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A.V. Chernov
M.V. Lomonosov Moscow State University, e-mail: Alexey.chernov@inbox.ru

Morphological features of river channels and floodplains in the Far East of Russia under various natural conditions

Abstract: Geographical analysis of river channel processes in rivers located along the meridional transect, running from the Arctic Ocean coast to Tibet and the East China Sea, confirmed that fluvial processes dominate in the formation of morphology and dynamics of river channels and floodplains in all natural zones and under different conditions of channel deformation development. However, even a small disturbance in "climate" conditions by other exogenous geomorphological processes changes the morphology and dynamics of channels and floodplains as well as the dynamics of fluvial processes. The effect of zonal factors depends on the size of a given river and is more pronounced in medium and small rivers than the large ones. Furthermore, the effect of zonal factors on the processes of river channels and floodplains depends on specific environmental conditions of the climate zones: the more extreme the manifestation of certain climatic phenomena, the more pronounced they are in the morphology and dynamics of river channels and floodplains.

Keywords: riverbeds, floodplains, climatic factors of channel processes, local factors of fluvial processes

1. Introduction

Morphology and dynamics of river channels and floodplains are determined by hydraulic characteristics of the water flow and lithology of the rocks in which the river valleys have developed (Chalov, 2011). With no lithological restrictions by the slopes and bottom of the valley, both deep and lateral erosion develops actively, forming wide river channels. Accumulation and erosion processes that shaped the river banks occur with no external constraints and are accompanied by river meandering and braiding, new sections of floodplains are formed and old floodplains are eroded. River channel deformations are determined by hydrological characteristics, mainly the water flow and sediment runoff.

In the valleys that are formed in rocks or clayey rocks, on the other hand, there is almost no lateral erosion, while valleys and riverbeds have no floodplains and are embedded in bedrock. Thus, the factors that determine channel processes are azonal, like lithology, and intrazonal, like river runoff. Therefore, channel processes should also be azonal, and the effect of zonal non-alluvial exogenous processes on the formation of riverbeds should be minimal.

However, the results of the research on the nature of channel processes within the transect that runs through the eastern part of Eurasia from the Arctic Ocean coast to the shores of the East China Sea have shown that this is not the case. Furthermore, the smaller the river runoff, the more strongly it is affected by local (not related to a climate zone) factors.

2. Results and discussion

In the subarctic zone, located on the shores of the East Siberian Sea and the Chukchi Sea, all floodplains and part of the channel deposits are associated with permafrost. This situation determines the erosion of floodplain banks. Frozen layers can be destroyed by thawing,

which is faster when a water stream affects the bank, i.e. on concave banks of river meanders. The thawed soil is saturated with water and collapses into the river channel, facilitating the erosion of the bank. The rate of erosion on concave banks of meanders is faster, and therefore the river channel is wider within meanders compared to non-meandering sections. Such extensions of river channels have a common erosion and thermokarst origin. This is particularly evident in small and medium-sized rivers – the upper Vilyuy and its tributaries, the upper Olenyok, the Sal, the Morkoka, the Muna, the Molodo, the rivers of Yana-Indigirka and Kolyma lowlands. In the plan view, their riverbeds are bead-shaped, where rounded extensions alternate with narrow-flow sections of a channel. In rivers with higher runoff, the effect of thermal bank erosion is visible only within meanders, whereas in such large rivers as the Olenyok, the Anabar (downstream), the Yana, the Indgirka, and the Kolyma, its impact is not observed even in meanders. Floodplains of rivers in the subarctic zone are covered with a network of frozen polygons, forming polygonal microrelief and contributing to land inundation (Chernov, 2009).

Most rivers in Russia and China, rivers of the Amur basin, the middle reaches of the Selenga river and its tributaries are located in the temperate zone. Channel processes in this zone are under the minimum influence of the zonal non-fluvial factors. On small and medium-sized rivers in the taiga, characterized by wide bottom of valleys, the river flow may be locally blocked by trunks of fallen trees. In deeply incised valleys, the river channel processes may be affected by landslide and talus processes on the slopes, but they are not zonal and depend on the depth of incision and the composition of rocks in the valley.

Rivers in the south form their valleys, channels and floodplains in the subtropical zone, which is characterized by semiarid and arid climate in most of the China and Mongolia territories. However, in the eastern provinces of China, the monsoon climate is typical of the subtropical zone. These zonal climatic features are evident in the morphology and dynamics of small and medium-sized river channels.

