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MARIA RĂDOANE, IONIŢĂ ICHIM (PIATRA NEAMŢ)

CONTEMPORARY TRENDS OF RIVER BED FORMATION IN THE EASTERN CARPATHIANS

The aim of our study is to discuss the quantitative trends of the river bed dynamics in almost the whole area of the Eastern Carpathians. The time series analysis in geomorphology has been used in this study. Data include the results of measurements of the maximum river depths in more than 70 cross sections, along with other hydrological parameters (water level, width, velocity etc.). Measurements were performed by the Ministry of Waters, Woods and Environment. For each measurement the river bed elevation was considered to be the thalweg position to the O mark at the gauging station. We calculated the difference between the water level value (in cm) and that of the maximum depth (in cm). This difference represents the relative river bed elevation. The results of measurements made at 73 cross sections were elaborated for periods of 11 to 30 years. Data were graphically represented (Fig. 1) to facilitate the study of the phenomenon behaviour with the passage of time, to apply some techniques of statistical analysis of the temporal series and, finally, to allow the comparison of the trends. We also analysed the discharge regime to establish the main causes which support some trends of the river bed dynamics. Fig. 2 and Table 1 show a synoptical situation of the investigated cross sections (numbers in the table correspond to those on the map).

THE NATURAL CONDITIONS OF THE PRESENT RIVER BED DYNAMICS

The Eastern Carpathians cover almost 35 000 km^2 of Romania's territory. They extend from the northern state border as far as the Prahova drainage basin, i.e. over 3° of latitude.

The actual river system of the Eastern Carpathians inherited some drainage directions from the pre-Quaternary period. Some eastern side

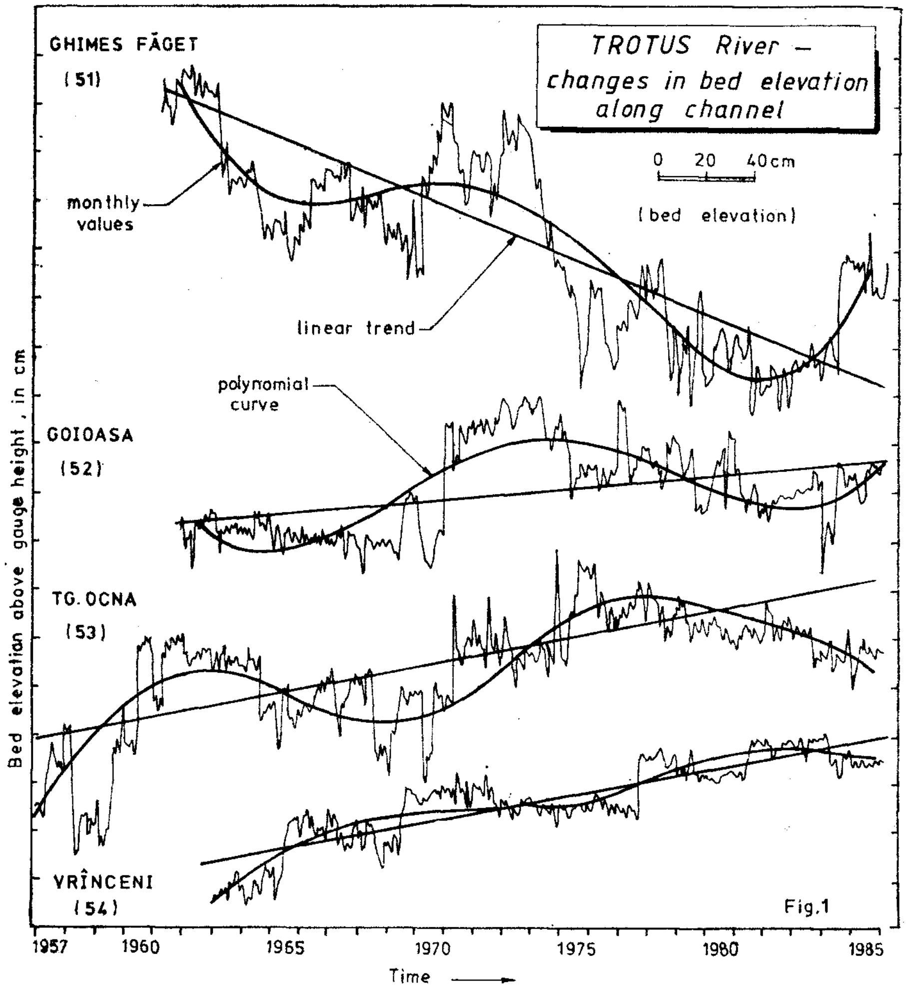

Fig. 1. Changes in bed elevation of the Trotus river along the channel
Ryc. 1. Zmiany wysokości dna koryta z biegiem rzeki Trotus

rivers such as the Suceava, Moldova, Ozana, Bistrița date even from the Sarmatian. From the geological point of view one may distinguish three great structural units there being related to the expansion of this mountain system. The westernmost unit was formed from the Neogene onwards to the early Quaternary. It stretches from the crystalline mass of the Eastern Carpathians to the Transylvanian Depression. The next crystalline unit is the oldest one. It is separated from the volcanic unit by a depression now. To the east there occurs the most extensive flysch zone. The real differentiation of the present river bed dynamics is related to the above three units. The study area included the greatest part of the Subcarpathian area. Further west it covered even a part of the Transylvanian Depression and the Western Plains (in case of the Somes river).

