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Generating Sequence Boundaries, Architecture and Sediment Storage in High vs. Low Accommodation Phases of Coastal Tropical Rivers

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Introduction

Tropical rivers are common place in both the modern and the ancient. With their tendency to drain areas of high precipitation they often form exceptionally large channels that are prone to high fluctuations in discharge. They thus have a high potential to do work. Their preservation and the architecture resulting depends upon the availability of accommodation vs. the sediment supplied. Likewise accommodation and sediment supply control the character and potential of sequence boundaries these rivers may form. These can be understood using the Buffers and Buttresses model.

The Buffers and Buttresses Model

Storage and preservation of sediment in river systems has long been modeled by consideration of shifts in the river longitudinal profile (e.g., Posamentier, 1988; Dalrymple et al, 1998). Rises in base level caused by sea level rise or other factors cause the profile to lift in proportion, thus causing the system to aggrade and fluvial sediments to accumulate beneath. Likewise, drops in base level result in erosion and incision. The effect of these changes dampens up dip to a position where the profile is not affected (reviewed in Holbrook, et al., 2006). These premises hold in general, but are not designed to account for the variability in fluvial systems inherent because of upstream variability observed over moderate to long durations. Increased runoff, and related water discharge, will cause rivers to incise if the sediment supply is not increased proportionally. Likewise increased sediment without increased water my cause aggradation and a profile rise. These input-driven shifts in profile are easily caused by changes in vegetation, rainfall, temperature, uplift, and other factors in the drainage basin that can change with much higher frequency than downstream drivers like sea level. The Buffers and Buttresses model incorporates this added variability, and also provides a platform for understanding variability in fluvial sediment storage as well as sequence-boundary properties and occurrence.

The Buffers and Buttresses model considers fluvial sediment storage to occur between upper maximum and lower minimum profiles. When dealing with ancient systems, the position of the river profile may not be constrainable at any instant; however, there exists a highest profile the river could have attained and a lowest profile it could have cut over the time interval of interest. All potential profiles are confined by these "buffer" profiles, and the profiles actually visited between define the preservation space where sediment was permanently or temporarily stored (Figure 1a). River profiles move freely vertically and laterally within this preservation space. The buffer all realized profiles must all meet down dip at some "buttress," or absolute base level (e.g., sea level, etc.), which controls the downstream influence on profiles. The preservation space will thicken up dip from this buttress, however, because more vigorously fluctuating upstream variables gain added influence over profile position in this direction. The preservation space between the buffers will shift with the buttress in the same manner as profiles in general (Figure 1b).

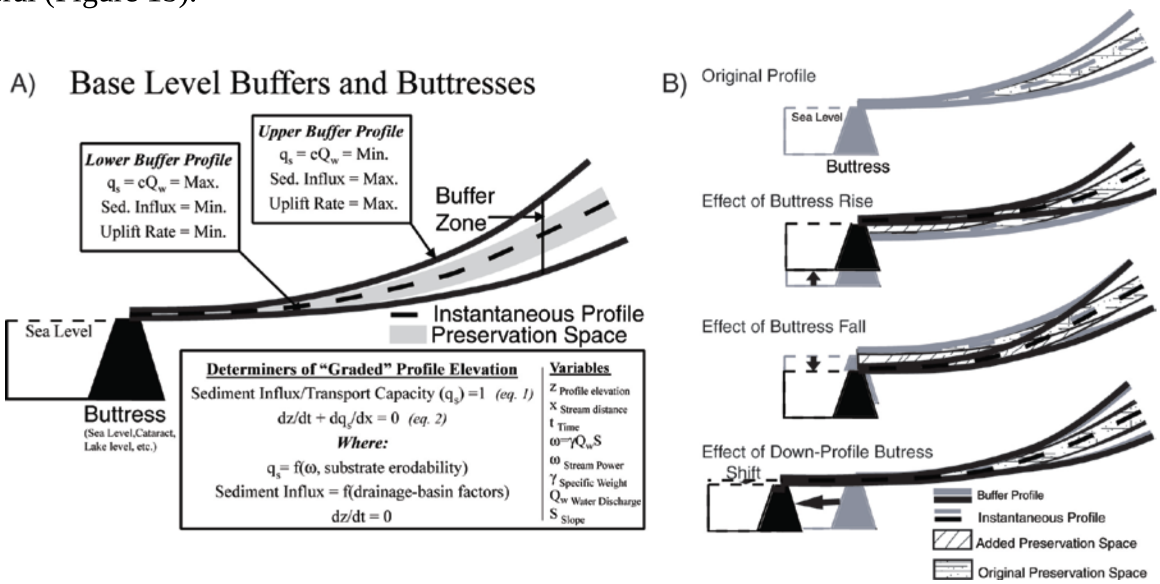

Figure 1: Basic concepts of the Buffers and Buttresses model (A). Changes in accommodation generated by shifts in the sea-level buttress (B). from Holbrook et. al. (2006)

