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TYOLOGY OF RIVER CHANNEL PROCESSES AND THE REGIONAL DIFFERENTIATION OF RIVER CHANNELS IN RUSSIA AND NEIGHBOURING COUNTRIES

Abstract: The typology of river channel processes is based on an analysis of those processes, defined as a combination of phenomena inherent in the interaction of flows and river beds; erosion, transportation and accumulation. It is shown that the river channel process types correspond to the distinguished river channels of mountain, semi-mountain, and flatland type of rivers. The morphodynamic classification also includes the geomorphologic channel types (broad floodplain, incised, and adapted), types of large river channel forms, morphodynamic types of river channels themselves, the hierarchy of river channel forms and the types of relief, which shapes the corresponding classification blocks. Consideration is given to the peculiarities in the distribution of rivers with different types of river channel processes, and the geomorphologic and morphodynamic types of river channels in Russia and neighbouring countries. Connections are shown between these peculiarities and the free and restricted conditions of river channel deformation development, river channel-forming discharges, etc.

Key words: channel typology, Russia.

The mechanisms and nature of the interaction between the flow, the river bed and the kinds of sediment transport, which represent the intrinsic features of river channel processes, vary widely. They depend on the water discharges, regime properties, flow kinematics, channel gradient, particle size and river channel forming sediment loads. As a result, there is a diverse range of conditions that form river channels and types of river channel processes, as shown in the morphological types of river channels, the complexity of their morphology and the different deformation regimes under different combinations of natural (and, nowadays, anthropogenic as well) conditions in different regions. But, due to the law of the limited number of morphological complexes (Velikanov 1958), the „mutual control of the flow and the river channel leads, as a result of deformation processes, to a certain probable combination of morphometric river channel characteristics and hydraulic performance of the flow”, and as a result: „...nature permits the appearance of only a limited quantity

of relatively stable river channel forms out of an infinite number of possible variations; thus allowing a classification of the natural river channel complexes” (Velikanov 1948). According to N.I. Makkaveev (1976), the limited character of morphological complexes and the relative stability of the river channel forms that result from the interaction process, are due to the latter being derived from the influence of the surface flow, stimuli, phenomena and processes within the flow, which enable their renewal, i. e. which define the formation of a certain kinematic flow structure. Thus, the flow velocity facilitates a conservation and even increase in the bend curvature and creation of islands in the channel bends and forks; the same is typical for the straight, non-forked channels (Makkaveev, Chalov 1986). Alongside, we can see variations in channel forms corresponding to different stages of their development. Therefore, a river channel classification should be based not just on the shape, but on the aggregation of the possible landform changes of channels from their origin to extinction, i. e. it must take into account both their morphological and dynamic characteristics. Since the morphological (based on the external features) channel classification must be dynamic, any cell in the classification scheme, being named as morphological, must correspond to a certain pattern of channel deformation. Similarly, if such a cell is described in dynamic terms, it means a certain morphological channel type: the tortuous channel and meandering of the channel, the forked channel and branching of the channel. Such a classification is termed a morphodynamic one, and its elements represent the morphodynamic channel types.

Types of channel processes were classified as either flatland, semi-mountain or mountain, depending on the slope gradient and flow velocity, kinetics (still or rapid), the quantity and size of particles, different forms of sediment transportation (with or without accumulation bars), and mechanisms of flow-channel interaction. In mountain rivers the mechanism of channel processes is characterised by the rapid flow, wave character of floods, high slope gradient, and, in many cases, by a compatibility of channel depth and the size of pebble-boulder and boulder-clod composition of the channel forming sediments. The great range of stream gradients (from dozens to hundreds pro mille) makes it possible to characterise mountain rivers by process type as those with rapids and falls, with non-developed (without bars) and developed (with bars) alluvial forms (Tab. 1).

River channels with rapids and falls are characterised by a tangential gravitational component in the sediment transport, enabling a sharp increase in the shifting capacity of the largest fragments with the minimum required force. Under the wave character of floods, the shifting of separate, loose fragments is easy due to the impact-effect of the waves. As a result, even small mountain rivers with high gradients can move large pieces of rock. The washing out of fine material from beneath the boulders (abluvial effect) additionally facilitates this movement.

River channels with under-developed alluvial forms and bottom sediment dragging across the whole channel width feature flat and relatively shallow cross-sections. In the wider parts they are braided due to active mudflow. The mechanism of coarse load movement and channel deformation is similar to that of the rapids/falls type of channels, but less efficient, as the „micro-rapids” formed by outcrops of large

Tab. 1. Types of channel processes and slope ranges during their development (Khakimov, Chalov 1993).