The Eastern Carpathians are affected by crustal movements now. North of the Trotus drainage basin the uplift values reach 6 mm/year (Cornea *et al.* 1979). The dominant part of the region shows movements of uplift of over 2 mm/year. At the point, where the Somes river crosses the Romanian border there begins a subsidence area showing values of —0.5 mm/year. The river bed sediments are formed of coarse deposits (blocks, gravels).

The hydrological conditions are typical of mountains of the temperate zone. About 70 per cent of the runoff value represent two seasons, namely spring and summer. The rivers investigated are rather small, since their drainage basins cover less than 1000 km^2, with a few exceptions. Average annual discharges do not reach 80 m^3s^{-1}, the majority is less than 5—6 m^3s^{-1}. Yet the maximum values may exceed 1000 m^3s^{-1} (the Somes and Bistriţa rivers).

Knowing the intricate relation between the river flow regime and the mobile river bed dynamics as well as the suspended sediment regime we also applied the time series analysis for them. It appears that a tendency toward increased flows and suspended sediment volumes has ben dominant during the last 30 years in the Eastern Carpathians. Thus, one may notice that flow volumes had increased by 1.5 times and those of sediment by 3—4 times. This tendency expresses itself in the increase in basin area. This explains the high values of the regression coefficient (b) towards the Carpathian foreland.

THE STATISTICAL TIME SERIES ANALYSES OF THE RIVER BED CHANGES

The time series are defined as a succession of values registered by a variable in different time units. Their study being applied to the geomorphological processes is a relatively new domain. For this reason some difficulties are obvious for, at least, three causes: i) the lack of both systematic measurements and the resultant data for long intervals, ii) the analysis of the temporal development of the geomorphological processes based on the study of the climatic and hydrological series; we must take into account the fact that these do not respond with the same sensivity to the stimulus of the hydro-climatic factors, iii) the sampling period often complicates the time series interpretation. There is first the problem of the relation between the sampling period and the serial properties of the physical geographical phenomena with time variations. In our case, we considered the three properties mentioned by Church (1980): tendency, persistence and intermittency. The variability of the natural phenomena includes all of the three properties. The duration of the sampling period may alter the contribution of one or the other to the time series composition. It is possible that in our investigations the 30 year period should not be significant to express the trend either of the process or of a well defined cycle. It is also possible that an intermittent signal may occur in the sampling period, i.e. a sudden deviation from the mean condition. This may lead to errors in the analysis and prediction of the evolutional process. Thus, the time series considered by us refer to contemporary times (Church 1980).

The graphical representation (Fig. 1) of the series of data and the use of techniques of statistical analysis enabled us to discover a great complexity of the river bed variability. For data interpretation we used Rao's classification (1980) of the series of changes in river bed processes with the passage of time:

— regular changes comprise oscillations of the river bed elevation, being approximately uniform about a statistical mean. We added to this type the cross sections that registered oscillations not exceeding ±50 cm and considered them a regime of stability;

— step changes are defined as sudden lowerings or rises of the river bed to be followed by changes which occur more or less regularly. Such situations are very frequent. Either the deposition of a great bedload or the erosion of the river bed in a short time may lead to sudden "up" and "downs" without momentary resources to reach the initial position of the river bed. Such behaviours of the river beds are usually generated by human activities (dams, embankments, dredging etc) and by some extreme hydrological events. The sections studied by us showed sudden jumps, especially during the floods of 1969—1970. A typical case is that of the Somes river. In its five cross sections (Fig. 2) there was registered both the sudden bed scour (about 1 m at Nepos) and the sudden filling (2 m in the Dej section and 1 m at Ulmeni) as a response to the exceptionally huge 1970 floods. The positions of these sections allow us to conclude that these phenomena may be generalized along the whole river.

— Ramp changes — in this case the evolution of the phenomena takes place on a slight slope. This is the most frequently occurring situation in the 73 studied cross sections.

— Transient changes are sudden jumps of the river bed level but returning to its initial position. Such variations are less specific of the river bed dynamics. They still existed in some sections but their amplitude was below 50 cm.

As these types coexisted we considered the measurement succession to be a time series. We applied some statistical techniques of analysis in order to define the tendency, the periodicty and the residuum for

