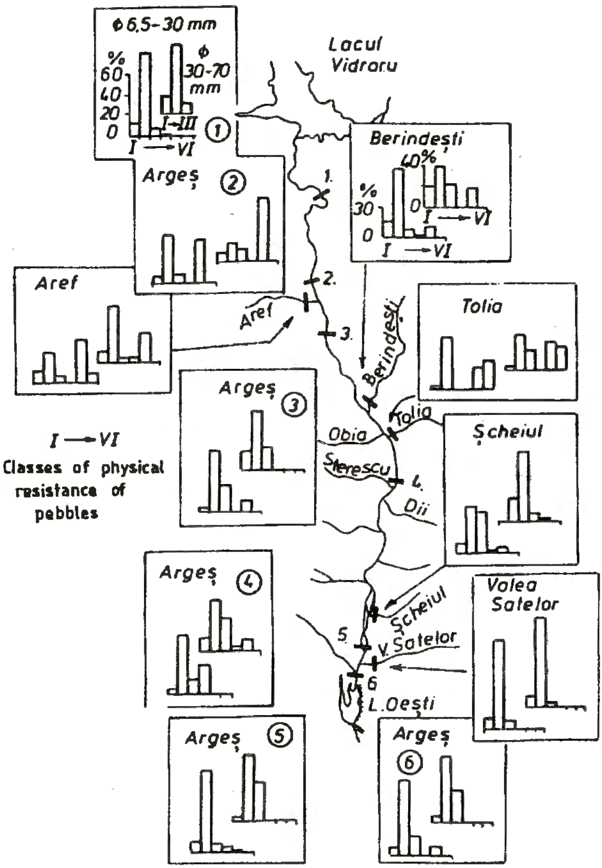

Fig. 1. – Histograms of physical resistance of pebbles from the Argeş River and some tributaries (see the text).

pebbles with diameters between 16.5 and 30 mm were analysed. The petrographical composition was clustered in six classes according to rock strength, namely: Class I (quartzites and quartzitic schists); Class II (quartz-feldspar schists, gneisses, metaconglomerates); Class III (schists with amphiboles, limestones, amphibolites); Class IV (micaschists, chloritous schists, sericitous schists); Class V (sandstones, conglomerates); Class VI (marls, gypsum).

The first four classes belong to crystalline rocks and the last two classes to sedimentary rocks. Histogrames of pebbles distribution (Fig.1) show the following characteristics:

– pebble petrography from the Argeş river channel is almost totally dominated by the second class of strength;

– channel deposits of direct tributaries of the Argeş River have a petrographical composition dominated by sedimentary rocks (IV & V classes of strength);

– sedimentary rock collapse in the Argeş River channel occurs as a consequence of high energy conditions of this river (even after closing of the Vidraru Dam); thus, in the transport process, the pebbles of crystalline rocks destroy the pebbles of sedimentary rocks which, in the previously described conditions, are predominantly friables.

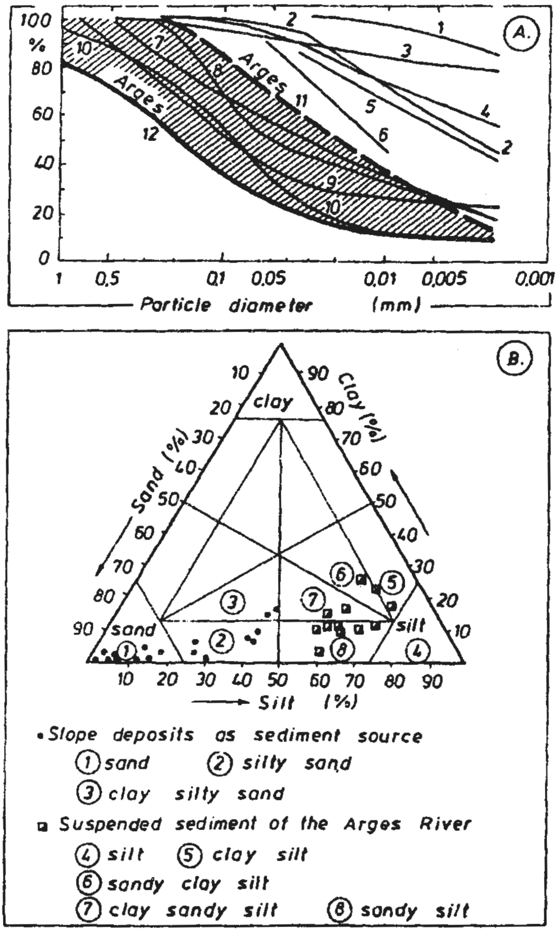

Fig. 2. – *A*, Global variation in the particle size composition of fluvial suspended sediment. *B*, Comparison of slope deposit grain size from the basins tributaried to the Argeş River (between Vidraru and Oeşti) and of suspended sediments of the Argeş River.