| Type of channel processes | Slope ranges [‰] of rivers with basin area [km ²] | | | |
|---|---|----------|--------|---------|
| | > 1000 | 1000-100 | 100-10 | < 10 |
| Flatland | < 0.6 | < 0.8 | < 6-7 | < 14-15 |
| Semi-mountain | 0.2-7 | 0.5-7 | 6-25 | 15-40 |
| Mountain with developed alluvial forms (bars) | 1.5-14 | 5-17 | 7-30 | 15-80 |
| Mountain with developed alluvial forms (without bars) | 3.5-20 | 7-40 | 18-70 | 25-125 |
| Mountain: rapids/falls | > 10 | > 20 | > 25 | > 40 |

boulders and clods are rather small in comparison to the depth and width of the water flow. The ratio between the dimensions of separate boulders and the flow depth is an important factor in the channel development. Therefore, the hydrostatic impact on boulders increases here in significance (Makkaveev 1973). The movement of coarse fragments can be observed during the „sharp” flood peaks. The shifting of each larger fragment is accompanied by a mass of smaller particles accumulated either behind or beneath. As a result, the flow turbidity is one to two orders of magnitude higher than during the gradual water-level increase. This phenomenon enhances the transporting ability of the flow with respect to coarse loads.

Symmetric accumulative bars represent characteristic forms of mountain river channels with well-developed alluvial forms. They occupy the stream bends, with their crests running practically parallel to the concave bank line with the still deep pools, where the channel turns almost 90°. Hence, the mountain-flow velocity decreases, and a zone of stable load accumulation appears. Such crossovers at mountain rivers during the low-water period are characterised by a narrow constant torrent flow. In its lower reach, the pool with still-flow during the low-flow period is formed, and the channel grows wider. The semi-mountain type of river is common in the foothills, as well as in mountain and mid-mountain basins. The corresponding type of channel process predominates in the large rivers of the middle and high mountains of Eastern Siberia. Possessing the small size particles in the channel-forming sediments, it can be of a limited distribution, being developed along the orographic boundary between mountains and plains. Depending on the geomorphologic conditions, the semi-mountain river type features a channel regime similar to that of the mountain type (with developed alluvial forms), and to flatland type of rivers in the foothills.

The specific conditions of pebble-boulder load transport are characteristic of the rivers corresponding in slope gradients to mountain rivers with alluvial channels, and to semi-mountain rivers with narrow channels. In this case the channel cross-section is not large enough for the discharge, especially during flood periods. The flow velocity increases up to 5-6 ms⁻¹ (momentary peaks up to 8-9 ms⁻¹) due to the low channel roughness; i.e. the channel bottom consists of bedrock such as granite, gneiss, diabase,

etc., smoothed-out by the flow. The considerable increase in velocity along with constant longitudinal slopes leads to the complete removal of coarse sediments from this rocky portion of a channel and moulds it into the shape of a rocky flume. These channel reaches range from 1 to 70 km in length. They are typical of the large rivers of Western Tian-Shan (Pskem, Chatkal, Akbulak) and the Altai (Katun) mountains, with slope gradients ranging between 1.5 and 30‰, thus comprising the entire range of conditions of the mountain channel development characteristic of all types of mountain river channels.

A change in the channel process factors and the resulting change in the form of action occur along the mountain rivers. Rivers with a developed longitudinal profile and a gradual decrease in slope gradient downstream experience a regular change of types due to the corresponding long-profile gradient intervals and the cross section of large valleys. As a result, a vertical zonality occurs in respect to the distribution of mountain river channels: uplands are characterised by the zone of rapids/falls channel type, medium height mountains by mountain channels with non-developed alluvial forms, and low mountains by mountain channels with developed alluvial forms.

