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Invited Review

Fluvial geomorphic elements in modern sedimentary basins and their potential preservation in the rock record: A review

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ABSTRACT

Since tectonic subsidence in sedimentary basins provides the potential for long-term facies preservation into the sedimentary record, analysis of geomorphic elements in modern continental sedimentary basins is required to understand facies relationships in sedimentary rocks. We use a database of over 700 modern sedimentary basins to characterize the fluvial geomorphology of sedimentary basins. Geomorphic elements were delineated in 10 representative sedimentary basins, focusing primarily on fluvial environments. Elements identified include distributive fluvial systems (DFS), tributive fluvial systems that occur between large DFS or in an axial position in the basin, lacustrine/playa, and eolian environments. The DFS elements include large DFS (>30 km in length), small DFS (<30 km in length), coalesced DFS in bajada or piedmont plains, and incised DFS. Our results indicate that over 88% of fluvial deposits in the evaluated sedimentary basins are present as DFS, with tributary systems covering a small portion (1–12%) of the basin. These geomorphic elements are commonly arranged hierarchically, with the largest transverse rivers forming large DFS and smaller transverse streams depositing smaller DFS in the areas between the larger DFS. These smaller streams commonly converge between the large DFS, forming a tributary system. Ultimately, most transverse rivers become tributary to the axial system in the sedimentary basin, with the axial system being confined between transverse DFS entering the basin from opposite sides of the basin, or a transverse DFS and the edge of the sedimentary basin. If axial systems are not confined by transverse DFS, they will form a DFS. Many of the world's largest rivers are located in the axial position of some sedimentary basins. Assuming uniformitarianism, sedimentary basins from the past most likely had a similar configuration of geomorphic elements.

Facies distributions in tributary positions and those on DFS appear to display specific morphologic patterns. Tributary rivers tend to increase in size in the downstream direction. Because axial tributary rivers are present in confined settings in the sedimentary basin, they migrate back and forth within a relatively narrow belt (relative to the overall size of the sedimentary basin). Thus, axial tributary rivers tend to display amalgamated channel belt form with minimal preservation potential of floodplain deposits. Chute and neck cutoff avulsions are also common on meandering rivers in these settings. Where rivers on DFS exit their confining valley on the basin margin, sediment transport capacity is reduced and sediment deposition occurs resulting in development of a 'valley exit' nodal avulsion point that defines the DFS apex. Rivers may incise downstream of the basin margin valley because of changes in sediment supply and discharge through climatic variability or tectonic processes. We demonstrate that rivers on DFS commonly decrease in width down-DFS caused by infiltration, bifurcation, and evaporation. In proximal areas, channel sands are amalgamated through repeated avulsion, reoccupation of previous channel belts, and limited accumulation space. When rivers flood on the medial to distal portions of a DFS, the floodwaters spread across a large area on the DFS surface and typically do not re-enter the main channel. In these distal areas, rivers on DFS commonly avulse, leaving a discrete sand body and providing high preservation potential for floodplain deposits.

Additional work is needed to evaluate the geomorphic character of modern sedimentary basins in order to construct improved facies models for the continental sedimentary rock record. Specifically, models for avulsion, bifurcation, infiltration, and geomorphic form on DFS are required to better define and subsequently predict facies geometries. Studies of fluvial systems in sedimentary basins are also important for evaluating flood patterns and groundwater distributions for populations in these regions.

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Contents

1. Introduction

Sedimentologists focused on continental environments (e.g., fluvial, alluvial, eolian, and lacustrine deposits) seek modern analogs to better understand processes that may have been responsible for forming the facies distributions observed in the rocks and for improved prediction of facies connectivity and geometries for applications in natural resource development (e.g., petroleum reservoirs, groundwater, and aggregate). To this end, geomorphic studies of rivers and other continental environments have served to help formulate facies models of these depositional systems (e.g., Collinson, 1996; Miall, 1996, 2010; Bridge, 2006).

A fundamental concept in sedimentary geology is that sediments that ultimately become sedimentary rocks must be buried and preserved at a depth, and this occurs primarily in sedimentary basins where tectonic subsidence occurs (Miall, 2000; Allen and Allen, 2013). Not all geomorphic studies used in understanding continental environments for facies models, however, have been conducted in sedimentary basins (Weissmann et al., 2011). In order to evaluate sedimentary basin-scale (e.g., 10^4–10^6 km^2) processes of continental sedimentary fill and the geomorphic processes responsible for facies distributions observed in the rock record, we must evaluate the geomorphic processes of modern sedimentary basins. Studies of continental geomorphology outside these sedimentary basins may be useful for understanding channel-scale depositional processes and upstream catchment contribution to sediment supply and stream discharge. However, these will not further the understanding of sedimentary basin-scale processes and overall geometries of deposits responsible for sedimentary basin fill and evolution (Hartley et al., 2010b).

In the continental realm, tectonic subsidence exists in sedimentary basins located in divergent, intraplate, convergent, and transform settings (e.g., Ingersoll, 2012; Allen and Allen, 2013). In these continental areas, long-term subsidence occurs and sediments are lowered below a level where erosion is possible (e.g., *preservation space* of Blum and Törnqvist, 2000). Nyburg and Howell (2015) showed that modern continental sedimentary basins cover only ~16% of the current continental area if one excludes the passive margin setting, thus only deposits from a relatively small portion of the modern continental area will ultimately be preserved in the sedimentary rock record.

Weissmann et al. (2010) identified 724 continental sedimentary basins (e.g., basins primarily located on the continents with minimal marine influence, thus excluding the passive margin setting) globally, a compilation that covers most climatic and tectonic settings. Though this has been reported as excluding all rivers that enter the ocean (e.g., Sambrook Smith et al., 2010; Fielding et al., 2012), this designation only denotes that sea level change did not affect deposition in most of these sedimentary basins. However, some of the axial rivers may exit the sedimentary basin and ultimately terminate in the ocean. Active subsidence in these sedimentary basins is indicated by relatively thick (10s to 100s of meters in many basins) accumulation of young (Quaternary and Neogene) sediments. Though subsurface data are not available for all 724 sedimentary basins identified by Weissmann et al. (2010), compilations describing sedimentary basins indicates that sediments are accumulating in these tectonic settings (e.g., Busby and Ingersoll, 1995; Busby and Azor Peréz, 2012; Allen and Allen, 2013). In our recent work (e.g., Hartley et al., 2010a,b, 2013; Weissmann et al., 2010, 2011, 2013; Davidson et al., 2013), we indicated that distributive fluvial systems (DFS) cover large areas in these sedimentary basins and comprise