Sediment Storage and Sequence-boundary Erosion at Low Accommodation

Fluctuation of river profiles within the preservation space during sea level rise and fall means that sediment is constantly stored and remobilized over the span of sea level shift, even if this shift does not itself add accommodation. For instance, if sea level fall forces an actual drop in river profiles, and related incision, the buffer profiles fall as well. Shortly up dip of the strand, the vertical space between the buffers permits aggradation and storage of sediment even during an overall incisional condition. If the buffer profiles are merely extended by sea level fall without an actual profile drop, sediment still aggrades and incises repeatedly between the buffers as before. In both cases, the profiles may also move laterally, and thus store sediment laterally in addition to vertically. This process of repeated vertical and lateral profile movement up dip of the strand causes repeated stacking, reincision, and lateral shifting of channel belts. The eventual architecture resulting is laterally arranged multivalleys, where the buffers are thick, and laterally arranged channel sheets, where the buffers are thin (Figure 3).

Beneath these laterally and vertically moving channels is a scour surface that is being constantly reshaped by channel erosion. This surface over time becomes what is generally referred to as a sequence boundary in the Hunt and Tucker (1992) sense, and is the more commonly mapped version of a sequence boundary. While this surface is architecturally a sequence boundary (Holbrook, 2001), it diverges from classic concepts of this surface in several ways. 1) The surface is not a time surface, but is a composite surface cut and reshaped over the duration of falling stage through transgression (Holbrook, 2001; Strong and Paola, 2008). 2) The fluvial sediments on top of the surface were deposited throughout falling stage through transgression as well; thus the surface is always buried by stored sediment, and is only locally exposed at any given time (Holbrook and Wright Dunbar, 1992, Holbrook, 1996 & 2001; Strong and Paola, 2008). The sequence boundary is thus never a subareal erosional surface. 3) This surface is cut by lateral planation rather than true incision. An actual drop in the profile during sea-level fall, followed by valley incision through knickpoint migration, is thus not required in order to generate this sequence boundary. Instead it can also be cut by mere base level stability during regression without a true base-level drop in coincidence. And 4) Since the surface is forming while sediment is stored above and regression still proceeds, it is possible to deposit progradational sediments beneath the surface that are actually younger than fluvial fragments preserved above the surface (Strong and Paola, 2008). This surface is thus not a true unconformity.

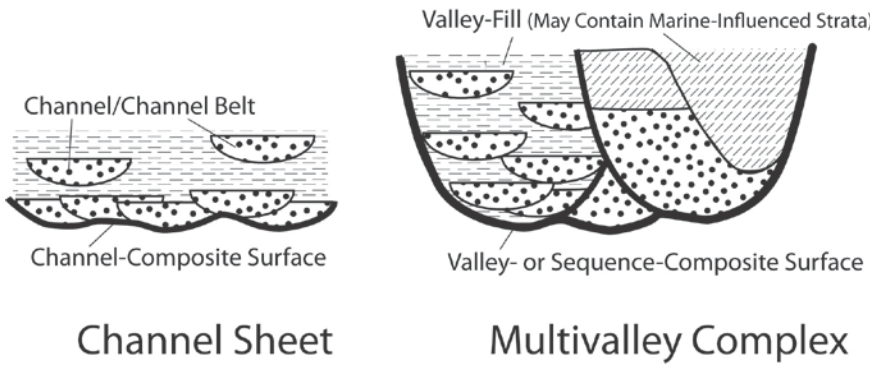

Figure 2: Channel sheet development within thin preservation space vs. multivalley architecture for thicker preservation space. Both sit above composite surfaces that are sequence boundaries.

Sediment Storage and Lack of Composite Surfaces during High Accommodation

High accommodation conditions are conducive to rapid aggradation. Sediment storage is known to be high during these conditions, especially for fine-grained material (e.g. Wright and Marriott, 1993; Berendsen and Stouthamer, 2001). Meandering is minimal during these times, though avulsion is common place (Berendsen and Stouthamer, 2001). Composite surfaces are rarely formed because the buffers are in constant vertical motion and do not remain stable for sufficient time to form regional erosional surfaces. During particularly high aggradation, the buffer profile may thin until reincision no longer occurs and high-order composite surfaces my not even form. Few good example of this condition are currently in process. The rivers of Tabasco State in Mexico form a rare example of an active high-aggradation system near the coast. Here tropical streams have little meander amplitude, and are separated by large lakes. Streams are in a constant state of avulsion producing ribbon-like sand bodies encased in muddy strata without noticeable reincision.

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