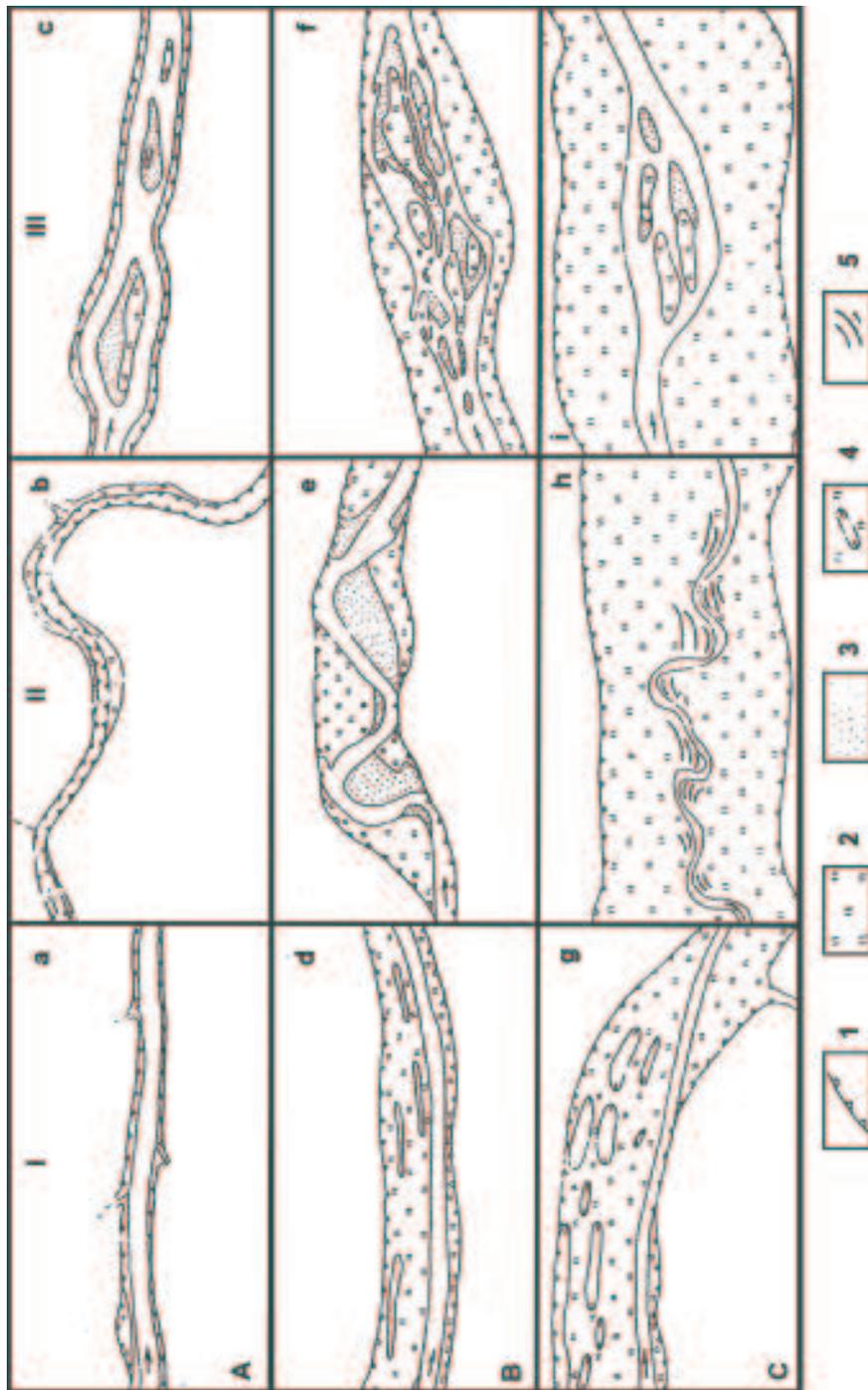
The flatland type rivers, with subcritical flow, represent the most widely spread class of a river channel. Due to the low gradient, transportation of sediments assumes the form of movement of asymmetric sandbars. At the same time, there exist flatland rivers with increased coarseness of sediments (pebbles, boulders). The large rivers of Eastern Siberia (Aldan in the middle and upper course, Vitim in the lower course, Lena in the upper and partially middle course, etc) represent this type. They dissect the areas of mountain rivers, and are formed within the low and middle mountain relief.

Each type of river channel process develops within a certain range of the slope gradient (see Tab. 1). The absolute value of the gradient range depends on a river's water capacity: the lesser the yield (and, correspondingly, the lesser the catchment area), the larger the slope gradients characteristic of the subcritical flow velocity. And, vice versa, the increase in stream velocity, due - for instance - to its narrowing, increases the critical slope; the increased coarseness of sediments leads to a corresponding critical slope increase. Thus, with the same slope, different types of channels are formed.

With such an approach to river channel typology, the meandering, braiding, as well as the relatively straight, non-braided channels represent the various kinds of channel processes and their corresponding morphodynamic channel types. Hence, the following types of channels may be distinguished (Fig. 1.): 1) channels with broad floodplains, corresponding to free development of channel deformation; 2) incised

Fig. 1. Morphodynamic channel types under different geological and geomorphologic conditions of channel deformation:

A - incised, B - with broad floodplains; I - relatively straight, non-braided; II - tortuous (meandering); III - branched into arms; a - river Yug at Vasilievo village; b - river Ponoj at the mouth of the river Lopeniarka; c - river Sukhona at the town of Totma; d - river Don at Kuliashovka settlement; e - river Gauia at the town of Tsesis; f - river Northern Dvina up to the mouth of the river Vaga; g - river Oka at the town of Shurovo; h - river Zhizgra at the Pavlovo settlement; i - river Pechora at the Velikanovysochnyi settlement. 1 - valley banks; 2 - floodplains; 3 - large shoals, dry during low-flow period; 4 - lakes at the floodplains; 5 - mane relief at floodplains (ridge and swale topography).



channels (without floodplains), corresponding to restricted development of channel deformation (the latter comprises two varieties due to a different lithology, namely: (a) crystalline rocks, (b) plastic rocks; and 3) adapted channels which develop in narrow valleys - the intermediate type between the incised and the broad flood plain channels.

