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PROGRESS IN THE KNOWLEDGE OF THE SEDIMENT SYSTEM IN ROMANIA

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Les progrès de la connaissance du système des alluvions en Roumanie. Pendant les dernières années en Roumanie on a enregistré un bond significatif dans l'étude du système des alluvions. Ainsi, on a élaboré et défini les concepts de travail appliqués aux conditions morphogénétiques actuelles de la Roumanie ; on a réévalué la carte du transport spécifique des alluvions (la suite de la période humide d'entre 1970—1980) ; on a réalisé la carte des ressources d'alluvions relicts et de leur exploitation comme agrégats de construction ; on a évalué à l'échelle locale et régionale l'impact anthropique sur les alluvions (par l'aménagement hydroénergétique ; les irrigations et les dessèchements, les travaux de contrôle de l'érosion, etc.) ; on a détaillé et élargi les analyses des minéraux lourds sur les rivières importantes, y compris le Danube. Le travail, dans ce contexte, passe en revue les principaux résultats de la période 1980—1990.

Key words : sediments system, sediment sources, sediment transport, anthropical impact, Romania

1. The "sediment system" concept, defined as a part of the cascade subsystem of the fluvial geomorphic system (Ichim, 1986) allows a comprehensive approach to an important segment of the rocks' cycle on the earth surface, expressed by the morphodynamic triad *erosion—transport—sedimentation*. Before performing a retrospection of the last 10 years of research in the domain, two specifications are necessary for Romania's territory : 1) Although the concept of "sediment system" is defined as a strict reference to the delimitation of a fluvial geomorphological system (Ichim, 1986), it can be applied also to a territory delimited on other criteria than dividing lines of a certain order, if that territory belongs only to a drainage area, irrespective of its size. The territory of Romania is drained 97.8 per cent by an autochthonous network, tributary to the Danube. So, the "sediment system" concept is correctly applied to the whole Romania ; 2) The "sediment system" definition points out four structural levels : a) *control factors* (geological, morphoclimatical, biological, human, space and time scale) ; b) *geomorphic processes* (erosion — transport — sedimentation) ; c) *sediment sources* (as areas of sources and processes of transfer) and *sediment sinks* (natural and anthropic) ; d) *sediment delivery* (it can be expressed also as sediment yield or sediment delivery ratio). A definition like this permits also a unitary approach, in the succesion of the following aspects related to the sediment system : control factors → sediment sources → transport → sink → sediment yield (sediment delivery ratio) → impact → strategies. Over all this chain, there is also an inverse relationship. It must be identified and used in the elaboration of the strategies of arrangement and use of the rivers and lands, in order not to move away too much, if possible, the hydrographic network from the natural tendencies of evolution and for the increase of

the safety of the systems' arrangements. This is the context in which we approach the progress in the knowledge of the sediment system from Romania.

2. As for the *general image of Romania's sediment system*, after the important paper by Diaconu (1971), two syntheses must be mentioned: the first, elaborated by Moţoc (1984) gives for the whole country an image of the sediments delivery related to the main types of morphogenetic processes and land use ; the second belongs to Mociorniţă and Brateş (1987) which updates the map of sediment yields on Romania's territory, after the decade 1970—1980, when discharges on the largest part of Romania reached assurance values of 1 per cent and 0.1 per cent. The paper is based on the complete content of data of the national network, over a period of over 35 years.

In 1986 the Laboratory of Geomorphology of the Research Station "Stejarul" Piatra Neamţ initiated and organized the First Symposium on "Source and Sediment Delivery Ratio", which has reached the fourth edition (1986, 1988, 1990, 1992), characterized by a large attendance: geomorphologists, geologists, hydraulics engineers, hydrologists, pedologists forestry engineers, etc. The printed papers of the first three editions amounted to over 1,200 pages. By the agency of these meetings, a series of concepts and notions compelled recognition : *sediment system*, *sediment yield*, *sediment residence time*, *sediment delivery ratio*, *anthropic influence time in geomorphology*, *temporal geomorphological paradox*, *geomorphological effectiveness*, etc. In this context, the contribution of the Research Station "Stejarul" Piatra Neamţ, acquired a certain notoriety and contributed to the opening of a new direction in geomorphology — *engineering geomorphology*. The two books printed over the last 10 years, related to the dams' effects on landforms and to the rivers' morphology and dynamics (Ichim and Rădoane, 1986 ; Ichim et al., 1989) and other tens of papers of this working group printed in this period, as well as its attendance to the elaboration of some great programmes of hydroelectric arrangements (Upper Olt, Buzău, Siret, Argeş, etc.) support our statement.

