Sequence Stratigraphy of Continental Rift Basins I: A Conceptual Discussion of Discrepant Models

Michael Holz, Edric Troccoli and Marcelo Vieira

Abstract Due to the asymmetry of half-grabens and their subsidence controlled by a single major boundary fault, the creation of accommodation space in a rift basin is variable; therefore, the traditional scheme of sequence stratigraphy is not applicable. The present paper discusses this issue, emphasizing the controversy about the initiation of a rift: some authors propose that the onset of a rift is marked by rapid subsidence and the creation of large accommodation, whereas others argue for a slow subsidence regime and consequent low accommodation rates. This paper offers an integrative approach, based on the fact that the initiation of a rift is characterized by isolated and restricted faults that create incipient half-grabens. Towards the phase of rift climax, the initial rift faults tend to link, and form a larger and deeper depositional area, hence developing lacustrine facies with an overall retrogradational trend. Therefore, in some parts of the basin, rift onset is characterized by fluvial sandstone, whereas the basal lacustrine mudstones found in other parts of the rift basin register an already more advanced rift phase. When the rifting ends, the accommodation rate decreases and the sedimentation regime becomes progradational, and the rift basin is filled with fluvial, deltaic, and aeolian facies.

Keywords Rift basin · Sequence stratigraphy · Conceptual models

Introduction

A continental rift system develops when one branch of a three-armed rift system fails to open and does not develop the passive margin stage, developing a system of linked half-grabens infilled with continental systems (i.e., alluvial fans, fluvial,

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R. Rocha et al. (eds.), *STRATI 2013*, Springer Geology,
DOI: 10.1007/978-3-319-04364-7_2,

deltas, and lacustrine turbidites). Modern examples include the East African rift system (mainly the Tanganyika and Malawi rifts) and the Baikal Lake in Russia. Due to the asymmetry of the half-grabens and their subsidence controlled by a single major boundary fault, the creation of accommodation space within a rift basin is variable, and zones of high accommodation rate develop close to zones with no accommodation or even erosion. Therefore, the traditional scheme of sequence stratigraphy, in which specific geometric systems tracts develop following a predictable order during a complete cycle of sea-level change, is not applicable. Adaptations are needed, especially concerning the initiation of a rift: some authors argue that the onset of the rift is marked by rapid subsidence and the development of large accommodation, whereas others support a slow subsidence regime and consequent low accommodation rates for this phase. Since the early 1990s, several authors have proposed comprehensive models for the initiation of rifts and the stratigraphic signature of rift basins from the viewpoint of sequence stratigraphy. The present paper provides a brief discussion of the main ideas and offers an integrative model.

Sequence Stratigraphy of Continental Rift Basins: A Brief Discussion of Rift Initiation

According to some authors, the rifting process is marked by stages of rapid mechanical subsidence typically followed by longer periods of tectonic quiescence, when sediment supply gradually fills the available accommodation, showing an overall progradational trend. In this type of model, flooding surfaces are the rift sequence boundaries, related to rapid tectonic subsidence and the consequent "instantaneous" generation of accommodation. Therefore, a typical rift sequence would initially develop a transgressive systems tract, and during the later rift phase, when the accommodation rate decreases due to lower rates of subsidence, a highstand systems tract wold develop. This is the conception of Martins-Neto and Catuneanu (2010), who applied this model to the Brazilian rift basins. However, the problem with this approach is that the initial rift phase has the following characteristics:

(1) The phase is characterized by low subsidence rates (e.g., Strecker et al. 1988), hence there is low accommodation relative to sediment input; therefore, the initial rift basin is easily filled and does not record extensive lacustrine facies. The initiation of the rift is characterized by braided river deposits with a progradational pattern, as demonstrated by both ancient (e.g., Prosser 1993; Melchor 2007) and modern examples (e.g., Rohais et al. 2007).

(2) The initial rift system is formed by locally restricted faults, resulting in small, shallow, disconnected basins rather than a basin of sufficient size and depth to record extensive lacustrine facies (e.g., Gawthorpe and Leeder 2000; Morley et al. 2007; Kinabo et al. 2008). These initial depressions tend to connect during