As a whole, the morphodynamic classification can be presented as a system of blocks (Fig. 2), each of them corresponding to the level of development of channel processes and forms; the channel processes of the preceding block create the environment for the channel forming the next block. Block 1 consists of the types of channel processes that correspond to the mountain, semi-mountain, and flatland river types. Here, a rather thorough analysis is made for channel processes in mountain rivers. As far as the flatland type rivers are concerned, this problem practically did not appear, with the exception of the identification of channel processes with channel deformation, and, subsequently, their varieties, as in the papers of the State Hydrological Institute (Kondratiev et al 1982). As the first approximation, the following channel process typology of the flatland rivers can be proposed: channel processes in small rivers (perhaps due to the streams of the first order - creeks); channel processes in medium size and large rivers (with delimitation of sand, pebble-boulder, and rocky ones); and channel processes at the mouth bars. The first type is characterised by a parabolic cross-section with low values of the channel width/depth ratio (b_p/H_p) and a rapid change from the first unit to dozens of units up to the rivers of 9 -11 orders in humid areas (Rzhanitsyn 1985). In medium and large rivers this ratio becomes practically constant (from about 100 upwards); the channels at the straight reaches are flattened, with a tapered shape and very small sides. Such differences in the cross-sections and in the ratio (b_p/H_p) define different conditions for the movement of the water mass, kinematic structure of the flow, and, correspondingly, its interaction with the bottom and banks of a river. The specificity of channel processes at the mouth bars is the broad flow and the direct influence of sea factors.

Block 2 of the classification includes 'geomorphologic' channel types - with broad floodplains, adapted and incised, which are delimited on the basis of the geological and geomorphologic factors of channel processes. Each of them has a certain ratio of a channel width (b_p) and floodplain width (B_f). N.I. Makkaveev (1955) interpreted this ratio as an indirect index of the predomination of the depth erosion (incision) (B_f/b_p), or lateral erosion (horizontal channel deformation) ($B_f > 2-3b_p$). Incision occurs when the sediment runoff is less than the transporting capacity, i.e. the deficit of loads is observed, and the flow energy is spent on the channel bottom erosion. Another aspect is that sediment deficit does not enable the development of bar forms of channel relief, and, hence, decreases horizontal deformation, i.e. valley bottom widening. As a result, the greater the sediment deficit, the more intensive the incision, the narrower the valley bottom, and the higher the probability for forming an incised channel without a floodplain. This regularity is clearly seen under conditions of the restricted development of channel deformation.

If there is no deficit of sediments (sediment runoff corresponds to the carrying capacity of the flow), or in the case of their excess (i.e. the directed sediment accumulation is observed), different bar relief forms develop (side bars, median bars