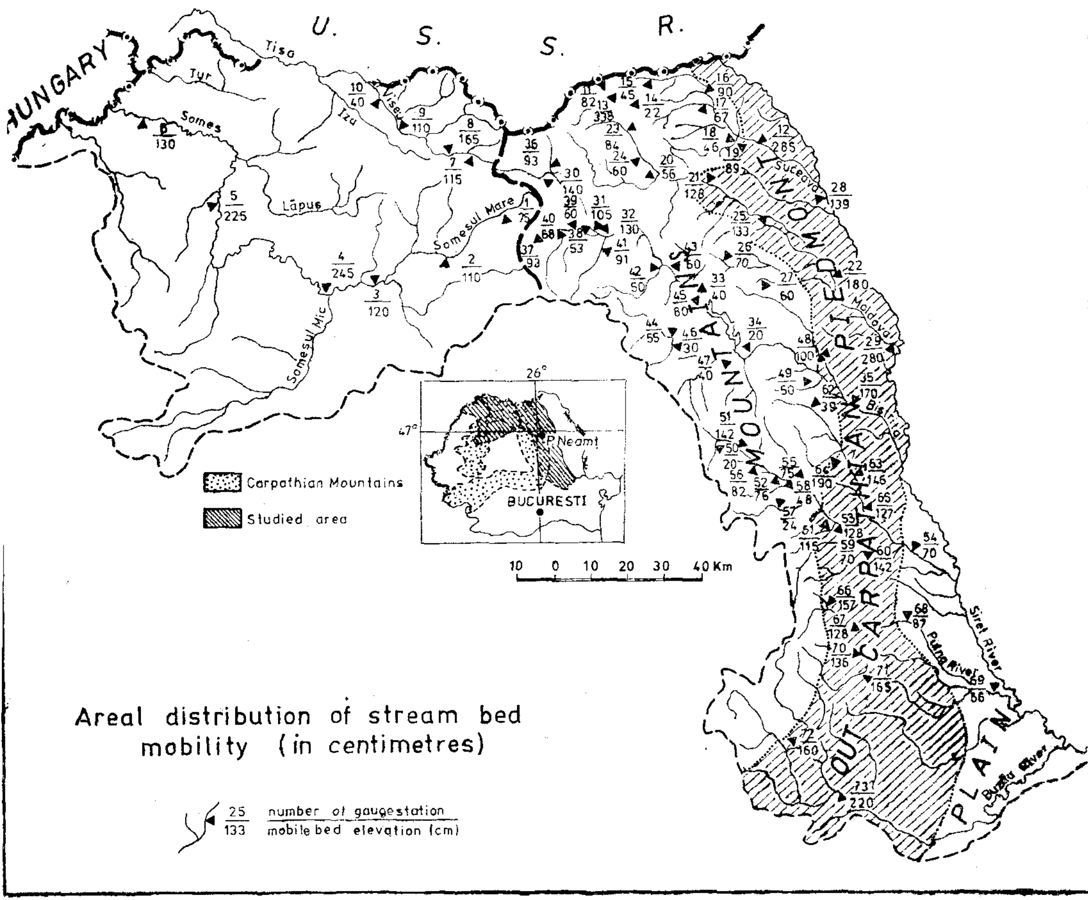

Fig. 2. Areal distribution of stream bed mobility (in cm)
Ryc. 2. Zróżnicowanie przestrzenne mobilności den koryt rzecznych (w cm)

each section studied. We used the simple regression, the polynomial regression and the spectral analysis.

The linear tendency of the vertical river bed dynamics was evaluated by means of a time function:

$$y = a + bx$$

where y = river bed elevation (in cm)
x = time (in months)

The tendency toward degradation expresses itself in the negative values of the regression coefficient, aggradation is indicated by the positive values and a certain stability is shown by the b coefficient close to 0. Thus, the value of the b coefficient indicates both the rate and

