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Patterns of anabranching channels: The ultimate end-member adjustment of mega rivers

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ABSTRACT

Large fluvial systems adjust to a combination of controls to form distinctive channels, which represent a dominant factor in the evolution of floodplain geomorphology and sedimentology. Fluvial geomorphology has commonly classified river channels into meandering, straight and braiding patterns, which are seen to represent a continuum of channel geometry. Anabranching patterns, rivers with multiple channels, however, are characteristic of many rivers. The identification of a combination of variables that discriminates specific channel patterns has been a significant focus of research in fluvial geomorphology. The development of this body of knowledge, however, has been established from medium and small rivers, and laboratory flume studies. Very few of these research ideas developed from analysis of large fluvial systems.

This paper assesses the pattern of channel adjustment of large fluvial systems by employing hydraulic geometry, discharge, *w*/*d*, slope, grain size, stream power, specific stream power, and Froude number ($Q_{mean} > 1000$ m^3/s). The study demonstrates that methods currently used to discriminate channel patterns are not useful when applied to very large rivers. Further, with the exception of the Lower Mississippi, alluvial rivers with mean annual discharges greater than ~17,000 m^3/s, here classified as mega rivers, do not generate single thread meandering or typical braided patterns. These mega rivers develop anabranching patterns.

1. Introduction

Fluvial systems adjust the floodplain and channels to a combination of controls, and a strong correlation exists between river channel patterns and floodplain sedimentology (Nanson and Croke, 1992; Bridge, 2003). Over small time-scales floodplain conditions affect channel patterns by influencing local bank resistance, flow transmission and sediment load. Over longer time-scales, however, the patterns of river channels are seen as the driver for floodplain styles (Nanson and Croke, 1992), and models of alluvial architecture and depositional environments are dependent upon the dynamics of channel patterns (Miall, 1996; Bridge, 2003).

Fluvial geomorphology has commonly categorized river channels as meandering, straight and braiding patterns, which are seen to represent end-member patterns (Leopold and Wolman, 1957, Knighton, 1998). The identification of a combination of variables that discriminates specific channel patterns has been a significant focus of research in fluvial geomorphology. The development of this body of knowledge, however, has been established from small and medium sized rivers, and laboratory flume studies.

This paper examines the adjustment of channel patterns for the largest fluvial systems on Earth, with the idea of being able to identify a threshold for what may be considered a large river. Simple definitions such as straight, meandering and braided are difficult to apply in large rivers (Latrubesse et al., 2005). In a recent paper, Jansen and Nanson (2004) indicate that the largest rivers are dominated by anabranching patterns, an observation made by Latrubesse (1992) a decade earlier. Anabranching channel patterns represent an additional planform geometry (e.g. Nanson and Knighton, 1996), and agreement exists among researchers that the physical causes for anabranching channels should be identified (Nanson and Huang, 1999; Huang and Nanson, 2007).

As addressed by several authors (Nanson and Croke, 1992; Knighton 1998, Miall, 1996; Fielding, 2007) a close association occurs between the type of channel pattern and the characteristics of floodplain development. The distinctive aggradation morphologies and the sedimentary architecture that characterize a floodplain can be related to the hydro-geomorphologic dynamics of the associated channel pattern. Nanson and Croke (1992), for example, quantitatively identified several types of floodplains and channel patterns as a function of specific stream power at bankfull discharge and sediment texture. The largest rivers, however, exhibited a variety of channel styles, and anabranching pattern were common. Considering the existing lack of knowledge on anabranching rivers on the varieties of sub-patterns or planforms as well physical causes for anabranching, understanding floodplain evolution generated by anabranching patterns remains incomplete.

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Table 1
Largest rivers of the world

River	Country to the mouth	Mean annual discharge (m^3/s)	Drainage area (103 km^2)	Annual Q_s (Mt/year)	Sediment yield (t/km^2 year)	Dominant channel pattern
Amazon	Brazil	209,000[a]	6100	~1000[e]	167	Anabranching
Congo	Zaire	40,900	3700	32.8	9	Anabranching
Orinoco	Venezuela	35,000[d]	950	150[d]	157.8	Anabranching
Yangtze	China	32,000	1943	970[e]	499	Anabranching-occasional complex and geologically controlled sinuous reaches
Madeira	Brazil	32,000[a]	1360	450[c]	330	Anabranching
Negro	Brazil	28,400[a]	696	8[b]	11.5	Anabranching
Brahmaputra	Bangladesh	20,000	610	520[e]	852.4	Anabranching
Japura	Brazil	18,600[a]	248	33[b]	133	Anabranching
Parana	Argentina	18,000	2600	112[g]	43	Anabranching
Mississippi	USA	17,000	3200	330[e]	102	Meandering

Data sources: [(a)] data estimated from the Brazilian National Agency of Water-ANA, [(b)]Filizola (1999), [(c)]Martinelli et al. (1993), [(d)]Meade et al. (1983), [(e)]Meade (1996), [(g)]Amsler and Prendes (2000).