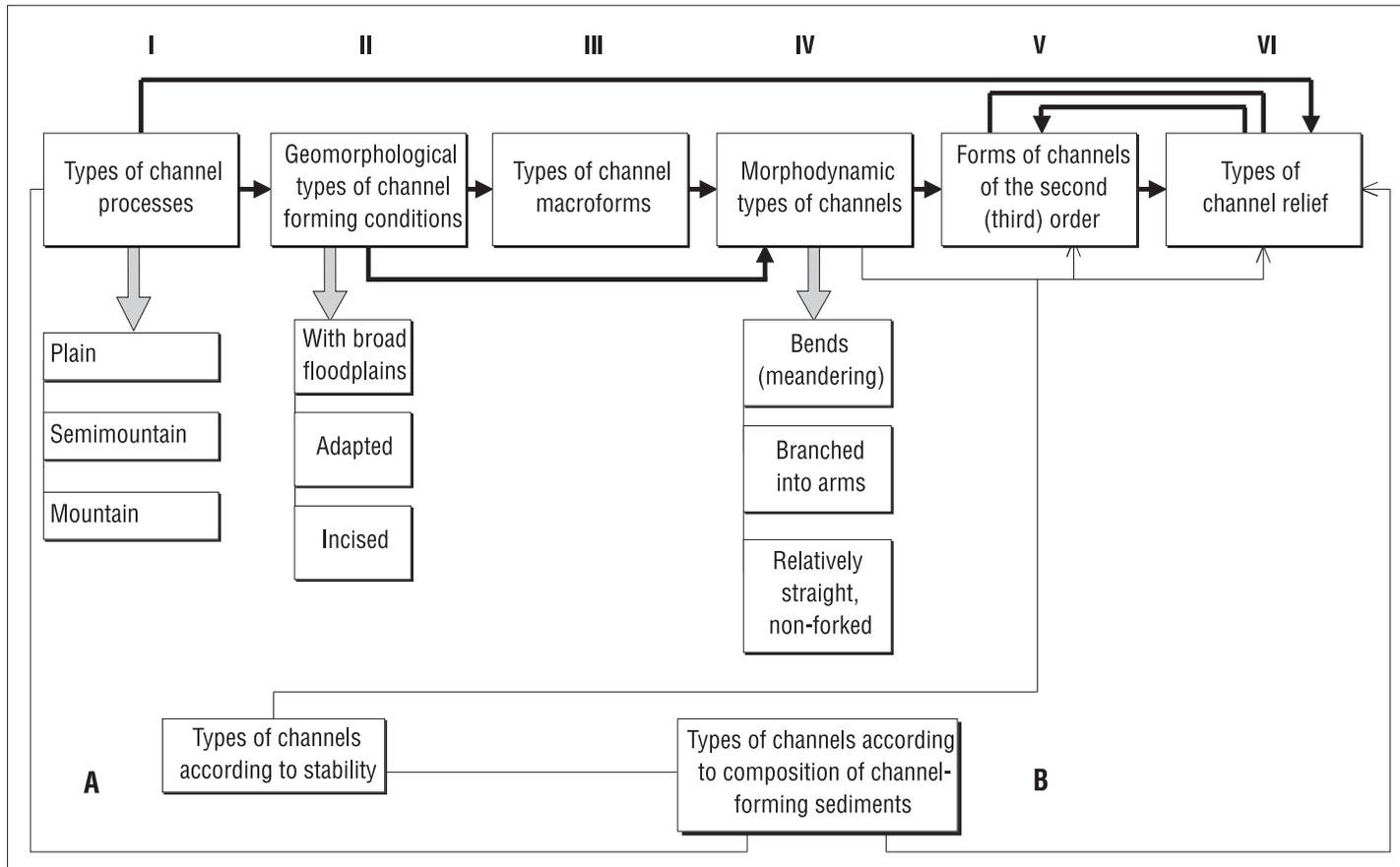


Fig. 2. Structure of the morphodynamic classification of river channels.

and spits), thus enabling a channel to wander and form a channel with a broad floodplain. It is seen most clearly under the conditions of free development of channel deformation, when the flow easily erodes loose sediments.

Adapted channels (where sediment deficit is small, and/or the quantity of sediments is insufficient to create large alluvium accumulations, $bp < Bf < 2-3 bp$), are to be found most often in either (1) boundary geomorphologic areas - such as Viliui river between Middle Siberian Plateau and Yakutian Lowland, River Dniepr below the town of Dubossary, where the river runs across the slopes of Volyn-Podolsk Heights and enters the Black Sea Lowlands; or (2) in valleys following linear morphostructures, where their narrow beds are confined by steep, rocky banking slopes, which limit the possible magnitude of lateral deformation.

Block 3 of the classification includes the channel microforms which although not directly connected with horizontal channel deformation, exceed the upper limit values of channel forms for contemporary water discharges, runoff, and sediment particles sizes, but, nevertheless, influence their development. This block has not been studied sufficiently, and is not rendered in detail on the classification chart. A.V. Panin (1991) suggested approaching the classification of macrobends in a similar way as for geomorphologic types, defining them as free, adapted (with one bedrock bank) and incised macrobends. They owe their development to the appearance of dynamic phenomena in their summits. These phenomena are characteristic of the bend of a flow, shift of the channel to the concave bank according to the regularities of development of channels with one-side floodplains, and accumulation of morphological changes under the influence of floods. Macrobends in channels with broad floodplains (free) are considered to be relic formations, i.e. bends of a river meander belt, revealed during their development in both the historical and geological periods through the consequent accumulation of morphological changes (e.g. the addition or subtraction of centrifugal forces at the normal bends and at the bends of a meander belt depending on the signs of bending).

The incised macroforks appeared due to the presence of high bedrock islands and are comparable in dimensions to microbends (for example, at Angara River). The braided floodplain serves as a counterpart to bends of meander belts at broad floodplains. The absence of one or other (when the flood plain is a single consolidated form) provides evidence concerning the existence of a straight broad floodplain channel form.

Block 4 is represented by morphodynamic types of channels: bends (meandering), braided (channel multiforks, branched into arms), relatively straight, non-braided channels covering all possible varieties. Each of them can develop on the background of certain macroforms, and can be a broad floodplain (the terms free bends, or free meanders are widely used to define bends), adapted (correspondingly -forced, adapted or inscribed bends), or incised (in the case of bends - incised bends). Mountain and flatland types of rivers are characterised by peculiarities in the development of morphodynamic channel types. Thus, free meandering is not characteristic to a mountain or semi-mountain river, which (when they have broad floodplains) are predominantly occupied by braided channels of the most intricate form. The highest

diversity of channel forms can be observed in flatland rivers under the conditions of free development of channel deformation, where they are of a broad floodplain character.

Each morphodynamic channel type is presented by different modifications (subtypes). In the classification chart, for the flatland rivers (Fig. 3.), these modifications (subtypes) are aligned to free, adapted or restricted conditions of channel deformation development, because the latter define to a considerable degree, the possibility of the development of different forms of bends, forks, or straight non-braided channels. Their substantiation and corresponding characteristics are specifically considered in the works of N.I. Makkaveev, R.S. Chalov (1986), R.S. Chalov (1987) and, with some supplements and amendments in V.P. Bukreev (1987) and A.E. Makhinov et al (1994). Among the broad floodplain braided channels the chart includes the cell called „scattered channels”. This subtype comprises a large group of channels whose morphology and dynamics have hardly been researched at all. This cell serves as a basis for further definition of new channel subtypes.

Morphodynamic classifications for mountain and semi-mountain rivers must be constructed in the same way. In this case specific channel types will appear, such as rocky and mudflow or new types of forks, etc. But, nowadays, alongside a rather thorough typology of channel processes and transportation of channel-forming alluvium at mountain rivers, evidence of their channel morphology and especially observations on the regularities of their reconstruction, are scarce and scattered.