No	River	Cross section	Recording period	Basin area (km^2)	Basin mean altitude (m)	Discharge Q (m^3/s)	Channel deposits	Channel process	Linear tendency	Correlation coefficient of linear trend (r)	Correlation coefficient of 4th-order polynomial regression
1	Someș	Rodna	1955-1986	290	1127	5.56	B + G	A	$E = 85.75 + 0.0898 t$	0,655	0.792
2	Someș	Nepos	1956-1986	1138	935	17.8	G	D	$E = 132.1 - 0.177 t$	0.623	0.687
3	Someș	Beclean	1956-1986	4323	710	48.4	G	D	$E = 98.36 - 0.234 t$	0.849	0,896
4	Someș	Dej	1956-1986	8873	645	76.0	G	D	$E = 133.74 - 0.0373 t$	0.125	0,660
5	Someș	Ulmeni	1956-1986	11646	580		G + S	D	$E = 159,87 - 0,407 t$	0.919	0,942
6	Someș	Satu Mare	1956-1986	15000	537		S	D	$E = 102,79 - 0.149 t$	0,615	0.670
7	Vișeu	Poiana Borșa	1961-1986	131	1268	3,63	G	D	$E = 117,0 - 0.219 t$	0.745	0,958
8	Vișeu	Moisei	1962-1986	405	1225	6.45	G	D	$E = 137,26 - 0.662 t$	0.959	0,979
9	Vișeu	Leordina	1962-1986	980	1026	18.0	G + S	D	$E = 79,64 - 0.389 t$	0.845	0,871
10	Vișeu	Bistra	1966-1986	1555	1006	32.7	S	A	$E = 73.85 + 0.0302 t$	0,349	0.622
11	Suceava	Brodina	1969-1984	354	990	4.2	G	D	$E = 60.506 - 0.187 t$	0.477	0.675
12	Suceava	Ițcani	1963-1983	2330	626	17,1	G+S	D	$E = 40.25 - 0.455 t$	0.521	0,869
13	Brodina	Brodina	1965-1984	154	989	1,98	G	S	$E = 115.09 - 0.00293 t$	0.012	0.387
14	Putna	Pojorîta	1976-1983	80	1130	1,46	B G	S	$E = 92.26 - 0.0041 t$	0.023	0.726
15	Putna	Putna	1967-1984	50	847	0.736	G	S	$E = 81.45 + 0,0271 t$	0,244	0.553
16	Pozen	Horodnic	1970-1984	70	488	0.695	G + S	A	$E = 87.9 + 0.1604 t$	0.488	0,676
18	Solonet	Parhauți	1963-1983	214	467	1,27	G + S	S	$E = 68.77 - 0.189 t$	0.589	0.812
19	Șcheia	Șcheia	1966-1984	26	388	0.201	S	D	$E = 103.27 - 0.256 t$	0.860	0,876
20	Moldova	Prisaca Dornei	1963-1988	666	1027	7.37	G	A	$E = 116.04 + 0.063 t$	0.438	0.726
21	Moldova	Gura Humor	1977-1988	1757	929	23,0	G	D	$E = 76,50 - 0.569 t$	0.568	0,661
22	Moldova	Tupilați	1959-1988	4016	703	34.0	G + S	A	$E = 54,89 + 0.397 t$	0.746	0.863
23	Moldovița	Lunguleț	1967-1988	149	977	2,0	G	D	$E = 82,30 - 0.209 t$	0.673	0.797
24	Moldovița	Dragoșa	1967-1988	475	937	5.13	G	S	$E = 102,51 + 0,0021 t$	0.054	0.601
25	Rîșca	Bogdanești	1973-1988	185	628	1,50	G + S	D	$E = 89,66 - 0.144 t$	0,181	0.881
26	Pluton	Pluton	1964-1986	27	920	0.462	G	D	$E = 163.85 - 0.163 t$	0,699	0,766
27	Agapia	Filioara	1962-1986	37	666	0,222	G	D	$E = 110,30 - 0.119 t$	0,773	0.820
28	Somuzu Mare	Dolhești	1977-1988	444	301	1.88	S	S	$E = 95,2 - 0.0065 t$	0.123	0,369
29	Moldova	Roman	1977-1988	4308	684	39.0	G + S	D	$E = 252.3 - 0.110 t$	0,215	0,699
30	Bistrița	Cîrlibaba	1968-1984	349	1343	7.86	G	D	$E = 73.3 - 0.131 t$	0,261	0.420
31	Bistrița	Dorna Giumalau	1964-1984	740	1255	12.2	G	D	$E = 152,33 - 0.413 t$	0,953	0,965
32	Bistrița	Dorna Arini	1965-1984	1656	1206	24.7	G	D	$E = 101.3 - 0.248 t$	0.684	0,734
33	Bistrița	Frumosu	1970-1984	2816	1172	36,0	G	A	$E = 46,62 + 0,0131 t$	0.128	0,567
34	Bistrița	Straja	1974-1984	5054	1093	9,49	G	D	$E = -5,107 - 0,00279 t$	0.231	0.369
35	Bistrița	Frunzeni	1975-1984	6661	942	11.4	G + S	D	$E = 160.11 - 0,0884 t$	0,820	0,898
36	Cîrlibaba	Cîrlibaba	1963-1984	110	1253	1.73	B + G	S	$E = 31.1 - 0,0699 t$	0,365	0,533
37	Dorna	Poiana Stampei	1975-1984	132	1305	2,56	B + G	S	$E = 74,7 + 0.096 t$	0.188	0,703
38	Dorna	Dorna Candreni	1964-1983	566	1138	7,22	G	D	$E = 104.8 - 0.0912 t$	0,704	0,735
39	Cosna	Bancu	1976-1984	101	1185	1,70	B + G	A	$E = 88,6 + 0,275 t$	0,607	0,650
40	Cosna	Tesna	1975-1984	208	1100	2,97	B + G	S	$E = 80.1 - 0,085 t$	0,247	0.804
41	Neagra Șarului	Gura Negrii	1967-1984	301	1256	4,58	B + G	D	$E = 89.14 - 0.103 t$	0,500	0,778
0	1	2	3	4	5	6	7	8	9	10	11