While the basis of knowledge in fluvial geomorphology continues to stem from studies of smaller rivers, a greater recognition exists that large rivers are unique fluvial systems, in terms of the controls, processes, and from the standpoint of management (Potter, 1978; Junk et al., 1989; Latrubesse et al., 2005; Gupta, 2007). Geomorphologists, however, have neither agreed upon how large a river needs to be to be considered "large", or have identified objective criteria to categorize such rivers. Indeed, commonly a great range in the size of rivers is considered "large". Kellerhalls and Church (1990) identified large rivers as having a bankfull discharge exceeding 20 m^3/s and channel width of greater than 20 m, which is too small to be classified a large river by most categories (e.g., Potter, 1978; Latrubesse et al., 2005; Wohl, 2007). Nevertheless, this implies that the channel would be unlikely to be significantly influenced by local factors, such as a landslide blockage or fallen trees, providing some distinction from smaller rivers in terms of the controls on channel morphology. Other authors suggest that the scale of large fluvial systems creates distinctive types of channel and floodplain hydrologic connectivity (Junk et al., 1989; Mertes et al., 1996; Mertes, 1997) which also suggests floodplain/channel style and scale-dependence in hydro-ecological process (Latrubesse et al., 2005, Latrubesse, in press). Other studies, however, have noted that large rivers generally require extensive geologic control by structure or tectonics (Potter, 1978; Latrubesse et al., 2005; Miall 2006; Tandon and Sinha, 2007). Indeed, this has emerged as the main criteria for identifying large rivers, which results in very long channels, a large drainage basin, and a high mean annual

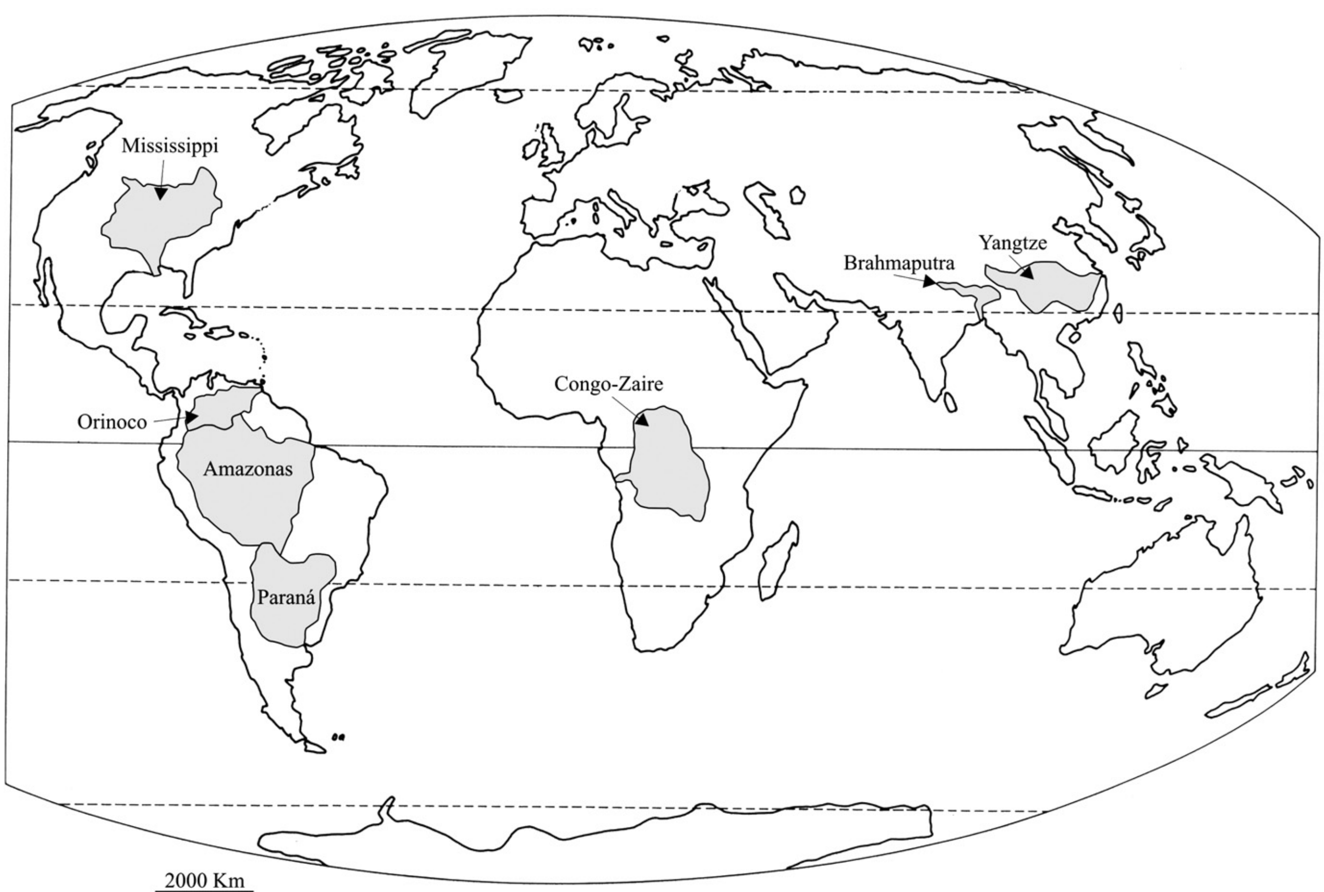

Fig. 1. Location of the ten largest river basins based on discharge.