Block 5 of the classification includes the forms of channels of the second and third orders; complex bends, forks, or relatively straight, non-forked channels. The lesser the stability of a channel and the larger the sediment runoff and the quantity of channel-forming discharges (Q_f), the more probable the development of forms enclosed in each other, including those, which developed during different phases of a hydrological regime (Chalov 1983). For example, in the rivers with free meandering channels, as Q_f changes by just one interval there appear bends of the simplest form, when the dynamic axis of the flow reflects generally the shape of the bend. If a river experiences the passing of two or three intervals, the hierarchy of bends develops: complicated bends consisting of several adjacent bends with less steps and less curvature, which, in their turn are complicated by bends with the dynamic flow axis and by rounding the side bars of shoals. In a braided channel the arms can meander, and the regular consequence of bends appears, developed within the braided channel: intricate bends, corresponding to main arms; bends of the second order forming the channel of each arm; bends of a flow dynamic axis. The division of arms by small islands is most common. Islands may form a chain, forming a linked system of forks of the second order. Each arm of the second order may in turn be subdivided into streams of the third order by a small island. Thus, a hierarchy of forks occurs, and in each order corresponds to a certain interval of Q_f .

In regions characterised by the restricted development of channel deformation, where wandering of channels is limited by river banks and bottoms formed in resistant rock, and where channel forming sediment runoff is rather low, channels evolve into

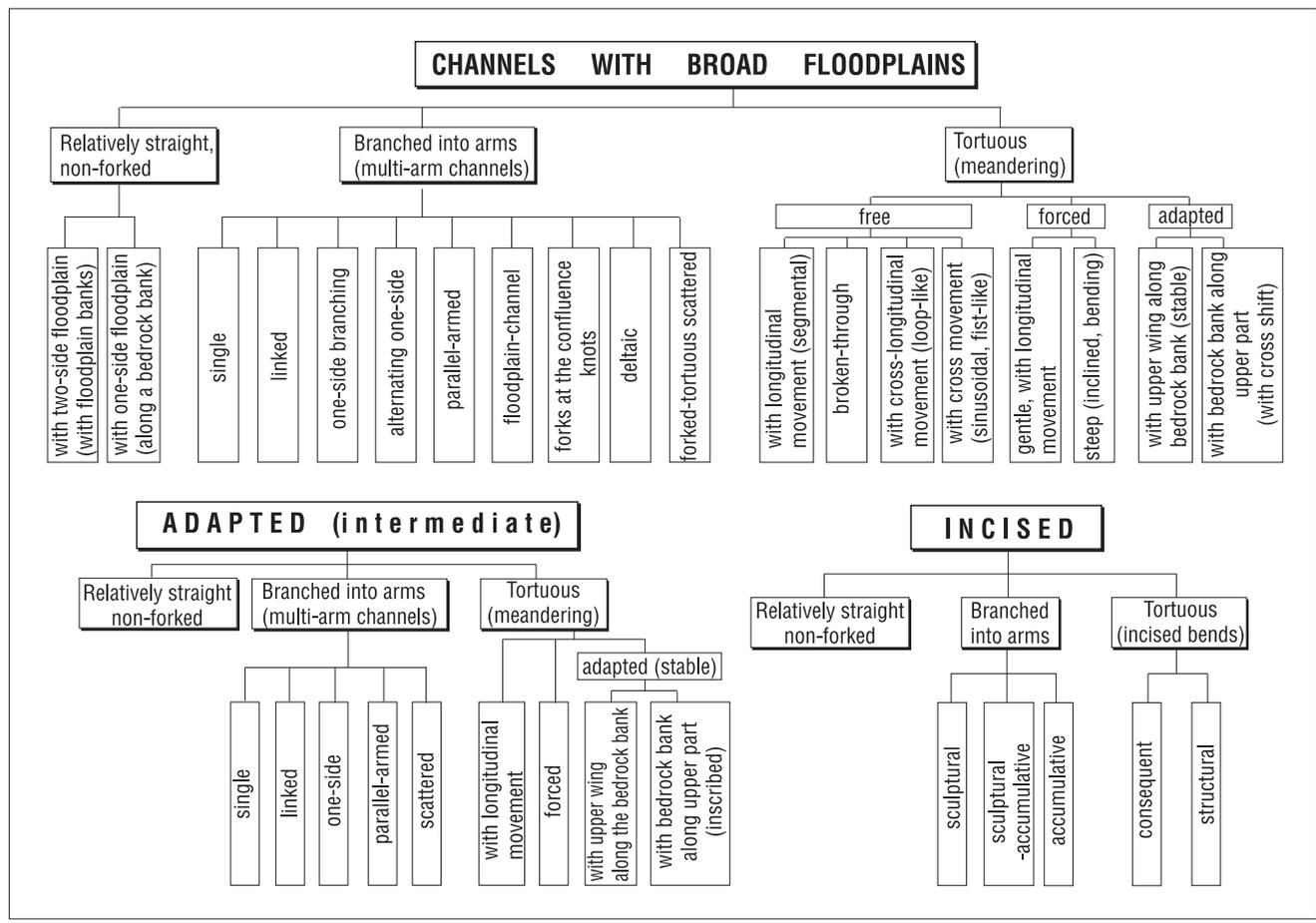


Fig. 3. Morphodynamic channel types of plain rivers and their varieties (block IV in classification, Fig. 2).

the incised types with a minimum set of features. The latter are rarely of the channel origin, being connected rather with the geological structures or reflecting the geological history of the river valley development.

