

A REVIEW: INDICATIVE FUNCTION OF SEQUENCE STRATIGRAPHY ON FLUVIAL TYPE

^{1,2}Zhipeng Lin, ^{1,2}Le Chen, ^{*1,2}Jingfu Shan, ^{1,2}Lili Xie, ^{1,2}Le Zhang, ^{1,2}Wei Fang and ^{1,2}Bo Liu

¹Key Laboratory of Exploration Technologies for Oil and Gas Resources, Ministry of Education, Yangtze University, Wuhan 430100, China

²School of Geosciences, Yangtze University, Wuhan 430100, China

³School of Energy Resources, China University of Geosciences, Beijing 100083, China

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ABSTRACT

At present, the recognition and research of the classification of fluvial types mainly focus on the description and analysis of a series of indicators, such as the plane shape and sediment characteristics. However, there is limited information on how to study the fluvial types from the deposition process. To propose the application of sequence stratigraphic framework for fluvial systems. We use the principle of concrete analysis for concrete problems by summing up the predecessors of the river type classification scheme. With the research thinking of Process Sedimentology, New systems tracts for fluvial are presented here, including four parts: Low fluvial system tract, Advancing fluvial system tract, Flooding fluvial system tract, Receding fluvial system tract. And apply it to the analysis of the problem of attribution of the traditional division of fluvial. This study embodies the characteristics of Process Sedimentology and helps on research the deposition process of the formation and development of the fluvial system. Moreover, it develops the fluvial classification system from the description stage to a complete rational stage.

*Corresponding author:

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INTRODUCTION

With the continuous deepening study on the fluvial sedimentary system, the emergence of new fluvial makes more and more scholars to recognize the contradictions between fluvial types and the classification scheme are gradually prominent. For instance, Leopold and Wolman(1957) put forward the classification of the meandering river and braided river very early. But in the actual situation, braided river and meandering river do not exist independently in a geological period, they will exist in the same provenance system during a geological period, and will also make reciprocal transformation with the development of the geological history(Tang *et al.* 2016; Lin 2017; Lin *et al.* 2017). Miall classified river as four types: braided river, meandering river, anastomosing river and straight river(Miall 2016). Qian Ning(1985), afterward, referred that many scholars in our

country thought it was inappropriate to take the anabranching river in the mid-lower Yangtze River and the wandering river in the lower reaches of the Yellow River as an anastomosing river, which is accepted gradually in foreign countries. The understanding of fluvial type is still in the view of the appearance and the results, so a new way of thinking and research methods is needed to solve the problem. The sequence framework of river system has been done some research by some predecessors. In 1988. Poasmentier and Vail(1988) established the first non-marine alluvial sequence stratigraphy models. Wright and Marriott(1993), based on the results, systematically proposed a simple sequence model for fluvial facies. Took that the lowstand systems tract(LST) was composed of channel fillings in incised valley and terrace soil layer, the transgressive systems tract(TST) featured with the uplift of base level and the growth of accommodation space, the highstand systems tract (HST) has a increased channel sand body density and more soil layer.

Table 1. Different classification scheme of fluvial types

Scholar	Time[year]	Classification basis	Classification index	Fluvial types
Powell & Davis	1875	structure control	structural control factor	along the river, reverse river, antecedent river, subsequent river, superimposed River
Davis	1899	erosion cycle	different erosion stage	childhood, prime, old age
Leopold & Wolman	1957	channel pattern	channel pattern	straight river, meandering river, braided river
Schumm	1963	sediment transport	sediment transport	lapse river, suspended river, mixed river
Drury	1969	channel pattern	channel pattern	braided river, meandering river, anastomosing river, straight river, anabranching river
Miall	1977	channel pattern	channel pattern	braided river, meandering river, anastomosing river, straight river
Galloway	1978	sediment transport	sediment transport	lapse river, suspended river, mixed river
Rust	1978	channel pattern	channel anabranching index and bending	braided river, meandering river, anastomosing river, straight river
Brice	1983	channel pattern	channel pattern	curved channel, curved beach type, micro bending
Qianning	1985	channel pattern	channel pattern	braided, straight braided type
Woolfe	1996	sedimentation rate	sedimentation rate	wondering river, meandering river, straight river, anabranching river
Wang Shuiji	1999	channel pattern	bending degree and channel system	mountain rivers, plain rivers, delta river, etc.
Xu Caicai	2015	river level, the degree of closure, the number of river and winding degree		braided river, meandering river, anastomosing river, straight river, anabranching river
				20 types of rivers

