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Straight river: its formation and speciality

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Straight river is generally regarded as one of the typical river patterns in conventional classifications in terms of their channel plain landforms. However, very few straight patterns were found to be distributed in wider spatial and temporal spans in the self-adjusted fluvial rivers. Thus, the questions occur such as that is it possible for a channel takes on a stable straight pattern? What are the main factors controlling the processes of the river pattern formation and transformation from a straight to other patterns? Various theories and hypotheses including geomorphic threshold hypothesis, the extreme hypothesis on energy dissipation rate, the stability theory, etc. have been developed to explain the aforementioned questions, but none of them is sound for the explanation to the straight-river formation. From the modern fluvial plain patterns, the straight patterns are not as stable as other typical patterns which occurred in nature; from the historic records of the river sedimentation, no apparent evidence was found to support the stable straight river evolution. Based on the analysis of existing theories, observations, evolvement processes of the channel patterns in the experimental results, this paper concluded that the straight pattern should not be included as one of the typical patterns that are self-formed and developed. This study is of importance to understanding of the river pattern formation and transformation.

Straight river: its formation and speciality WANG Sui-ji1, NI Jin-ren2 (1. Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China; 2. Center for Environmental Science, Peking University, Beijing 100871, China) 1 Introduction What is a straight river? About this problem there does not exist a definite concept in fact. It is agreed that the straight river has single straight channel and then the straight braided river with multiple channels is another river pattern. But there are different opinions about if the river can be regarded as a straight river under how much the value of channel sinuosity is. Someone thought that the channel sinuosity is lower than 1.3, the river is straight. For example, Galay et al. (1973) thought that straight river has very low value of channel sinuosity. This indicates that it is still difficult to confirm the upper limit value of straight channel sinuosity. Someone also named the straight river as low-sinuosity river because a pure straight river seldom appears in nature. Rust (1978) defined the straight river as single channel system with the sinuosity lower than 1.5. However, whether the upper limit value of straight channel sinuosity is 1.3 or 1.5, it is a parameter set by researchers. It is difficult to say that the river is completely different from a straight river when the channel sinuosity is slightly higher than the upper limit values. Knighton (1984) divided straight rivers into two sub-types, the straight river with interchannel sand bars and the straight river with cross side bars, according to channel bed characteristics. Many studies indicate that the favorable conditions for a river transforming from straight river patterns to meandering and then to braided river patterns may include: 1) the increase of channel width/depth ratio which usually goes with the decrease of channel bank stability and the increase of transported bed loads; 2) the increase of river flow capacity which means the increase of water discharge under invariable channel gradient or increase of channel gradient under invariable discharge; and 3) the increase of transported sediments, especially bed loads. Qian (1985) and Qian et al. (1987) divided straight rivers into three sub-types according to their channel formation. (1) On the two banks there are materials with higher stability such as outcrop of rock, clay sediments and dense vegetation and so on which will confine the channel lateral migration. For example, the single straight reaches of Lower Changjiang (Yangtze) River which have outcrops of rocks in one or two banks, or get short nodes controlling. The straight channel planform under these conditions maintains chronically. (2) Temporarily formed straight channel during the development of meanderi

ng river. This straight channel has some stability and its planform may change or disappear during the channel migration. (3) In river delta areas there are straight channel planforms which have higher stability because thick clay sediments in banks confine channel lateral migration. For examples, there is a straight river about 4.86 km long in the river-mouth area of southern Mclin, New Zealand; the channel reach down New Orleans of Mississippi River, USA is a straight river (Qian et al., 1987). Lin (1992) and Chen (1992) divided straight rivers into three sub-types according to the relative movability of channel banks: non-alluvial bed, semi-alluvial bed and alluvial bed straight rivers. The formation of non-alluvial straight river generally relates with bedrock and geological structure. Because bedrock has high capability to resist weathering and its denudation velocity is low, but the geological tectonic movement may cause a series of faults and fissures in bedrock. The flowing of the ground water and surface water flowing along these faults and fissures will corrode and dissolve the bedrock and result in the broadening or/and collapsing of the faults and fissures. Finally, a confined straight channel will form gradually after a long time span. The formation of semi-alluvial straight river is similar to that of non-alluvial, but its water flow may moderately curve in straight channel and cause the formation of alternate side bars. Because the water flow is confined by fault sections and the curve is limited. Alluvial straight river has very stable banks consisting of clay sediments. Its side bars may be divided into two types according to their sediments: sand side bars and double layer bars of upper clay and lower sand sediments. The former is unstable and migrates continually downstream, but relative position of the bars is approximately fixed. The latter is very stable and the channel variation is not prominent. The characteristics of straight river form are mainly shown in two aspects: alternant deep trough and shallow shoal, alternant side bars. Despite the river channel is straight in channel planform, its mainstream curves in normal discharge periods because the alternant side bars appear regularly in interior of the two banks. The straight reach of Dnepr River is a typical representative (Rossinsky, 1950). In flow longitudinal profile, the deep trough appears in the forehead of a flow bend and the shallow shoal appears between deep troughs. Keller et al. (1973) compared the distributions of deep troughs and shallow shoals between meandering and straight rivers and concluded that they follow a same law. The space between deep troughs of the two different river patterns is similar, but the deep troughs in meandering river are deeper. Statistical analysis indicates that the spaces between deep troughs are commonly 3-5 times and its average values are 5-7 times of channel width. For example, 2 times of the spaces between deep troughs of Nay Creek and three other straight rivers are 12 times of channel width: 2Lp=12B (Lp is the distance between deep troughs, and B is channel width). This relation is similar in meandering river. It indicates that the two different river patterns had some commonness (Qian et al. 1987). Frenette et al. (1973) pointed out that long straight river was rare in nature. Several rivers in the provinces of central Canada may be regarded as straight patterns. The main distributary of Lawrence River in Quebec Province shows single straight channel, but its thalweg is still curving as its side bars are alternant. If the river channel is not restricted, it may develop into braided channel pattern. In many classifications of river patterns, straight river is regarded as a typical river pattern, but someone thought that straight river was only a temporary form in the process of river transformation (Frenette et al., 1973) . The curving flow which winds side bars in straight channel indicates that there is a circumfluence which changes its direction alternately. In fact, there are two kinds of circumfluence of straight river, bend circumfluence and secondary circumfluence. Their growth and decline one another will form side bars. Einstein et al. (1964) qualitatively explained this properly. Besides, Parker (1978a, b) also studied some characters of straight rivers with sand-silt bed and gravel bed self-formed under the condition of equilibrium banks and mobile bed. Besides, other important studies (Fang, 1999; Lu et al., 2000; Miller and Ritter, 1996; Ni and Zhang, 1991; Rosgen, 1994; Wang and Ren, 1999; Xu, 2001; Yao and Liu, 1995; Yin, 2000; Zhang et al., 1998) revealed some features of this river pattern. However, the cause and speciality of this river pattern are not clear hitherto. Furthermore, as an independent and typical channel pattern, the position of this river pattern is still doubtful because it always appears together with other river patterns especially anastomosing river pattern. In this paper we will discuss the straight river further from forming and transforming theories and hypotheses, channel variation, flume experiments, sedimentation and ancient sediment records and so on. 2 Theories and hypotheses on straight river 2.1 Geomorphic threshold hypothesis 2.2 Extremum hypothesis on energy dissipation rate 2.3 Stability theory 2.4 Statistical analysis 3 The evolution of a straight river 4 Flume experiment 5 Sedimentation and old sediment record 6 Conclusion

关键词： straight river; formation cause; evolvement; sedimentation