Block 6 of the classification is composed of the channel forms and channel deformation connected with the ridge type of sediment transport, or in other words, sculptural ones, with the unevenness of a river bed. The morphodynamic types of small river channels are related here, if they are silted and covered with vegetation - reed-covered flats, etc.

The additional (parallel) blocks classify channels according to (A) their degree of stability, providing an integrated assessment of the reforming intensity (in relation to ranks of Lokhtin's number of channel stability coefficient, by N.I. Makkaveev), and (B) by the composition of channel forming sediments, defining differences in the morphology and dynamics of sand-silt, sand, and pebble-boulder channels. The first of them influences the development of channels of the fourth, fifth, and sixth blocks of the morphodynamic classification. The second one represents one of the most important conditions governing the type of channel processes namely channel stability, and at the same time the ridge structure of the channel relief.

Channel types have been determined for all the rivers in Russia and the neighbouring countries (within the former USSR) longer than 500 km (measured along the axis of the valley bottom), in accordance with blocks 1, 2, and 4. Channel forming discharges (number) and the different geological/geomorphologic conditions of channel formation were taken into account (Matveev et al 1987). The mountain, semi-mountain, and flatland type of river channels occupy 3.9%, 21.6% and 74.5% respectively and cover 25%, 26% and 49% of the total area. The difference between the corresponding square area and length stems from the predominance of mountain rivers shorter than 500 km. Mountain and semi-mountain river channels are found mainly in the mountain and foothill relief areas, and, as a rule, have restricted development conditions for channel deformation (84% of mountain and 62% of semi-mountain rivers in length). Mountain rivers did not develop in the areas with free conditions of channel deformation development, but semi-mountain rivers constitute more than 4% of the total river length (foothills, upper reaches of rivers originating in uplands).

The prevailing type of flatland rivers is that featuring broad floodplains; they occupy approximately 65% of the total river length (Tab. 2.), and in excess of 92% in the areas of free development of channel deformation (lowlands of the European part, Western Siberia, Central Yakutia, etc.). Only 4.1% of the flatland rivers feature incised channels over the positive structures (Viatski Val, at the river Viatka, Liulimvor Heights, at the North Sosva River, Priirtyshskoe, at the Irtysh River). The remaining part (3.6%) belongs to the adapted channels (mainly forced and adapted bends), seldom predominant, but encountered at separate locations on rivers. The only exception is the area of the Pre-Salair Heights in the Altai Mountains (river Chumysh with tributaries), where rivers of the Salair Ridge form adapted channels.

Under the conditions of restricted development of channel deformation (uplands of the European part of the former USSR, Middle-Siberian Plateau, mountain regions), 9.7% of channels are mountain type, 39.6% are semi-mountain type, and more than

Tab. 2. Distribution of channel types of flatland rivers due to the development conditions of channel deformation (% of river length in regions).

| Geomorphologic types of channel | For the whole territory | Conditions of channel deformation development [%] | | |
|---------------------------------|-------------------------|---|------------|--------------|
| | | free | restricted | transitional |
| Incised | 30.6 | 4.1 | 74.8 | 44.6 |
| With broad floodplains | 64.8 | 92.3 | 20.9 | 47.3 |
| Adapted | 4.8 | 3.6 | 4.3 | 8.1 |

50% - flatland type (lengthways). Of the latter type, 75% have incised channels, and 25% have broad floodplains or adapted channels. They are located in mountain depressions, fault zones, etc.

Under the alternation of conditions of channel deformation development in plastic and crystalline rocks, the portions of rivers with broad floodplains and incised channels are approximately the same. At the same time, the areas composed by crystalline rocks have mountain rivers although they are absent in the areas with plastic rocks. These areas are characterised by the occurrence of the semi-mountain type of rivers (17.0% of the total river length), which can be explained by lesser erodibility of crystalline rocks as compared with clay loams and clays. In the areas with a wide distribution of succeeded river valleys (Eastern Siberia, and the north-east), the large slope gradient provides an opportunity for the development of semi-mountain type of braided channels with broad floodplains (about 70% of the river length). Incised flatland rivers (about 4%) form on large intrusions and massifs experiencing constant uplifting neo-tectonic movement (Upper Kolyma). The upper reaches and tributaries of rivers belong to the mountain type (total more than 8%).