3. *As for the knowledge of the control factors* of the sediments system, for the first time in Romania the typological and the multivariated analysis of discrimination was applied, also the classification and hierarchization related to their rate in the genesis and variation of size of the sediment yield (Ichim and Rădoane, 1987 ; Pricop et al., 1988). The series of multiple regressions deduced from the evaluation of sediment yield in the flysch area and in the Subcarpathian Hills is edifying. For the elaboration of these models were used 31 variables for 100 drainage basins with available sediment measurements (Ichim and Rădoane, 1987). In the same context, one can consider different relationships, like the type of power functions of the sediment yield related to a series of control factors as surface of drainage basins (Ichim, 1988), suspended load (Bătucă, 1986 ; Duma, 1990), etc. Simultaneously, *Gaspar — Apostol method* was continued and studied thoroughly, to emphasize the role of some factor categories of control from small drainage basins (Gaspar et al., 1982, 1986, 1988). All these have created the premises to achieving the map of sediment yield potentialities on the Romanian rivers.

4. Notable results were obtained in the *knowledge of the initiation of erosion and denudation* as well as of the rates of these processes by the promotion of field geomorphic experiment research (Ichim et al., 1980 ; 1983 ; 1987 ; Bălteanu, 1983 ; Ioniţă, 1985 ; Surdeanu, 1985, 1986 ; Zăvoianu, 1986 ; Rădoane, 1986, 1987 ; Vătau, 1986 ; Leu and Otlăcan, 1988 ; Teodoru and Teacă, 1988) and by the simulation, in laboratory, especially at the Hydraulics Institute. These results permit today a better evaluation of the weight of some geomorphic processes to sediment yield.

5. A new aspect, investigated on a broad scale in Romania over the last yers, is the *sediment and suspended sediment quality*, not only under drain size aspect, but also petrographically and geochemically (Ichim et al., 1985 ; Ichim and Rădoane, 1990 ; Hadnagy, 1988, 1990). So, a methodology of sampling is available for the analysis of the facies of channels with gravel and boulders, connected to international standards (Ichim et al., 1988). The petrographic and geochemical spectrum of the more important rivers channels is known : the Danube (downstream of Călăraşi), the Criş drainage basin, the Siret, Bistriţa, Argeş (Ichim et al., 1988). They are elements with a high significance in the identifying and reconstitution of some palaeogeomorphological features. The context in heavy metals of those deposits is known, with notable concentrations of magnetite (up to 16.5 kg/cu m), ilmenite (9 kg/cu m), hematite (6 kg/cu m), rutile (0.2 kg/cu m), zircon (0.01 kg/cu m) (Hadnagy, 1988, 1990).

6. Much attention was paid in this period to the research on *evaluation of sediment yield*. But, unlike the research papers previous to the 1980–1990 period, when such analyses were based exclusively on discharges measured in river cross section, during this interval the foundations of multifactorial analysis of the genesis and variation of the sediment yield ratio were laid and the evaluation was made of magnitude variation of these rates depending on other elements than the discharge. In this way guide marks were got that lead to establish more accurately the weight of the different processes in the genesis of sediments. In the same context reasonable data were obtained, related to the bed load discharge in the general quantum of the sediment yield (Rădoane, 1986, 1987 ; Apopei, 1986 ; Ichim and Alexandru, 1990 ; Ichim et al., 1990 ; Armencea, 1990). Such an approach reaches a special importance in the absence of field measurements on bed load.

The next step was the generalization on a broad scale of the sediment balance, reported to the sources of sediments as origin area, as process and order of hierarchization of drainage network (Moţoc, 1984 ; Ichim, 1990 ; Ichim et al., 1990). Walling's methodology (1981) of evaluation of the delivery ratio was also applied on the basis of clay content of sediments, comparatively with the origin area, for the Subcarpathian Hills and Moldavian Tableland (Ichim et al., 1990).

7. *Resources of sediments* become a research problem of great interest, not only for an assessment of the reserves of construction aggregates, but also for a forecast of regeneration of these riches. By the agency of up to 1000 big borrowing pits and other 270 secondary points of exploitation, over 80 mil. cu m of coarser sediments are exploited, much over the natural regeneration power of stream channels (Călinoiu et al., 1988). Because of this, some channels are strongly decalibrated (Siret, Argeş,

Mureș, etc.); for the end of this century only 65 per cent of the sediment reserves of the stream channels are expected to be available in exploitation.