The second most important factor affecting the river channel processes in semiarid and arid conditions of subtropics are aeolian processes. They occur in semi-deserts and deserts, where migrating sands are widespread, e.g. crescent-shaped and pyramidal sand dunes, barchans and sand ridges. While moving in accordance with the prevailing wind directions (northern in winter and southern in summer), these sand formations reach river valleys and successively cover higher terraces, the bottom of valleys and river channels. Further development of the processes of interactions between the water flow and the sand masses can proceed under different scenarios.

The Tarim river, located in the Taklamakan desert, is fed in its middle reaches by the tributaries flowing from the southern slopes of the Tian Shan – the Khalygtau, Sarmik-Ula, Chyoltag, Kururtag mountain ridges. All of them are left-bank tributaries of the Tarim, while the Taklamakan desert is located to the right (further south). The sand coming from this desert fill the right-bank part of the valley, including the river channel. Then the river develops a new channel, displaced relative to the previous one to the north, towards the foothills of the above-mentioned ridges. The old river channel is filled with sand, but its position is well visible as a meandering dry paleochannel. As a result, a dense network of dry meandering paleochannels can be observed in the bottom of the Tarim valley in the right-bank part of the valley and waterlogged meandering channels in the left-bank part. The width of the entire valley bottom is about 50 km and the width of the river channel located in its central part – 80 m.

In the lower reaches of the Tarim River, where its valley moves further away from the above-mentioned mountain ridges, the process of the floodplain and riverbed filling with sand is activated in the meridional reaches of the river, while small strips of sand may migrate along the river, because the floodplain is almost devoid of vegetation. The water flow along the river channel is not visible in the winter period. In such sand-buried fragments of the valley, there are areas (40-50 km apart) where the water discharge is restored along meandering river channels, and the location of the river valley bottom in the ground depression results in the formation of small water bodies and marshes, often strongly saline. Some of these water bodies and marshes (except those

with high salinity) are used for agricultural purposes.

The Cherchen river located on the southern edge of the Taklamakan Desert can be described the same way. The river originates in the Przhevalsky and Altyntag ridges and the waters of its middle course sink into the sand of the desert and does not even reach Lake Lop Nor. The channels covered with sand are also located further south of the preserved riverbed. This indicates the predominance of southern winds (prevailing in the summer) in the desert basin, which ensures the displacement of dunes and river channel to the north.

Right-bank tributaries of the Selenga river are located in the northern peripheries of the Gobi Desert; they are characterized by specific morphology and dynamics. Aeolian processes in the catchments of these rivers are camouflaged by the undulating landscape and the varied relief caused by selective erosion of rocks, which results in a large dispersion of the landscape. At the same time, the slope processes, typical of semiarid conditions, are manifested through deluvial erosion, contributing to the formation of badlands. All this leads to excessive accumulation of alluvium in riverbeds and their siltation. Most of the river basins are characterized by steep slopes and flat bottoms, the width of which exceeds the width of narrow and silted river channels 50–100 times. The river channels are meandering or braided and lateral erosion is common. Wide floodplains are almost completely transformed by a large number of floodplain streams, there are many dry dead channels and oxbow depressions.

In some rivers (the Ider, the Chuluut, the Tamir, the Orkhon), the bottoms of the valleys expand even more at some locations, forming intermontane valleys. Their relief bears traces of material removed from low-mountain catchments, visible in the form of cones. Most likely they were formed in the past when the volume of the river flow was greater compared to the modern one. A large amount of material was carried down from the low-mountain terrain by slope and channel flows, filling the valleys. The water spread over these flat cones, forming a large number of streams. Many of them are still functioning, supplying fine material to the river channels, but most of the streams in such valleys have turned into dry dead channels.

The morphology of the channel and the floodplain of the Kharuukh River is typical of the desert river valleys located further south. The fluvial relief of the valley have been transformed by landscapes of solonchaks and aeolian barchans characteristic of the arid climate. The solonchaks can be found both in floodplain channels, preventing water runoff, and on the surface of the floodplain. The higher terraces, distant from the contemporary river channel and the saline floodplain, are now covered by barchans. In some areas, dunes and barchans completely cover the whole valley, leaving no place for surface runoff.

As we approach the eastern coast of China, the subtropical climate affects the river channel processes, even in the case of such large rivers as the Yellow River. In the middle reaches of the river, with the Alashan desert west of the valley and the Ordos loess plateau in the east, the nature of the riverbed and floodplain processes is similar to those of desert rivers. However, the same processes like in the arid zone occur in the river valley, covering the valley bottom with sand and migrating sand dunes in the "aeolian" sections of the valley, and in a vast cultivated floodplain (up to 10 km wide, with a low terrace of up to 50 km width), where the desert is located far from the river.