Within the distribution of morphodynamic types of both incised channels and those with broad floodplains, bends predominate, and among the free types - segment- and loop-like bends. The proportion of non-braided and weakly braided (single and one-sided forks) channels is higher than braided channels. Among the broad-floodplain channels more than 77% of are of the meandering type, more than 14% of the non-braided type (relatively straight, with single and one-sided forks), and more than 8% are braided (simple and complicated linked forks), scattered channels. Incised rivers have a different channel type breakdown: straight - 30%, meandering - 58%, and forked - 12%. The proportion of the latter seems to be higher because the „transitional” channel types are related to meandering (braided-meandering) or to straight (with single or one-sided forks). Taking into account the above, as well as the lack of information on small rivers, we consider the proportion of forked rivers to be 1.5-2 times higher, i.e. about 30%. In this case the floodplain multi-arm character is not considered, i.e. forking of long arm, dissecting the floodplains (Akhtuba at the Volga River, Little Ob in the low reaches of the Ob River, Polois in northern rivers).

Under the conditions of free development of channel deformation, there are few forced and adapted bends. Within the areas of restricted development of deformation,

the proportion of braided channels is increased relatively (incised by more than 14%, with broad floodplains by more than 13%). It can be explained by the high slope gradient variability of the rivers as they enter the foothill areas, the formation of islands in a local channel widening, and sediment accumulation at crystalline outcrops. Ground ice is an additional factor that promotes channel braiding in the mountain regions of Siberia and the Far East. The proportion of braided channels is high in broad consequent valleys. Due to the above factors, the proportion of the breached bends exceeds here the proportion of loop- and segment-like bends by 2.5 to 3 times, although the overall numbers for the country show a reverse ratio.

The small proportion of channels with a predomination of adapted and forced bends is observed as the channel forming conditions change. These channel types represent the transition from incised meandering to freely meandering forms (rivers Dniestr, Viliui, Mezen, Low Tunguska, Chumysh). Under alternating conditions of channel deformation development, the greatest rivers have broad floodplains (Northern Dvina, Pechora), while the lesser rivers (in terms of water discharge) feature incised channels (Onega, Daugava). Small rivers of this region often „slide” over the surface of resistant rocks, forming channels with broad floodplains on sediment rocks (rivers at moraine plains of the European Part of the studied area and trap plateaux in Central Siberia). If floodplains of small and medium-size rivers have vast forest coverage, the straightening of a bend is hardly possible, and loop-like bends of small curvature radius predominate (Tiung, Markha, Vasiugan, and Konda rivers). Breached bends are characteristic of rivers with greater discharges (Viliui, Irtysh rivers).

Some peculiarities of channel morphology and deformation are related to the conditions in which channel forming discharges occur. Their largest extent occurs under the conditions of free development of channel deformation, due to the development of breaches in river bends and multi-channel streams at floodplains. The occurrence of Qf of the upper interval above the floodplain rim promotes the straightening of segment bends and their further conservation alongside the new straightened channel of a floodplain stream. Within the Russian Plain, the proportion of channels with bend breaches among the freely meandering is 21%; while where Qf pass within the floodplain rims (rivers in the strip along the main water divide), their proportion is less than 4%. The same characteristic for Western Siberia totals 17% (northern half), and 10% (southern half) respectively. At the North Siberian and Central Yakutian lowlands, where Qf occurs on the inundated floodplain, it increases up to 20%.

About 20% of rivers have braided floodplains. They flow through areas with free development of channel deformation and alternation of conditions, with consequent valleys (Tab. 3.); 81% of them are related to rivers with channel forming discharges occurring at inundated floodplains.

Shorter rivers (up to 50 km), under the conditions of free development of channel deformation development have mainly meandering channels, with the formation of loop-like bends with a small radius of curvature. Complex combinations of morphodynamic channel types occur in small rivers under alternation of free and restricted conditions of channel deformation development and in rivers with adapted channels. Regions of intensive economic development are characterised by the

Tab. 3. Distribution of river reaches with multi-arm floodplains (% of river lengths).

| Geomorphologic conditions of channel deformation | Conditions of channel forming discharges [Qf] occurrence | |
|--|--|------------------------|
| | at inundated floodplains | within floodplain rims |
| Free | 50.2 | 4.8 |
| Restricted | 1.8 | 5.9 |
| Alternation of conditions | | |
| in plastic rocks | 3.0 | 0.7 |
| in crystalline rocks | 2.8 | 1.1 |
| wide distribution of consequent valleys | 23.2 | 6.5 |

transformation of the natural channel forms due to silting, vegetation growth, and degradation. To the South of the Russian Plain and in Western Siberia, numerous rivers of the first order disappeared due to impact of anthropogenic factors. The total decrease in the length of the river network ranges from 3.5 to 30% (Kovalchuk, Shtoiiko 1983). In the South, small rivers either experienced slight changes, or remain in their natural state (with the exception of urbanised and industrially developed areas and extended forest cutting areas). Small rivers of the southern part of the forest zone and the northern part of the steppe zone occupy the intermediate position: their channels are characterised by the process of shallowing, due to the increased influx of eroded material from watersheds, and by the conservation of the morphodynamic channel types.

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