0	1	2	3.	4	5	6.	7	8	9	10	11
42	Neagra	Broșteni	1976-1984	353	1220	4,16	B+G	S	$E = 154.5 - 0.037\,t$	0.180	0,347
43	Sabasa	Sabasa	1967-1986	78	1070	1.17	B+G	S	$E = 100.41 - 0.0824\,t$	0.582	0.687
44	Bistricioara	Tulgheș	1967-1986	416	1073	3.61	B+G	D	$E = 89.84 - 0.177\,t$	0.863	0.920
45	Bistricioara	Bistricioara	1974-1986	716	1043	5.95	G	D	$E = 198.7 - 0.292\,t$	0.651	0.799
46	Putna	Tulgheș	1974-1986	170	1069	1.42	B+G	S	$E = 140.48 - 0.0172\,t$	0.019	0.526
47	Bicaz	Bicaz Chei	1964-1986	184	1167	2.77	B+G	S	$E = 98.81 - 0.114\,t$	0.138	0.179
48	Cracau	Slobozia	1956-1983	399	577	1.86	S+G	D	$E = 96.76 - 0.063\,t$	0.446	0.642
49	Iapa	Luminiș	1964-1986	58	745	0.758	G	S	$E = 97.41 - 0.0534\,t$	0.350	0.792
50	Trotus	Lunca de Sus	1965-1985	89	1140	0.957	B+G	A	$E = 29.3 + 0.0023\,t$	0.649	0.798
51	Trotus	Ghimes - Faget	1961-1985	331	1116	3.56	G	D	$E = 221.7 - 0.336\,t$	0.785	0.896
52	Trotus	Goioasa	1962-1985	763	1052	6.59	G	D	$E = 192.4 + 0.0817\,t$	0,363	0,769
53	Trotus	Tg. Ocna	1957-1985	2084	924	17.2	G	A	$E = 31.12 + 0.164\,t$	0.680	0.799
54	Trotus	Vrînceni	1963-1985	4077	734	33.1	G+S	A	$E = 166.8 + 0.186\,t$	0.870	0.893
55	Asau	Asau	1955-1985	196	951	2.15	G	D	$E = 204.9 - 0.167\,t$	0.878	0.912
56	Sulta	Șulta	1964-1985	116	1041	1.21	G	D	$E = 208.4 - 0.231\,t$	0.890	0.924
57	Uz	Valea Uzului	1968-1985	160	1070	2.04	G	S	$E = 233.7 - 0.0652\,t$	0.666	0,719
58	Ciobanus	Ciobanuș	1964-1985	132	1052	1.46	G	D	$E = 214.4 - 0.102\,t$	0.698	0.709
59	Oituz	Fierastrau	1962-1985	263	810	3.70	G	D	$E - 221.0 - 0.173\,t$	0.853	0.867
60	Casin	Haloș	1967-1985	215	717	2.86	G	D	$E = 220.08 - 0.250\,t$	0.644	0.845
61	Slanic	Cireșoaia	1967-1985	100	775	1.68	G	A	$E = 168.9 + 0.0625\,t$	0.168	0.443
62	Tazlau	Tazlau	1969-1985	138	793	1.82	G	S	$E = 165.2 - 0.0287\,t$	0.252	0.550
63	Tazlau	Helegiu	1970-1985	984	520	7.19	G	D	$E = 214.7 - 0.181\,t$	0.357	0.606
64	Tazlau Sarat	Lucacești	1963-1985	123	801	1.69	G	D	$E = 201.6 - 0.569\,t$	0.908	0.927
65	Tazlau	Slobozia	1958-1985	1095	505	6.02	G+S	D	$E = 39.97 - 0.152\,t$	0.626	0.677
66	Putna	Lepșa	1969-1983	143	1022	2.26	G	A	$E = 67.88 + 0.594$	0.819	0.880
67	Putna.	Tulnici	1956-1983	362	990	4.65	G	A	$E = 80.32 + 0.155\,t$	0.501	0.571
68	Putna	Colacu	1967-1982	1100	921	11.3	G	A	$E = 93.9 + 0.00097\,t$	0.003	0.290
69	Putna	Botîrlau	1956-1983	2518	554	17.1	S	D	$E = 190.07 - 0.039\,t$	0.426	0.567
70	Naruja	Herastrau	1968-1983	137	1040	2.25	G	D	$E = 212.4 - 0.418\,t$	0.720	0.906
71	Zabala	Nereju	1967-1982	244	1171	4.82	G	D	$E = 195.6 - 0.256\,t$	0.357	0.653
72	Bîsca Unita	Bîsca Roziliei	1967-1988	759	1108	11.60	G	A	$E = 36.89 - 0.0991\,t$	0.177	0.614
73	Buzau	Magura	1967-1988	2273	886	26.10	G+S	A	$E = 30.71 - 0.0407\,t$	0.072	0.731

E = river bed elevation (cm) t = time (months) A = aggradation D = degradation
S = stability B = boulder G = gravel S = sand

the direction of the tendency toward a given process changing the river bed level. The farther is „b" from zero the more intense is the process. Consequently, the river bed is farther from a state of equilibrium. The closer is „b" to zero the nearer are the conditions of „close to equilibrium". Hence one may deduce that the linear tendency may explain the river bed behaviour (Tab. 1, column 10). For the situations studied the temporal variation of the river bed deviation shows a tendency with a significance of 57 per cent in all of the cross sections investigated. This situation allowed us to use the regression coefficient b as an index of the vertical river bed mobility. On this base we evaluated the dominant river bed process: either degradation or aggradation or stability (Tab. 1, column 8) in the 73 cross sections. The b coefficient also enabled us — through the repartition frequency — to notice that degradation is the dominant river bed process in the Eastern Carpathians (Fig. 3a). Degradation has been observed to occur in 54 per cent of the sections examined. The stable river beds, i.e. river beds which do not show neither a well defined tendency nor vertical oscillations of over 50 cm constitute 24.5 per cent. River beds showing a tendency toward aggradation make up 21.5 per cent (Fig. 3 A).

The polynomial trend in the vertical river bed dynamics was determined by means of polynomial functions of the 2nd, 3rd and 4th orders (Fig. 1). They indicate the existence of aggradational-degradational cycles being superposed on the general trends of river channel evolution (rise, lowering). As example (Fig. 1) the Trotus river bed was selected. At the confluence with the Siret the Trotus is under control of 4 370 km^2, the mean multi-annual discharge is 31.1 $m^{-3}s$ and the suspended load reaches 38.1 $kg^{-1}s$. The river crosses the flysch mountains, the Subcarpathians and the Piedmont area. Along most of its longitudinal profile the river bed behaviour may be described as follows (Fig. 1):

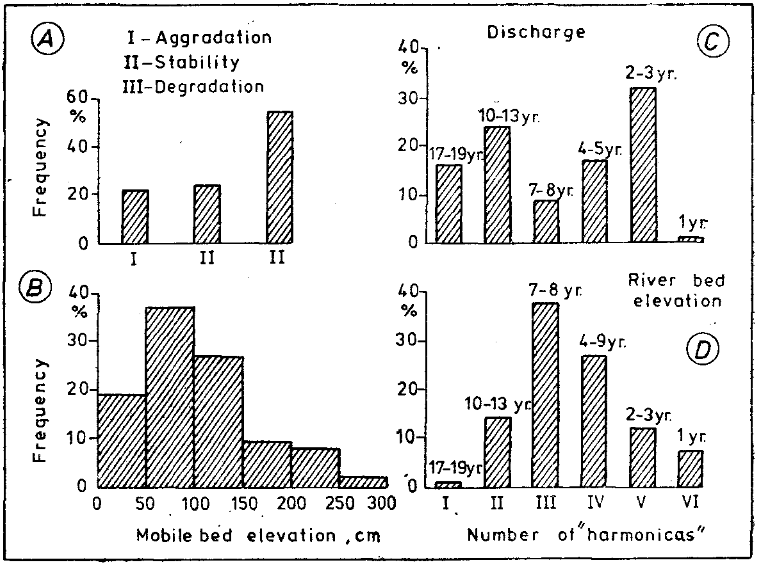

Fig. 3. A — frequency distribution of channel processes in the Eastern Carpathian streams, B — frequency distribution of the mobile stream bed elevation of the streams studied, C — frequency distribution of flow „harmonicas", D — frequency distribution of river bed elevation „harmonicas" of the streams studied