Surface sediment grain size into Oeşti Reservoir and drainage basin deposit grain size. The analysis of lake sediments was obtained from 22 sediment samples. Long profile distribution of the silt-clay-sand content and of the median diameter shows a prevalence of particles below 0.02 mm. The median diameter of sediment of the Oeşti Reservoir is of 0.0165 mm.

The sediments of the Oeşti Reservoir have been used as a substitute for grain size characteristic evaluation of suspended sediments transported by the Argeş River. The top layer of sediments formed after autumn–winter period, 1991 – 1992 (when discharge and load had low values) was assimilated, as a result of the suspended load transported by the Argeş River. This assessment has been suggested by the conclusion of an extensive study, including data of rivers of the four continents (Walling & Moorehead, 1989) and showing that 80–90% of the suspended sediments are formed of silt-clay, but the sand particles rarely exceed 10% (Fig.2). Our granulometrical data allow an equalization as follows: the latest sediment layer formed into the Oeşti Reservoir has a sand content of about 30–35%, and silt–clay content of about 65–70%, respectively.

As compared to the average sand content of suspended sediments of the rivers crossing different physiographic conditions, the Argeş River transports a larger percentage of these particles (up to 30%) (Fig.2) and it is comparable to the sediment transport of rivers crossing areas with friable rocks. This index shows the suspended sediments of the Argeş River as being closely dependent on the grain size of slope deposits from the Oeşti Reservoir drainage basin.

Soil samples and parent material were collected from the slope basin to make the deposit analysis, knowing that in the case of small and middle drainage basins, the particle size characteristics of the suspended sediment, mainly, reflect those of source eroded material. The relationship between these two deposit types also influenced by the selectivity of the erosion and transport processes (Fig.2), shows how the suspended sediments are enriched in the finer fractions and depleted in the coarser fractions as compared to the source material. Thus, if sands and silty sands prevail in the source material, in the suspended sediment sandy silts and clay silts prevail. In the sediment system, from source to delivery, the larger the coarse fraction loss the longer the distance from source to delivery. The enrichment degree in the finer fractions of suspended sediment may be estimated using *the clay enrichment ratio*, calculated as a ratio between clay percentage in the sediment and in the soil. The enrichment ratio decreases as a response to erosion rate increase within the area sources (Rhoton *et al.*, 1979). In the case under study in which the clay enrichment may range between 1.161 and 2.020, the

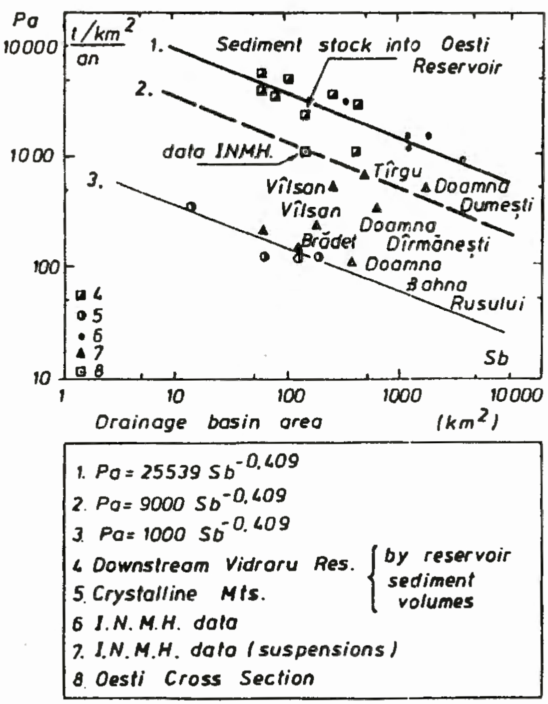

Fig. 3. – Sediment yield (t/km²/yr) in relation with the Argeş drainage basin area, evaluated from some sources.

sediment yield may vary between 3500 and 1500 kg/ha/year, values inscribed in the range of variation determined by the relationship in Fig.3.

To conclude, if the source area holds 60% sand + gravel, the suspension sediment contains only 30% sand, and in the Oeşti Reservoir 96% sands and gravels occur the result is that the largest amount of the sediments entered within the lake (between 60 – 70%) are transported by dragation and saltation. Their source lies in the small basins tributary to the Argeş River bed.