Table 2. Study of sequence stratigraphy

Scholar	Time[year]	Content stage	Stage
Sloss	1950	The concept of sequence is put forward	Origin stage
Vail	1977	Founded seismic stratigraphy	
Vail	1987	Used stratigraphic unconformity or unconformity with the integrated interface as the sequence boundary; Took the seismic data to interpret the seismic stratigraphy. And then based on the relationship between the sequence and sequence unconformity interface, explained the sedimentary system and depositional system, In particular, the global sea level change was the main control factors of sequence development	Classical sequence stratigraphy stage
Galloway	1989	Used the maximum flooding surface and its corresponding sedimentary section as the sequence boundary, and the data of the well were used to analyze the sedimentary system. In particular, the sequence is a set of sediments deposited along the edge of the basin.	
Johnson	1992	Used the stratigraphic unconformity or transgressive erosion unconformity interface as transgressive-regressive cycle, that is, from an enhance mutual events to another with equal in size to the deepening of events prior to the start of a period of time in the deposited layers	
Cross	1995	High-resolution sequence stratigraphy theory was proposed, which includes the principle of the reference plane, the principle of volume partition, the principle of phase differentiation and the comparison of the cycles.	high-resolution sequence stratigraphy

Subsequently, in the summary of the control action for accommodation space from the tectonic subsidence, material supply, and many other factors, Shanley and McCabe(1994) proposed a set of fluvial facies strata sequence pattern from the mode of deposit loading. On the basis of summarizing the previous models of the predecessors, Zhang Zhouliang(1996) put forward the sequence patterns of fluvial facies, by analyzing the differences, similarities, advantages, and disadvantages of different models, systematically. And for the first time, he pointed out the relationship between fluvial stratigraphic sequence and fluvial type. Just figure out the list of previous research results, it is not difficult to find the development of the fluvial classification and stratigraphic sequence. In fact, there are many problems that are not suitable for the fluvial system(Chen and Chen 2010; Crombez *et al.* 2016). In order to solve these problems, the author tries to combine the formation process of the fluvial sequence and the river course through the river channel evolution, and then reconstructs a set of sequence framework for the river, moreover, makes it respond to the fluvial type.