The North China Plain is not separated from the ocean by mountains and, during monsoons, the oceanic air masses reach far inland, penetrating the river basins in this area – the lower reaches of the Huang He, the Huai He, the Yangtze and others. In this area, arid and semi-arid climate conditions are replaced by humid conditions. Therefore, the intrazonal riverbed processes dominate again in the formation of river channels and floodplains. The rivers are characterized by wide valleys and channels forming either meanders with a low radius of curvature or single streams. Lakes in the mouths of tributaries connected with the main river by short and narrow streams are characteristic of this river system. These lakes are fed by water during monsoon floods, and in the dry season they are the source of water for the main river. However, such floodplain lakes are not a zonal feature of the areas – they also occur in the lower Amur and indicate the neotectonic lowering of all coastal lowlands in the Pacific coast of Eurasia and the accumulation

of alluvium in river channels as a consequence of this process.

In the conditions when the development of the valley floor is limited by lithological factors, the influence of zonal non-fluvial factors on channel processes in the subtropical zone is manifested in a different way. In the high mountain region of East Tibet, where the upper reaches of the Yangtze River are located, the climate is semiarid, but due to strong winds prevailing at the altitudes of 4–5 km, no sandy massifs, hence no aeolian processes occur. The tributaries of the Yangtze river, flowing down the slopes of relatively low ridges, develop their valleys in intermontane lowlands. The bottoms of the valleys are flat and channel processes are initiated easily. The channels of these rivers are braided and the floodplain is covered with scattered shrub vegetation. Such types of channels and floodplains are similar to those of arid subtropical rivers.

Such zoning elements are not observed in the middle reaches of rivers flowing down the massifs of the Eastern Himalayas into the Pacific Ocean and deeply cut into the surrounding rocks (entrenched rivers with no floodplains developed). Moreover, channel deformation is influenced by non-fluvial factors such as azonal landslides and sloughing, related to lithological conditions.

In small high-mountain rivers, flowing from the glaciers' floor (subglacial rivers) or from the relict periglacial lakes located at the direct forefield of glaciers, unique "planar" channels are formed (Chernov, 2016). The water flow down the valleys in a non-organized way (without the formation of channels), due to the lack of both suspended and bedload sediments. The water flows between small rhododendrons and is characterized by small velocity up to the place of a relict rapid in the valley bottom. The height of such rapids do not exceed 10-15 m. The whole mass of water flows down as a uniform stream, forming waterfalls. Lack of visible erosion forms proves that there is no linear concentration of the flow. Downstream of the waterfalls, the flow rate is reduced and the water flows again between the bushes and does not form a channel.

3. Conclusions

The geographical analysis of channel evolution of rivers located in the north-south transect, running from the Arctic Ocean coast to Tibet and the East China Sea, confirmed that fluvial processes control the formation of morphology and dynamics of channels and floodplains in all climate zones and affect channel deformations under different local conditions. However, even a small disturbance in "climate" conditions by other exogenous geomorphological processes changes the morphology of channels and floodplains and the dynamics of fluvial processes.

In the subarctic zone, the development of channel deformations is modified by permafrost. Permafrost consolidates alluvial and marine sediments and protects against erosion in some river sections. In other sections, however, permafrost caused riverbank erosion processes more effective due to increasing permafrost thawing along concave banks. This results in the formation of channel sections characterized by exceptionally large width, not resulting from fluvial conditions in this climate zone. However, this phenomena occurred only in small and medium-sized rivers of the subarctic zone.

In the humid temperate zone, the influence of zonal fluvial factors on channel processes is negligible. Further south, in the subtropical zone, climate aridization occurs over most of the territory of Mongolia and China. On the one hand, the river flow decreases and small rivers predominate, on the other hand, eolian processes are activated in the valleys. Aeolian processes limit the possibility of free channel development and the formation of floodplains. Large amounts of sand entering the channel can often cause the termination of surface runoff in dry seasons. While moving from the watersheds, barchans fill the floodplain and rive channels with sand. Backfilling the river channel with sand may cause the river to form a new channel, even if it is not in line with the tendency to develop fluvial processes in these areas. In the arid highlands of the subtropical zone (Eastern Tibet), the factors related to lat-

itudinal zonality do not affect the channel evolution, but the channel processes are shaped by specific high-mountain non-fluvial factors, e.g. lithology.

With the increasing humidity of the climate in the south of the North China Plain, the impact of the aeolian factor is negligible and the main factors affecting the channel evolution of large rivers are related to climate and hydrological conditions.

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