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Rift-Segment Interaction and Its Relation to Hydrocarbon Exploration in Continental Rift Systems[1]

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ABSTRACT

In both the early stages of continental rifting and the onset of sea-floor spreading in the more advanced rifting, longitudinally continuous rifting is accomplished by the propagation and linkage of isolated pockets of extension. In the early continental rift phase, these isolated pockets of deformation are defined as rift segments. Rift segments initially are distributed in a loose association of in-line and en echelon geometry. Their propagation, interaction, and linkage into a continuous rift system creates a variety of rift geometries, including rift splays, gaps, offsets, passes, and large-scale transfer zones. An understanding of these geometries and their associated fault patterns is critical for effective hydrocarbon exploration in these zones.

INTRODUCTION

Cratonic rifts and passive continental margins are end members in a continuum of rifting processes. In particular, the Clysmic Rift (Gulf of Suez and Red Sea), which displays the entire spectrum of deformation from incipient continental rifting at its northwest end to sea-floor spreading at its southeast end (Figure 1), has been studied (Martinez and Cochran, 1989, for example) as a model for this process. Bonatti (1985) suggested that the onset of true sea-floor spreading, advancing from the southeast within the continental rift, is preceded by the occurrence of regularly spaced upwelling of hot mantle plumes, called multideeps. Bonatti's concept is that these "hot spots" or isolated pockets of embryonic ocean crust formation will propagate or elongate with time along strike of the continental rift system (Figure 1), eventually to coalesce into a continuous oceanic ridge (see also Crane, 1985, 1989). A similar process is envisioned to occur in the earlier continental or cratonic rifting phase where isolated, commonly regularly spaced pockets of crustal extension develop and link over time to form a punctuated, but laterally throughgoing, continental rift system (Courtillot, 1982; Ebinger et al., 1984; Bosworth, 1985; Ebinger, 1989a, b). The early isolated pockets of continental extension herein are termed rift segments. The spatial relationship of these continental rift segments and how they propagate, interact, and coalesce into continuous rift systems is the topic of this paper. We discuss nomenclature, characteristics, and examples of these segment relationships, as well as inferences pertaining to hydrocarbon potential.

A cornerstone to this approach is the mechanical principles governing the propagation and interaction of microcracks, fractures, and faults. These principles have been worked out in theory, experimentation, and observation, and are summarized in Pollard and Aydin (1984). These authors documented similar brittle crack-linking geometries from microns to kilometers in scale (nine orders of magnitude). In this paper, we extend by analogy these geometries and principles to scales larger than those of Pollard and Aydin (1984) to include fault arrays of hundreds to possibly thousands of kilometers in larger rift systems (eleven to twelve orders of magnitude). In this way, we attempt to infer mechanical processes for fault and graben arrays from arguments of self-similarity.

PROPAGATION OF RIFT SEGMENTS AND RIFT SYSTEMS

Global-scale rift systems are punctuated along strike or in time by pockets of extensional deformation. This is true during both the brittle early continental rift phase as well as during the later more ductile sea-floor spreading phase (dominated by igneous activity and the formation of new crust) of the complete rift cycle. These pockets grow and interact as the rift system matures. On a regional scale, developing rift systems

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