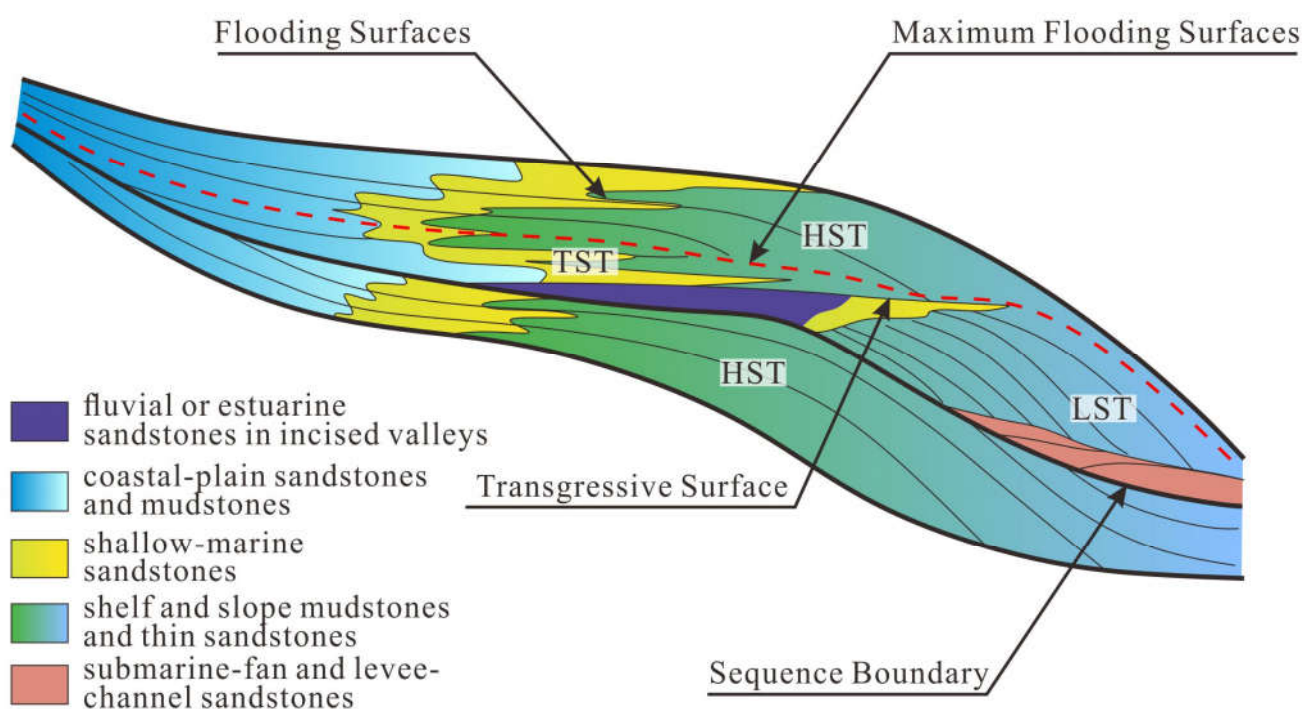
MATERIALS AND METHODS

Problems in the current classification scheme of rivers. River classification is the basis of the establishment of facies model(Tang, Wang *et al.* 2016; Xu *et al.* 2016; Lin 2017), and is also the term used in the petroleum geology work. In the continental petroleum basin of continental China, the fluvial

sand body is very important, and it has attracted people's attention in recent years. The following lists a brief introduction to the classification status of fluvial sedimentology (Table 1), for reference only. Shanley (1994) believed that classification was a cognitive process of complex things, according to the principle of cognition, there are three ways of classification. Leopold and Wolman(Leopold and Wolman 1960), according to the channel pattern, proposed the classification of "straight river, meandering river, and braided river". In accordance with the geometric characteristics of the river, Rosgen(1994) proposed geomorphic classification framework. These two reflect the first way. The second way is based on the prototype theory or probability theory. Montgomery and Buffington(1997) and Croke are in line with the method of prototype theory to some extent. The development and application of the theory of sequence stratigraphy. The sequence stratigraphy is a comprehensive interpretation science for stratigraphic sequence framework. It is based on seismic stratigraphy and the comprehensive utilization of seismic, drilling and outcrop data, combined with the sedimentary environment as well as lithofacies and ancient geographical interpretation. Gradually formed a set of relatively independent theory and method system (Xiao *et al.* 2006; Yang 2009; Hu *et al.* 2017). The development of sequence stratigraphy can be divided into three stages: the origin, the classical sequence stratigraphy stage and the high-resolution sequence stratigraphy. The three stage of the understanding and summary is visible in Table 2.

Table 3. Fluvial sequence patterns of different scholars

Scholar	Year	Systems tract	Features	Fluvial types
Posamentier & Vail	1888	I type sequence	Sea level falls incised valley fillings, linear and curved distribution. The Late stage of high water level, widely distributed in the plain, in the lateral is not restricted.	—
		II type sequence	In the late stage of high water level, river facies are widely deposited, and there is no filling in the valley.	—
wright	1993	Lowstand systems tract	Composed of the incised valley fillings and the high maturity of soil layer, topographic slope larger, in the source region of the denudation rate is higher.	low sinuosity river
		Transgressive systems tract	Uplift of the base surface, increasing the accommodation space. The vertical accretion rate increases, and the distribution of a wide range of thick layers of the floodplain deposition.	Isolated and laterally confined river
		Highstand systems tract	Accommodation space growth rate decreased, The increase rate of the river floodplain is reduced, The density of river sand body increases.	—
Shanley & McCabe	1994	Lowstand systems tract	The channel sand bodies are horizontal and vertical to each other, and the bed load is mainly coarse grain, and Upward coarsening.	braided river
		Transgressive systems tract	The bed load and suspended load are mixed, and the bed load can be changed to a fine and can accommodate space growth.	meandering river,
		Highstand systems tract	The suspended load is the main form of the channel sand body and more soil layer, which can slow down the speed of space growth.	anastomosing river
Zhang Zhouliang	1996	Lowstand systems tract	The gravel sediment filling, river vertical cutting each other, mutually overlapping, contiguous transverse distribution of sand body.	braided river,
		Transgressive systems tract	Fine sediment deposition, which contains some of the narrow band channel sand body.	anastomosing river
		Highstand systems tract	The uplift rate of the surface is slow, accommodation space growth rate is lower.	meandering river,
Fangshi	1997,2000	Lowstand systems tract	The sand body in the horizontal, vertical contiguous, associated with the pervious soil on the terrace.	braided river,
		Transgressive systems tract	Two stage, first is the water surface increased, the large area of the development of the marsh, the formation of peat and coal bed, often to the bottom of the coal bed or mud layer. Then, the base surface uplift rate increases, the formation of a set of fine grain vertical to the accumulation of the characteristics of the deposit, associated with better preservation of coal	meandering river, anastomosing river
		Highstand systems tract	The base surface of the largest uplift, the rate of change is reduced, coal, peat, soil, etc.	meandering river,
		Regressive systems tract	The base surface uplift rate decreases, erosion of some of the material deposited in the high water level.	braided river,