SEDIMENT SUPPLY OF TRIBUTARIES

The absence of the sediment measurements for the Argeş network between Vidraru and Oeşti forced us to appeal to the use of some empirical relationships proposed by the authors for the Subcarpathian hills and piedmonts, which are relevant within the region under study. Moreover, we took into consideration the situation of sediment regime for the whole drainage basin of the Argeş upstream Piteşti. An observation must be made, namely: referring to sediment measurements on the tributary network, upstream Piteşti they express values much under those represented by the stock in the reservoirs. It is a ratio of about 1/3 which may be interpreted as a weight of the suspension sediment from the whole supply of sediment (that is 30 – 35%). Evidently, in such a case, the evaluating basis of sediment yield must be the reservoir stock itself – between Vidraru and Goleşti – and the sediment budget, especially, from the Oeşti Reservoir. We also paid attention to the part and the significance of two major factors in the control of the sediment yield, the lithological role and the drainage basin area role, respectively, factors which both express, at the same time, the local particularities for erosional process differentiation and focus the action of exogenic agents, especially, of the discharge and of sediment transport - storage relationships (Walling, 1983).

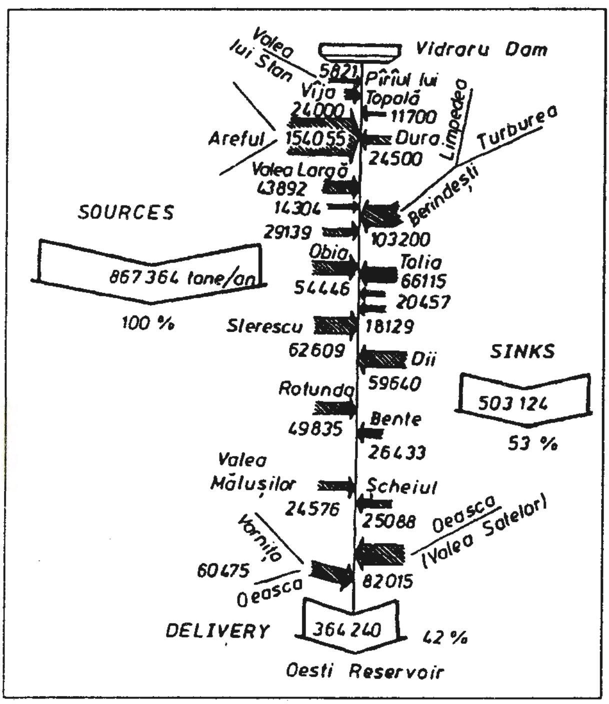

Fig. 4. – Relationships between source, storage and delivery for the reach Vidraru Dam – Oeşti Reservoir (first variant).

Thus, to the relationships mentioned, those obtained from reference to sediment stored within the reservoirs were added. These gave relationships illustrated in Fig. 3, that had a reasonable determination coefficient (r = 0.826). They offer the possibility to appreciate that 70% of the sediment yield variance is explained by the drainage basin area size.

The sediment yield of the drainage basins in Strahler's system (ordered III, IV, V orders) as estimated by means of these relationships (Fig.3). The sediment supplies predicted to reach directly the Argeş riverchannel are shown in Fig. 4. It follows that out of 867,364 t/year materials moved by different processes in the Vidraru – Oeşti channel about 364,240 t/year (42%) reach delivery. The Berindeşti, Arefu, Valea Satelor, Tolia, Varniţa are the most important tributaries.

SEDIMENT BUDGET IN OEŞTI CROSS SECTION

The sediment budget was evaluated for the three variants related, especially, to the recurrence periods of climatic phenomena favourable to erosivity within the Argeş drainage basin.

As a *first evaluation*, we considered a maximal erosivity within the Argeş drainage basin for the 1969–1975 period, when the Vidraru Dam accident was added to the flood interval. The yearly average volume of sediment entering the reservoir during this period was of 232,000 m^3 /year (364,240 t/year), which represents 23% from the gross erosion under the conditions of a VIIth order basin. In this situation, within the source basin of the Oeşti Reservoir, about 1.57 mil. tons sediments are moved yearly out of which 46% are stored within the small basins, and 32% reach the Argeş riverchannel.

For a *second evaluation* we considered both all stock of sediment from the Oeşti Reservoir and dredged stock in the period covering 1968 – 1990, which resulted in a value of 123,000 m^3 (193,000 t/year). In this case, the source provides 836,633 t/year, out of which 77% is stored in the small basins and in the Argeş riverchannel.

In a *last variant* we considered a low erosivity within the Argeş drainage basin. In this case the slope basin provides only 628,135 t/year out of which 153,000 t/year sediments reach Oeşti cross section.

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