

**UNDERSTANDING THE ORIGIN AND CONTROLS ON THE DEVELOPMENT OF
ANABRANCHING RIVERS**

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Abstract

This is a PhD thesis by publication which consists of five papers. Each manuscript focuses on a different aspect of the understanding of the origin and controls on the development of anabranching rivers. Anabranching rivers have been defined as a system of multiple channels characterized by stable alluvial islands that divide flows at discharges up to nearly bankfull; they are the least understood river type. Better understanding of fluvial styles and their deposits is crucial to improve characterization of fluvial petroleum reservoirs. The lateral continuity of sand-bodies as well as sandstone and mudstone distributions are often hard to predict, especially when channel bodies are below seismic resolution. In such cases, reliance on modern analogues and scaling relationships are essential. To explore the relationship between facies distribution and changes in river style, we conducted a field investigation of a reach that presents a change from single channel to anabranching in the dryland Neales River, Australia (Paper 1). An additional motivation for focusing our investigation on a dryland case study is that dryland endorheic basins have been prevalent throughout geological history and their deposits can be of significant economic importance as hydrocarbon reservoirs. Based on the grain size and channel geometry (width and depth) data presented in this paper we conclude that the planform geomorphology exerts a greater control on channel bed material size than channel geometry. Therefore, to investigate the factors controlling the change between single channel to anabranching in this reach of the Neales River, sedimentologic, topographic, geologic, and remote sensing data were collected (Paper 2). We propose that the development of anabranching in this site is related to a downstream change in floodplain width, which occurs downstream of a fault, due to a lithological change from more resistive to more erosive substrate. Statistically significantly larger floodplain width values in the anabranching reach compared to the single channel reach allow me to propose that the change in floodplain width is a primary control in the development of anabranching. This is in

accordance with other Australian anabranching rivers, highlighting that a change in floodplain width seems to be necessary for the development of anabranching; as opposed to the control on floodplain width itself. To investigate the mechanisms that unravel which conditions are necessary within a fluvial system for a downstream increase in floodplain width to result in the development of anabranching we carried out a series of morphodynamic numerical simulations using boundary conditions from field-scale modern anabranching rivers spanning different climatic and geologic settings as well as hypothetical floodplain aspect ratios (Paper 3). We propose that anabranching rivers can originate from alluvial bar growth similar to the origin of braided rivers. This occurs on floodplains where the flow has a large aspect ratio (width divided by depth), which favors bar growth and the development of anabranching systems. Floodplains with large aspect ratios favor the development of anabranching because the reduction in bar-top shear stress caused by emergence of deep anabranches stabilizes the bar and hastens their transition to large, immobile islands. Compared with field measurements, our simulations accurately predict the number of active channels, supporting the validity of this explanation for the origin of anabranching rivers.

Avulsion has been proposed as another mechanism for anabranch formation. However, little is known about the thresholds that trigger avulsion, partly because of the scarcity of ongoing avulsions and because of our inability to predict when they will occur in order to be able to observe them. To gain further insight into avulsion processes, and the generation of new anabranching channels, we investigated a 2007 avulsion event that took place in one of the anabranching reaches of the tropical Magdalena River, Colombia (Paper 4). This was selected because it forms an excellent example of a recent avulsion that led to the formation of anabranching channels, and had not previously been investigated. On a regional scale, the location of the avulsion node seems to be related to changes in gradient caused by a fault. On

a reach scale the position of the avulsion node seems to be linked to the location of the channel's thalweg, which is up against the bank where the avulsion node is located. The trigger of the avulsion and maintenance of the newly avulsed channels can be ascribed to high discharge magnitudes related to the 2007 -2008 and 2010-2011 extreme La Niña events. To test this trigger hypothesis on a larger temporal and spatial scale, we collected a record of satellite images from three South American rivers, hundreds of kilometers apart (Paper 5) and recorded the occurrences of avulsion activity during 41 years and 12 La Niña events. Results show that the frequency of avulsion activity significantly increases during La Niña conditions. Discharge data from one of the case-studies (the Magdalena River) suggests that this is ultimately related to increases in the magnitude of river discharge during the cold phase of ENSO. We suggest that the intensity of la Niña occurrences seems to play a significant role in the triggering and development of partial and full avulsions because the onset of three events reported in this study corresponds to strong La Niña phenomena (1975-1976, 1998-1999, 2007-2008 and 2010-2011).

This thesis contributes to the understanding of the origin and controls on the development of anabranching rivers by using a variety of field, remote sensing and novel modeling approaches. The anabranching rivers investigated in this thesis are located in four continents, spanning different climatic and tectonic settings. I have contributed new field observations for previously unstudied anabranching rivers (Neales and Magdalena rivers) in two of the least-well studied climate zones for anabranching. The hypotheses presented in this thesis are globally applicable as they are based on first order controls (floodplain width and ENSO) and mechanisms (bar formation and avulsion).

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19/05/2016

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Statement of Author's Contributions

All the papers presented in this thesis are co-authored. Hence, detailed statements of relative contributions are summarized below and endorsed by the co-authors.

Statement of Authorship

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|---------------------|--|---|--|
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