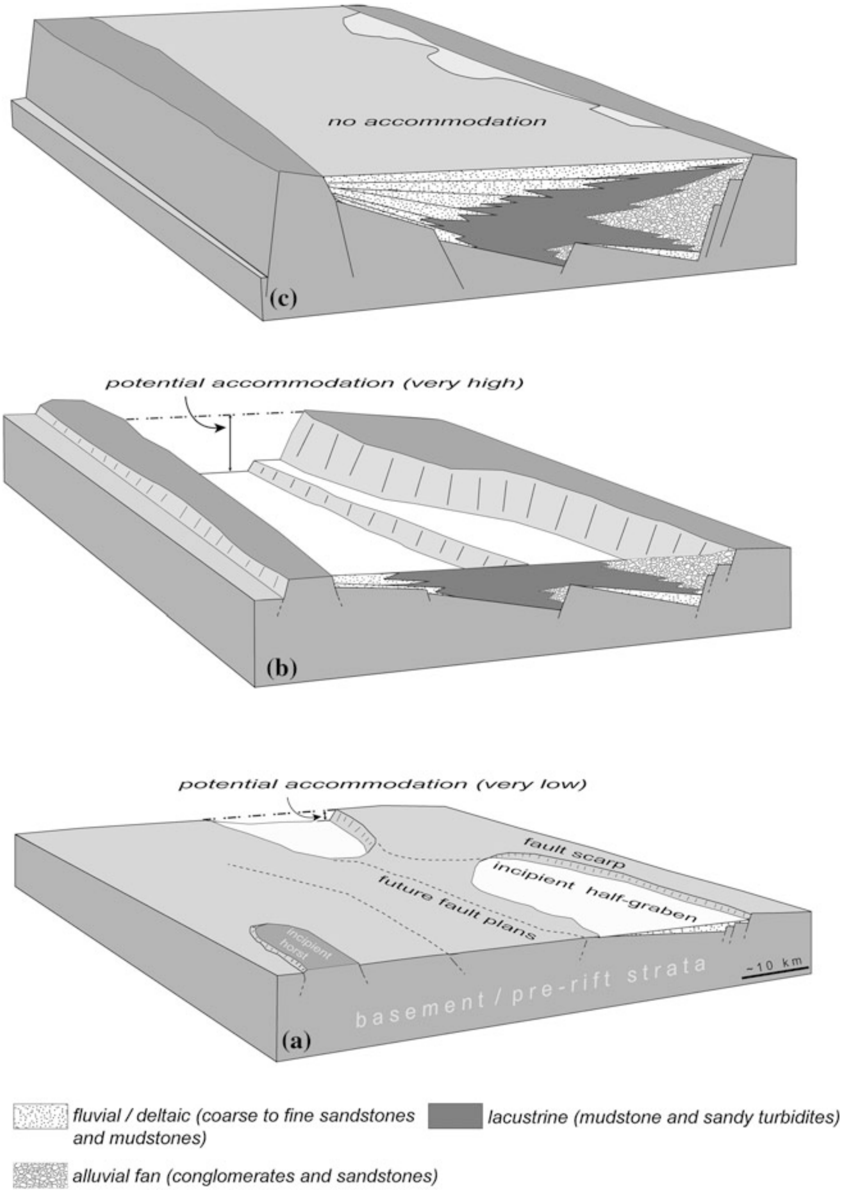

Fig. 1 **a** Rift initiation: isolated and restricted faults create incipient half-grabens infilled by fluvial–deltaic facies. Many areas of the rift system have not yet become zones of deposition; **b** Rift climax: the initial rift faults are linked, forming a larger and deeper depositional area. The previously nondepositional areas then rapidly subside, hence forming lakes. During this phase, the areas with fluvial sedimentation and the previously nondepositional areas constitute part of the rift basin, and are infilled with lacustrine facies; **c** When the rifting ends, the accommodation rate decreases and the sedimentation regime becomes progradational. The rift basin is filled with fluvial, deltaic, and aeolian facies

the rifting process, forming large half-grabens in which lacustrine facies may develop.

Therefore, the core issue is as follows: is the onset of the rift marked by rapid subsidence and large accommodation, and hence lacustrine facies develop from the very beginning of the rifting process, or is it marked by fluvial sandstones with a progradational pattern due to the slow subsidence regime and consequent low accommodation rates of this initial tectonic phase?

Sequence Stratigraphy of Continental Rift Basins: An Integrative Approach

We base our concept on the observation that the initiation of a rift is characterized by isolated and restricted faults that create incipient half-grabens, that is, small loci of deposition that are characterized by low accommodation and are infilled by fluviodeltaic facies under a progradational sedimentation regime (Fig. 1a). During this initial phase, many areas of the rift system have not yet become zones of deposition. Towards the phase of rift climax, the initial rift faults tend to link, forming a larger and deeper depositional area (Fig. 1b). The previously nondepositional areas then rapidly subside and the accommodation space is significantly increased, hence lacustrine facies are developed with an overall retrogradational trend. Therefore, during this phase, the areas with fluvial sedimentation and the previously nondepositional areas become part of the rift basin and are infilled mainly with lacustrine facies. Therefore, in some zones of the basin's base, the rift onset is characterized by sandstone and in others by lacustrine mudstones deposited during a later rift phase (Fig. 1b). When the rifting ends, the accommodation rate decreases, the sedimentation regime becomes progradational, and the rift basin is filled with fluvial, deltaic, and aeolian facies (Fig. 1c). This conceptual model helps to understand why within a given continental rift basin some well logs show fluvial sandstone at the base, whereas in nearby logs the rift succession begins with lacustrine facies. This model is tested in the Brazilian Reconcavo Rift Basin, presented volume.

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http://www.springer.com/978-3-319-04363-0

STRATI 2013
First International Congress on Stratigraphy At the Cutting Edge of Stratigraphy
Rocha, R.; Pais, J.; Kullberg, J.C.; Finney, S. (Eds.)
2014, XLV, 1335 p. 285 illus., 165 illus. in color., Hardcover
ISBN: 978-3-319-04363-0