**Figure 1. Type-I-Sequence modified from Van Wagoner**

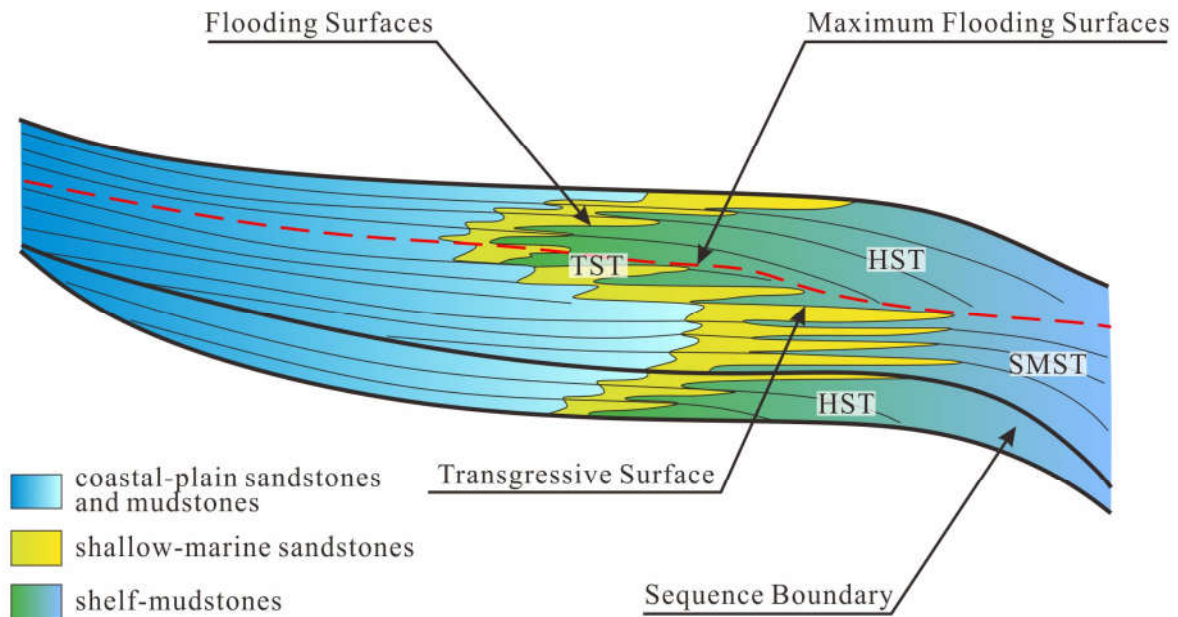


Figure 2. Type-II-Sequence modified from Van Wagoner

It can be seen, as one of the forefronts of the earth science research, the theory and practice of sequence stratigraphy has brought a leap to the theory and thinking, and therefore in recent years, won much of the popular (Sloss 1963; Vail *et al.* 1977; Vail 1987; Galloway 1989; Johnson and Klapper 1992). New ideas for the division of the fluvial sequence framework. The river is a very important source of transmission tube system. The sediment will transport from provenance to the sedimentary basin and the ocean. In the new referred source-sink system (Archer 2017; Bonneau *et al.* 2017; Hawie *et al.* 2017; Lin *et al.* 2017; Mason *et al.* 2017) - formed from eroded area source, including weathering flake particles of the sediment and dissolved matter, moving into the final deposition in the deposition zone or catchment basin, rivers can also be regarded as the "blood". It is not only an important channel for the flow of water from the land to the lakes and oceans (Zhu 2008) but also the important medium for the completion of the whole ecological cycle.