Ryc. 3. A — częstotliwość występowania procesów korytowych w rzekach wschodniokarpackich, B — częstotliwość występowania zmian wysokości den koryt badanych rzek, C — częstotliwość występowania oscylacji przepływów rzecznych w różnych interwałach, D — częstotliwość występowania oscylacji wysokości den koryt badanych rzek w różnych interwałach

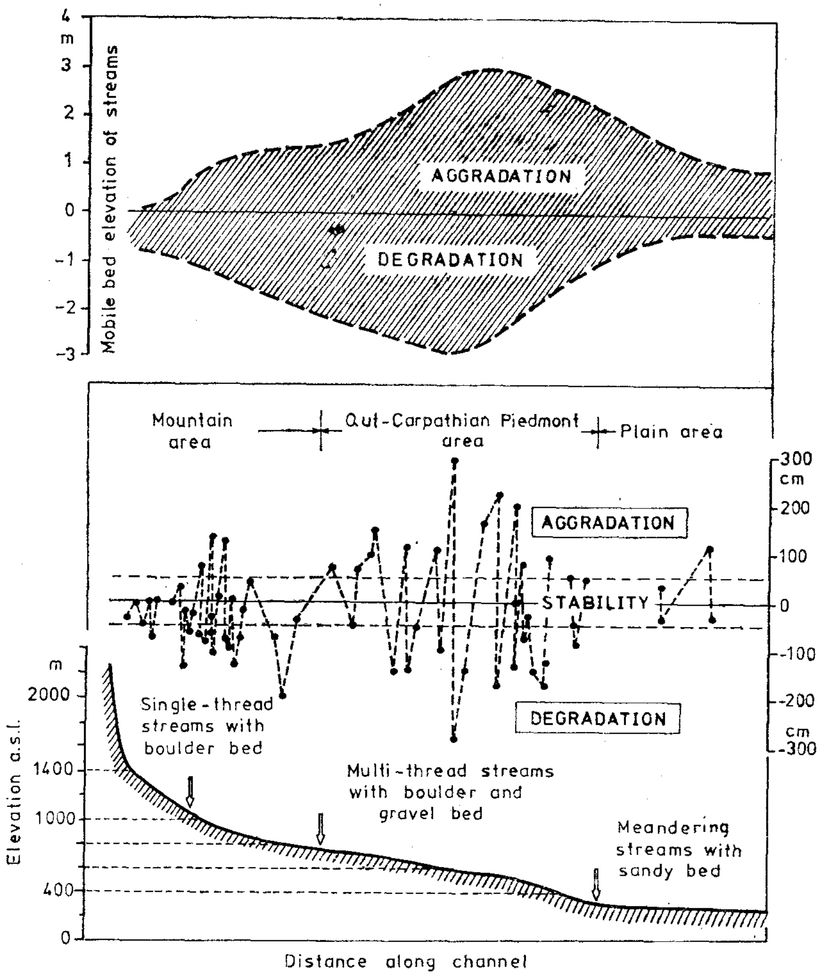

Fig. 4. Mean longitudinal profile of the Eastern Carpathian streams and channel processes

Ryc. 4. Sredni profil podłużny wschodniokarpackich rzek i procesy korytowe

i) In the uppermost section (51) on the general degradational trend an aggradational wave is superposed with a maximum in 1971; it is limited by two phases of degradation with minima occurring in 1965 and 1981.

ii) In the Goioasa section (52) lying 30 km downstream of the former one the general river bed trend is that of a sensitive process of aggradation; the position of the present aggradational wave approximates that of 1969—1975.

iii) In the downstream section 53 two degradational waves may be discerned: the first one with a maximum occurring in 1962 and the second one with a maximum stated in 1977—1978. Both are superposed on a marked aggradation.

iv) Finally, at Vrinceni about 25 km downstream of section 53 on a general aggradation two aggradational-degradational waves are superposed. These are of a shorter duration and of a smaller range than the upstream ones.

Such a succession was identified in almost all of the rivers studied. Worthy of note is the fact that the polynomial function of the 4th order has a better control over the temporal variations of the investigated series. This may be checked by the increase in the value of the correlation coefficient (Tab. 1, column 11). In 89 per cent of the sections examined this coefficient exceeds 0.5.

The successions of the aggradational-degradational waves may be associated with some transfer waves of bedload dragged down the rivers over a long time. Yet other investigations are necessary to explain this hypothesis. They would greatly facilitate the bedload prognosis which is almost exclusively done by means of calculations and not by measurements. Some researchers (Bennet 1970; Nakamura 1986) stated the existence of some bedload transfer waves of a long duration and extending for tens of kilometres. Thus, our hypothesis may have a chance of being confirmed. We may also conclude that the „residence time" of the sediments in the river bed also is under the control of a pulsatory river bed behaviour. This is expressed in the succession of storage areas (with a great residence time) being separated by transport areas (with a very short residence time).