8. *Human impact on sedimentary system* has got consequences without precedent, becoming a factor of regional influence. The Romanian concerns on implications of impact were among the most numerous, and among the multiple aspects, several are pointed out by consequence and proportions. We mention them:

a) *hydroelectric buildings*, that today *are controlling the biggest part of the hydrographic systems* of Romania, have reduced considerably the possibilities of sediment regeneration in a natural way (especially coarser sediments, gravel and boulders) and their transit to rivers of higher order or to Black Sea. So, the sediment transit was reduced considerably on the Olt, Someș, Argeș, Bistrița, Siret Rivers and alarmed the specialists, on the Danube (Gâștescu and Driga, 1983; Roșca and Mițurca, 1988; Olariu, 1988; Iulian, 1988, 1990; Duma, 1990). Moreover, it is considered that the scarcity of sediments load at the Danube Mouths is responsible for the increase of the aggression of the Black Sea upon the shoreline. The drastic reduction of the sedimentary transit on rivers is *first of all* an expression of accelerated silting of anthropic reservoirs, which at the level of 1986 year were silted in a proportion of over 20 per cent of the whole volume (Podani, 1988); *secondly*, the expression of the impossibility of the majority of the arranged rivers to self regenerate and supply the quantity of sediment deposited in reservoirs. It is a situation generated by the ignoring of the rivers' trend to remake their sediment discharge and implied a stressed trend of deepening downstream of dams, up to 2–2.5 m on the Someș (downstream of Gilău Dam) and the Tazlău (downstream of Belci Dam) (Armencea et al., 1980). The distance of migration of the deepening of stream channels downstream of dams amounted on some rivers to several tens of km (the Someș, about 44 – 45 km downstream of Gilău; the Argeș, about 100 km downstream of Golești Reservoir; the Olt – 85 km downstream of Drăgănești; the Ialomița – over 100 km downstream of Pucioasa Reservoir; the Siret, 150 km downstream of Berești Reservoir), with values of 0.40 – 0.60 m (Roșca and Theodor, 1990). Concomitantly, upstream of reservoirs there are intense processes of aggradation and migration of filling processes, with 250 – 400 m/yr on the Moldavian Bistrița (Ichim and Rădoane, 1986) and on some tributaries of the Olt (Roșca, 1986).

b) *Exploitations of sediment resources in river channels* induced also great decalibratings of channels and changes of the sediment transit. A decreasing of solid discharges of 30 – 50 per cent, is registered, result of their decantation, in the holes of loan and overflow in precincts, as it is pointed out for example on the Someș (Satu Mare), the Crișul Repede (Oradea), the Mureș (Arad); the Olt (Sebeș-Olt), the Prahova (Adîncata), the Siret (Lungoci), etc. Sometimes upstream of the big borrowing pits (over 10,000 m cu/yr) important tearings of profile are registered, as could be seen at Dej (on the Someș), Glodeni and Nădlac (on the Mureș), Blaj (confluence of the Tîrnava), Lugoj (on the Timiș) (Călinoiu et al., 1988).

c) Purloining of water from rivers for irrigation involved the emergence of some phenomena of underfitting riverchannels (the majority of the rivers channel from the Moldavian Tableland are in this situation), but also to a redistribution of sediments in areas that, excepting the river channels, are practically not exposed to erosional processes. We have the great system of irrigation in view: the Olt — Călmățui irrigation system, with an area of 46,760 ha, consumes an average discharge of 32 cu m/s and a sediment discharge of 12.03 kg/s, the suspensions being redistributed in the irrigation channel network, without reentering, like water, the immediate cycle of ± the hydrographic network. The sediment concentration varies from about 300 gr/cu m in the area of source to 4 — 5 times less at 25 — 35 km from the source (Dobrescu,1988). But the impact upon the sediment system occurs also when the action is antagonistic to irrigation, respectively, in the draining systems. It is estimated that there are 65,900 km of main canals, of which 47,300 km collectors of last order and 18,600 km of canals of evacuation (with role of transport of surface waters to rivers). Such a canal network takes over about 6 — 8 cu m/ha/yr of sediments (30 — 40 per cent coming from the volume of excavated enbankments) and introduces them in the secondary hydrographic network, or makes a silting of this system of canals, raising the elevation of their bottom with 0.3 — 0.6 m in 15 — 20 years (Mihnea and Dobre, 1988).

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