Therefore, it is of vital significance for the whole geology research to realize the full and complete understanding of the river. Influence factors of the fluvial sequence. In 2000, it was concluded that the interaction between the supply and the accommodation space of the sediment is an important factor to affect the sequence of the river. In sequence stratigraphy, 4 basic control factors, such as tectonic subsidence, global sea level fluctuation, sediment supply and climate change, are basic factors. In the early stage of fluvial sequence stratigraphy, the classical sequence stratigraphy theory originated from the passive continental margin, and the sea level change and the river sediment structure were linked. Shanley *et al.* (1994) researched the system in the Kaiparowits, Wright and Wagoner did the alluvial system study of the BookCliffs system of the state of Utah and linked The changes of fluvial sedimentary characteristics to the changes of the sea level at that time. Catuneanu (2006) thought that sea-level change and shoreline migration of fluvial sequence sphere of influence from the shoreline to the upper reaches of the river and general was only a few tens of KM. For inland rivers, in addition to the tectonic and climatic factors, riparian and

floodplain material composition, vegetation coverage, basin sediment size, and sediment composition, flow rate changes can affect the base surface changes in a certain extent, thus influence river sediment (Sanz-Perez and Menendez-Pidal 2016; Debnath *et al.* 2017; Fryirs 2017; Hawie, Deschamps *et al.*, 2017). Sequence boundary of fluvial. In stratigraphic records, two types of sequences can be identified, that is, the sequence I and sequence II. Respectively correspond to the sequence I and sequence II. Sequence I boundary is a regional unconformity, which is that the decrease of the global sea level is greater than that of the sedimentation velocity of the sedimentary basin (Fig. 1). Sequence II boundary is due to the decrease of the global sea level, which is lower than that of the sedimentation velocity of the sedimentary basin. (Fig. 2) However, the sequence boundaries of the river, I do not know because people think it is not needed or is not meaningful, has been no one to mention. This paper argues that the river should have a unique set of sequence boundary, regardless of the meandering river, braided fluvial or anastomosing river. Sequence stratigraphic model of fluvial facies in fluvial system. Here makes a systematic summary of previous results about Sequence stratigraphic model in fluvial system. Different scholars get different answers, however, there is truth in these.

Fluvial sequence stratigraphic model. Wright and Mariott proposed a relatively simple fluvial facies sequence model. Their model is that the lowstand system tract is composed of channel fillings in incised valley and high maturity of soil layer in river terraces. The water inlet system is characterized by the uplift of the base surface and the growth of the accommodating space. The high water level system is formed with the reduced growth rate of the space and the decreased speed of the river flooding. Shanley and McCabe also proposed a sequence pattern of fluvial facies strata. The low water level system is composed of many horizontal and vertical cutting and merging channel sand bodies, which are composed of coarse grains and coarse grains. The water inlet system is composed of the bed load and suspended load. The total trend of the upward trend, which reflects the growth of

the space. The high water level system is the main material of suspended load but also can form some isolated river sand bodies and more soil layers. Zhang Zhouliang, combined with the actual data, put forward its own model, lowstand system tract composed of the vertical and horizontal interconnected braided channel sand body and the soil of layer terraces. Transgressive system tract is the anastomosing river for isolated inthick floodplain fine sand bodies. During the high water, the period is the lateral distribution of meandering river sand. The Fluvial sequence patterns of different scholars can take detailed as Table 3.

RESULTS AND DISCUSSION

In view of the problems in the model proposed by the river, there are some questions to discuss with you.

- Will it be fixed in the actual situation to applicate the sequence stratigraphy to fluvial facies analysis and decision and just use the previous situation of the river system?
- There is no doubt that the relationship between the types of the river and the sequence framework is important. But how to establish a better relationship between each other, so that the fluvial sequence can be a guide to the classification of the river, while the river type can reflect the corresponding sequence, to achieve a set of relatively complete standards.
- Is it OK to consider a reconstruction for fluvial sequence system, not traditionally for river basin inlet basin or lake basin inlet, but to proceed into the whole river system itself?

Combined with the problem discussed in this paper, some ideas are presented here. An analysis of the sedimentary sequence of the river can be made from the evolution history of the whole river system. From the mountain to sedimentary basins, the process can be divided into low water erosion stage, river-into sedimentary stage, water flooding stage and water receding and transforming stage. And combined with the research ideas of Process Sedimentology, they can be four systems tracts: Low fluvial system tract, Advancing fluvial system tract, Flooding fluvial system tract, Receding fluvial system tract. And hopefully it will work for the development of oil and gas reservoir.

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