In conclusion, observation of the polynomial trends of the data series concerning the elevation of the Eastern Carpathian river beds indicates that:

i) the river bed elevation registers a cyclic evolution which expresses itself in the alternating degradational-aggradational waves; the respective waves include phases of a lower amplitude of scour-and-fill;

ii) the degradational-aggradational waves migrating downstream are accompanied by length and amplitude reduction; in case of the Trotus river bed the migration speed is about 8 km^{-1} year;

iii) there is a general „pushing out" of the coarse sediments from the upper parts of the drainage basins, where degradation is dominant toward the outlet from the mountains, where the aggradation phenomenon is half-present. The result is also obvious in the deformation of the longitudinal profiles in this area (Fig. 4). Such an estimation is necessary because the majority of the up to now investigations considered the relatively great thickness of the sediments in the drainage basins of these rivers either as an effect of neotectonic movements or of some climatic causes. The problem must creatively be analysed —

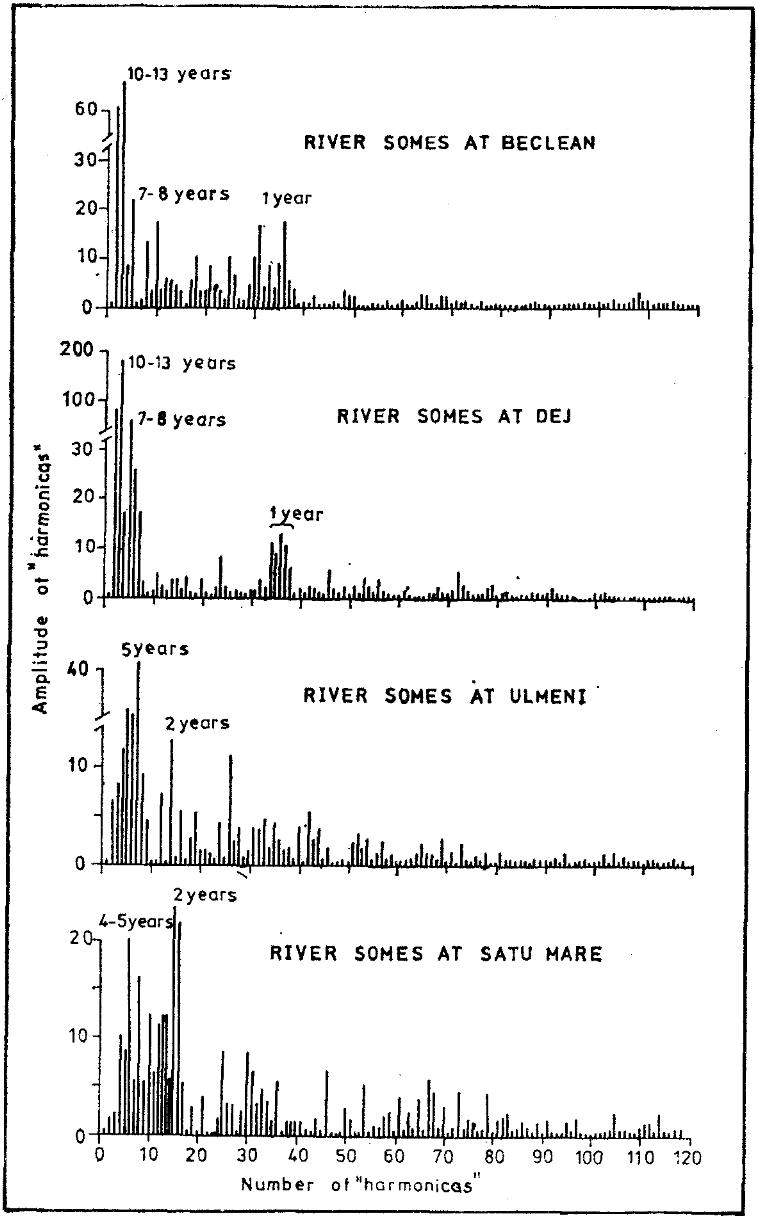

Fig. 5. The power spectrum of the river bed elevation along the Somes river
Ryc. 5. Spektrum wysokości dna koryta wzdłuż rzeki Somes

starting from the river bed deformation regime as an expression of the temporal differentiation of the evolutional trends along the river.

The periodical components of the series referring to the river bed elevation were determined by means of the spectral analysis. Finally, we obtained amplitude spectra for each cross section of the river bed studied. As examples we chose some graphs to illustrate the range of variations of the river bed deviation of the Somes river (Fig. 5). Cummulating the observations of all sections studied we may reach the following conclusions:

i) There are six „harmonicas" (10—13 years, 7—8 years, 4—5 years and 1 year) the presence of which was identified with different weights, but important at the river bed elevation.

ii) The „harmonica" of 7—8 years has the maximum weight, namely 38 per cent of the total of river bed sections examined; following is a „harmonica" of 4—5 years (in 27 per cent of the cases; Fig. 3 D).

iii) Using the spectral analysis also for analysing discharge variations in the same river bed sections we noticed the synchronism of the long-term flow oscillations and of river bed elevation (Figs 3C and 3D). But at the level of both temporal processes there is no longer the same weight of the „harmonicas". For example, the frequency of the „harmonica" of 7—8 years was greatest at the level of the river bed elevation, but it was lowest at the flow level. From the point of view of their amplitude, the composition of the aggradational-degradational waves (when compared to those of discharge) is also altered by the caliber of sediment, by river bank resistance and by some anthropic interventions.

iv) The behaviour of the amplitudes of „harmonicas" in the longitudinal river profile shows that oscillations of the river bed elevation vary probably with the size of the river bed material (Fig. 5). In the upstream sections the power spectrum gives evidence of a „harmonica" of 10—13 years. We think this situation may be due to the fact that in the river bed very coarse material predominates. Downstream the deposits become finer, and the greatest weight in the power spectrum is that of the short interval (5 years, 2—3 years).

THE AREAL DISTRIBUTION OF THE RIVER BED MOBILITY

Plentiful data on river bed behaviour which have been collected from a large area allow some general conclusions to be drawn. We prepared the illustrations to synthesize some of the noticed trends (Figs 2 and 4). The main attention was paid to the eastern side of the Eastern Carpathians, where there exist more river bed observations, and the drainage directions show a certain similitude. The most important conclusions are as follows:

i) The amplitudes of variations of the river bed elevation are also indirectly controlled by the presence of the great lithological groups forming the Eastern Carpathians. In the crystalline unit the longitudinal profiles show the greatest gradients, oscillations of the river bed level are below 50 cm, and degradation is dominant. In the river beds there occur numerous rapids and water falls. Thicknesses of the coarse gravels are reduced to 20—30 cm. In comparison with the other Carpathian regions sediment yield is very low there (less than 100 tonnes $km^{-2}yr^{-1}$).

ii) In the flysch mountain area river bed elevations oscillate from between 50 and 100 cm. The beds are uniform, and the bed sediments consisting of better rounded boulders and gravels are increasing in thickness. Sediment yield also increases up to 800 tonnes $km^{-2}yr^{-1}$. Although the slopes are steeper, the longitudinal profiles are less concave there.

iii) In the Subcarpathians and in the Carpathian foreland the amplitude of the vertical river bed fluctuations is greater, up to 2—3 m. In the Pericarpathian Piedmont the river beds with excessive sediment supply from the steep slopes show the greatest vertical and horizontal mobility which expresses itself in braiding. In the Subcarpathian area sediment yield reaches 2000—3000 tonnes $km^{-2}yr^{-1}$. These are the highest values noted in Romania. Sediment supply decreases to 800—1500 tonnes $km^{-2}yr^{-1}$ in the Pericarpathian area. Sedimentation in masses occurs at the Subcarpathian/Piedmont contact. The result, are rising longitudinal river profiles.

iv) In the confluence area of the Carpathian tributaries with the Siret river gradient reduction takes place. River channels tend to form meanders because both river beds and banks are mostly formed of sand. Consequently, the vertical mobility becomes reduced to less than 100 cm.

v) The great mobility of the river beds in the Carpathian foreland is responsible for the great thickness of the late Quaternary sediments under the actual thalwegs.

The geomorphological activity of the Carpathian tributaries had a marked influence upon the deformation of the longitudinal profile of the Siret river. This led to a „geomorphological paradox" (Ichim, Rădoane 1990) which is defined as follows: The Siret, a river situated beyond the Carpathians for the greater part of its length, is from the point of view of its facies, of its longitudinal profile and of its stream bed dynamics a Carpathian river along almost 85 per cent of its total length. This phenomenon is explained by the high sediment load of the Carpathian streams. When the Siret leaves the Piedmont area (in its lower course) the shape of the longitudinal profile retakes the character of a graded river.

Research Station „Stejarul"
Piatra Neamț 5600
Str. Alexandru cel Bun 6

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STRESZCZENIE

M. Rădoane, I. Ichim

WSPÓŁCZESNE KIERUNKI KSZTAŁTOWANIA DEN KORYT RZECZNYCH W KARPATACH WSCHODNICH

Badania zmierzały do ilościowej oceny dynamiki zmian den koryt rzecznych w Karpatach Wschodnich. W ciągu 11—30 lat dokonywano systematycznych pomiarów największych głębokości rzek w 73 przekrojach poprzecznych ich koryt. Na tej podstawie obliczono względną wysokość dna koryta rzecznego, którą określa różnica między poziomem wody w rzece a jej największą głębokością w danym interwale. Uwzględniono także stosunki geologiczne i morfoklimatyczne oraz warunki hydrologiczne, zwłaszcza przepływy rzeczne i transport zawiesiny. Wyniki pomiarów poddano wielostronnej analizie statystycznej.

Zróżnicowanie wskaźnika pionowej mobilności dna koryta nawiązuje do zróżnicowanej odporności przeważających skał podłoża w dorzeczu położonym powyżej przekroju pomiarowego. W obszarze krystalicznym koryta rzeczne są stabilne, a rozmiary degradacji niewielkie. Cechą koryt w górach fliszowych jest znaczna ich degradacja. Pionowa mobilność den koryt rzecznych (agradacja — degradacja) wzrasta w Subkarpatach i na przedpolu Karpat. Zastosowane funkcje polinomialne drugiego, trzeciego i czwartego stopnia ujawniły cykliczny rozwój dna koryta rzecznego, występowanie na przemian fal degradacyjnych i agradacyjnych, wędrujących w dół rzeki i nakładających się na ogólną tendencję rozwojową koryta. Dla przykładu, w korycie rzeki Trotus fale te przemieszczają się z prędkością 8 km/rok.